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Sustainable Urban-Industrial Supply Systems: Ecosystem-based Theory Formation, Empirical Analysis and Transformation Designs

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II List of Contributions

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Lubjuhn, S., Bouman, M., Lutkenhaus, R., & **Krumme, K.** (2019). Communicating Sustainable Logistics Innovations to Various Consumer Groups. In A. Melkonyan & K. Krumme (Eds.), *Innovative Logistics Services and Sustainable Lifestyles: Interdependencies, Transformation Strategies and Decision Making* (pp. 115–139). Springer.

de la Torre, G., Gruchmann, T., Kamath, V., Melkonyan, A., & **Krumme, K.** (2019). A System Dynamics-Based Simulation Model to Analyze Consumers' Behavior Based on Participatory Systems Mapping – A "Last Mile" Perspective. In A. Melkonyan & K. Krumme (Eds.), *Innovative Logistics Services and Sustainable Lifestyles: Interdependencies, Transformation Strategies and Decision Making* (pp. 165–194). Springer.

Gruchmann, T., de la Torre, G., & **Krumme, K.** (2019). Mapping Logistics Services in Sustainable Production and Consumption Systems: What Are the Necessary Dynamic Capabilities? In L. de

[1] Selected as cumulative contributions to this dissertation.

Boer & P. Houman Andersen (Eds.), *Operations Management and Sustainability* (pp. 223–246). Palgrave Macmillan.

Gruchmann, T., Melkonyan, A., & **Krumme, K.** (2018). Logistics Business Transformation for Sustainability: Assessing the Role of the Lead Sustainability Service Provider (6PL). *Logistics*, *2*(4), 25.

Melkonyan, A., **Krumme, K.**, Gruchmann, T., Spinler, S., Schumacher, T., & Bleischwitz, R. (2019). Scenario and Strategy Planning for Transformative Supply Chains within a Sustainable Economy. *Journal of Cleaner Production*, *231*, 144–160.

Conference Contributions[2]

(In chronological order)

Krumme, K., Noche, B., Hoene, A., & Wang, N. (2011). Global-demographischer Wandel - Perspektivierungen vom Standpunkt der Logistik. In T. Wimmer & T. Grosche (Eds.), *28. Deutscher Logistik-Kongress: Flexibel - sicher - nachhaltig. Flexible - secure - sustainable. Kongressband 2011*. Bundesvereinigung Logistik (BVL).

Hanke, T., & **Krumme, K.** (2012, , November 8–9). *Risk and Resilience in Sustainable Supply Chain Management – Conceptual Outlines*. 10th International Logistics and Supply Chain Congress: Sustainability in the Era of Global Crisis, Istanbul, Turkey.

Krumme, K., & Melkonyan, A. (2015, November 9–10). *Fertilizing Solutions on the Water Energy Food Security Nexus from a Sustainable Supply Chain Management Perspective.* BHP Billiton Sustainable Communities/UCL Grand Challenge Symposium Series: Global Food Security: Adaptation, Resilience and Risk, London, United Kingdom.

Krumme, K. (2016, April 12). *Logistics, the Energy Transition and a Future Green Economy: Challenges, Needs and Opportunities*. 3rd German-Dutch Logistics Conference, Duisburg, Germany.

Krumme, K., Hanke, T., & Melkonyan, A. (2016, September 6–9). *Resilience and Sustainability as Drivers for a Conceptual Transformation in Logistics: Shared Options for Green Economy Research and Practice*. 7th International Sustainability Transitions Conference (IST): Exploring Transition Research as Transformative Science, Wuppertal, Germany.

[2] Prior contributions to academic conferences in the thematic context of the dissertation. Not included as text, but taken into account as lead to the cumulative contributions with respect to content and research concepts.

III List of Figures

IV List of Tables

V List of Abbreviations

6PL	Sixth Party Logistics Service Provider
B2B	Business to Business
B2C	Business to Consumer
CIB	Cross-Impact Balance Analysis
CLD	Causal Loop Diagram
CSR	Corporate Social Responsibility
CTB	Conceptual Theory Building
DCs	Dynamic Capabilities
EA	Ecosystem Approach
EE	Ecological Economics
EEG	Environmental Economic Geography
EMA	Exploratory Modelling and Analysis
ESGS	Ecosystem Goods and Services
GCC	Global Commodity Chains
GHGE	Greenhouse Gas Emissions
GPN	Global Production Networks
GST	General Systems Theory
GVC	Global Value Chains
ICT	Information and Communication Technologies
IE	Industrial Ecology
IM	Industrial Metabolism
IPCC	Intergovernmental Panel on Climate Change
LCA	Lifecycle Assessment
LSP	Logistics Service Provider
MA	Millennium Ecosystem Assessment
MAB	Programme on Man and the Biosphere
MDS	Multi-Dimensional Scaling
MLP	Multi-Level Perspective
OI	Open Innovation
OM	Operations Management
PNS	Post-Normal Science
PSC Ecosystem	Production Supply Consumption Ecosystem
PSM	Participatory Systems Mapping
RSD	Regional Sustainable Development
SCC	Supply Chain Coordination
SCRES	Supply Chain Resilience
SCM	Supply Chain Management

SD	System Dynamics
SDGs	Sustainable Development Goals
SE	Systems Ecology
SES	Social-Ecological Systems
SETS	Social-Ecological-Technological Systems
SFD	Stock and Flow Diagram
SOM	Sustainable Operations Management
SSCM	Sustainable Supply Chain Management
ST	Systems Thinking
STEEP	Social Technological Environmental Economic Political (Scenario Building Methode)
SUD	Sustainable Urban Development
SUM	Smart Urban Metabolism
SUSY	Sustainable Supply Systems
TBL	Triple Bottom Line
ToC	Tragedy of the Commons
UM	Urban Metabolism
WCN	World City Networks
WEF Nexus	Water Energy Food Security Nexus

VI German Summary – Deutsche Zusammenfassung

Im Zuge dieser kumulativen Dissertation werden Aspekte des Forschungsgegenstandes der *„Sustainable Urban-Industrial Supply Systems“* bearbeitet. Das übergeordnete Forschungsthema ist die konzeptionelle Übertragung des Ökosystemansatzes („Ecosystem Approach“, Kay et al., 1999) für den systemdynamischen Zusammenhang von Naturkapital, Produktion, Supply und Konsumption im Sinne eines „Production-Supply-Consumption Ecosystems“ (PSC Ecosystem).

Die globale Typizität dieses Versorgungszusammenhangs ist heute „urban-industriell“ geprägt, d.h. urban dominierte Senken sind in Netzwerken mit typischerweise globalisierten industriellen Quellen der Produktion und Supply Chain Services verbunden. Der Gesamtzusammenhang resultiert in die Dynamik eines unnachhaltigen globalen Ökologischen Fußabdrucks mit ca. 75% des Konsums natürlicher Ressourcen und ist der wesentliche Treiber des Klimawandels mit rund 80% aller globalen Treibhausgasemissionen.

Die Übertragung des ursprünglich aus der Systemökologie stammenden Ecosystem Approach trifft in der Geschichte der Geographie einige Vorüberlegungen sowie auf kompatible ältere und aktuelle Konzepte. Die Anwendung auf den komplexen sozioökonomischen Systemzusammenhang war aber insgesamt weder in der Wissenschaft noch in der Praxis vollzogen. Er ermöglicht die systemorientierte Darstellung von Problemebenen, die Verortung von systemgeleiteten Forschungsansätzen für nachhaltige Entwicklung und die Erarbeitung von alternativen Systemkonstellationen im Sinne einer „Sustainable Economy“.

Um dies zu tun, werden zentrale Elemente der gewählten Forschungs- und Problembezüge in den kumulativen Teilen der Dissertation gezielt angesprochen. Die wissenschaftlichen Arbeiten der drei kumulativen Hauptkapitel (Theory Formation, Empirical Analysis, Transformation Designs) sind bewusst inter- und transdisziplinär akzentuiert. Der Common Ground ist dabei „Sustainability Science“. Berücksichtigung finden schwerpunktmäßig neben der Geographie Vorarbeiten der Umweltwissenschaften, Economics und der Management Science.

Es stellen sich mit Bezug auf die drei kumulativen Hauptkapitel drei übergeordnete Forschungsfragen:

1. *Wie müssen Theoriekonzepte der Sustainability Science erweitert und verändert werden, um geeignete konzeptionelle Bausteine für einen Ecosystem Approach (EA) für nachhaltige urban-industrielle Versorgungssysteme darstellbar zu machen?*

2. *Wie können sich die interaktiven Teile eines PSC-Ökosystems individuell und in Relation zueinander verändern, um ambitionierte nachhaltige Lösungen zu ermöglichen, insbesondere im Hinblick auf Nachfrage-Angebots-Dynamik?*
3. *Welche zentralen systemimmanenten transformativen Hebel lassen sich identifizieren, um Systemveränderungen hin zu nachhaltigen PSC-Ökosystemen zu ermöglichen und zu stärken?*

Aus Sicht der zugrundeliegenden Forschung ist entscheidend, wie die Elemente des Systems sich in der Interaktion verhalten, insbesondere Supply Chain Strukturen und Services/ Logistik im Wechselspiel mit Konsummustern und Lebensstilen. Es kann nachgewiesen werden, dass nicht allein Nachfrage das Systemverhalten bestimmt, sondern der Konsum von zwei wesentlichen Treibern grundlegend determiniert wird. Dies sind – vereinfacht dargestellt – einerseits urban-industriell geprägte Lebensstile und andererseits globalisierte industrielle Services in Supply und Value Chains.

Methodisch baut die Dissertation über die kumulativen Beiträge einen „Mixed-Method Approach“ auf, der insbesondere Forschungsmethoden aus den System Dynamics (SD) mit einem Schwerpunkt im Participatory Systems Mapping (PSM) in das Zentrum der Forschung stellt. Der methodische Ansatz wird genutzt, um Transformationsentwürfe für Services und Strukturen des PSC Ecosystem mit Stakeholdern konkretisieren zu können.

Die Ergebnisse der einzelnen eingebrachten Forschungen sind innerhalb des Rahmens von insgesamt 10 eingebrachten Publikation interpretiert. Im Sinne von „Building Blocks“ werden dann Ergebnisse im finalen Teil der Dissertation synthetisiert und im Sinne des Gesamtthemas diskutiert und interpretiert.

Ein zentrales Ergebnis betrifft Systemservices, die Dynamiken der Nachhaltigkeit erzeugen und steuern können, was im Zuge der Transformationsdesigns konkretisiert wird: Transformative Supply Chains und den Business Archetyp des „Lead Sustainability Service Providers“.

Im Rahmen der Synthetisierung der Forschungsergebnisse kann darüber hinaus das PSC Ecosystem grundlegend konzipiert werden und es können PSC Ecosystem Properties als konstitutionelle Merkmale definiert werden. Das PSC Ecosystem interpretiert sich vor dem Hintergrund alternativer Wirtschaftskonzepte der Ecological Economics.

Im Rahmen des Theorieaufbaus wird ein Multi-Domain Framework für Sustainable Urban-Industrial Supply generiert, in das einzelne Entwicklungen der Arbeit (Lead Sustainability

Service Provider, Erweiterungen des Sustainable Supply Chain Management, Metabolismus-Modelle des Urban-Industriellen Konnex sowie Social-Ecological-Technological Systems) strukturiert einbezogen und in Wert gesetzt werden.

Dabei steht neben der Impulsgebung für eine Fortentwicklung der Sustainability Science eine genauere Betrachtung der Geographie im Fokus: die Unterstützung der weiteren Entwicklung der Environmental Economic Geography (EEG) sowie der verwandten Geography of Sustainability Transitions. Am Beispiel der Forschungsergebnisse des Sustainable Urban-Industrial Supply Systems und der Strukturierung als PSC Ecosystem, können geeignete Interfaces zwischen der Geographie, Umweltwissenschaften, Economics, und Management Science als transformative Wissenschaft herausgestellt werden.

VII English Summary

This cumulative dissertation is dedicated to the research subject of "Sustainable Urban-Industrial Supply Systems". The overarching goal is the conceptual transfer of the "Ecosystem Approach" (Kay et al., 1999) to the system-dynamic connection of natural capital, production, supply, and consumption as a "Production-Supply-Consumption Ecosystem" (PSC Ecosystem).

The global typicality of this supply context today is "urban-industrial": Urban-dominated sinks are driving forces in the networks with typically globalized industrial sources of production and supply chain services. The overall context results into an unsustainable global ecological footprint with around 75% of the consumption of natural resources and is the main determinant of climate change with around 80% of all global greenhouse gas emissions.

The transfer of the Ecosystem Approach, which originates to Systems Ecology, meets some groundwork considerations in the history of Geography as well as compatible recent concepts. However, the application upon the complex socioeconomic system context was not completed either in science or in practice. It would enable a new system-oriented representation of problem levels, the concretization of research for sustainable development and the conceptualization of alternative system designs for a sustainable economy. This dissertation intends to close this gap.

In order to do this, central elements of the selected research are specifically addressed in the cumulative parts of the dissertation. The academic work within the three cumulative main chapters (Theory Formation, Empirical Analysis, Transformation Designs) is deliberately framed in an interdisciplinary and transdisciplinary manner. The common ground is "Sustainability Science". In addition to Geography, the focus is also on preparatory work in Ecology, Economics and Management Science.

With reference to the three cumulative main chapters, three overarching research questions arise:

1. *How must concepts of Sustainability Science be expanded and changed to present suitable theoretical building blocks for an Ecosystem Approach (EA) to rationalize sustainable Urban-Industrial Supply Systems?*
2. *How can the interactive parts of a PSC Ecosystem change individually and in relation to each other, to facilitate ambitious sustainable solutions, particularly with respect to demand-supply dynamics?*

3. *Which system-inherent transformative levers can be identified to enable and to strengthen system changes toward sustainable PSC Ecosystems?*

It is crucial how the elements of the system behave in the interaction, in particular supply chain structures and services/ logistics in an interplay with consumption patterns and lifestyles. It can be shown that the system behaviour and its impact of unsustainable resource consumption is not just triggered by demand, but rather by complex dynamics of urban consumption patterns and lifestyles with globalized industrial services in supply and value chains.

Methodologically, the dissertation uses the cumulative contributions to build a “mixed-method approach” that places research methods from System Dynamics (SD) with a focus on Participatory Systems Mapping (PSM) at the centre of the research. The methodological approach is used to specify transformation designs for services and structures of the PSC Ecosystem in a participatory manner with its stakeholders.

The results of the presented research are interpreted within the framework of a total of 10 submitted publications. In terms of “building blocks”, findings are then synthesized in the final part of the dissertation and discussed and interpreted in terms of the overall topic.

A central outcome relates to system services that can generate and control the dynamics of sustainability, which is specified in the chapter of transformation designs: transformative supply chains and the business archetype of the “lead sustainability service provider”.

By synthesizing the research results, the PSC Ecosystem can be fundamentally outlined, and specific PSC Ecosystem properties can be defined as constitutional characteristics. The PSC Ecosystem is interpreted against the background of Ecological Economics.

As part of the theory formation, a multi-domain framework for Sustainable Urban-Industrial Supply is generated, in which individual developments of the research (lead sustainability service provider, extensions of sustainable supply chain management, urban-industrial metabolism models as well as social-ecological technological systems) are included in a structured way.

In addition to providing impetus for Sustainability Science, a closer look is at Geography for supporting the further development of Environmental Economic Geography (EEG) and the related Geography of Sustainability Transitions. By applying the presented research findings, new transformative common grounds and interfaces between Geography, Ecology, Economics, and Management Science can be highlighted.

1 Introduction

1.1 Motivation and Problem Background

Various global socioeconomic developments have changed the characteristics of the human society and the planet Earth within the last two centuries, and even more radically during the least decades. That is particularly true for industrialization, urbanization and globalization as fundamental processes that changed basic planetary constellations. Growth and spatial distribution of population and their settlements are strongly connected to new forms and patterns of globalized industrial production, supply and consumption, interacting with today's lifestyles and the respective material and informational equipment within this increasingly "urban" global society.

"Urban" in this context does not stand only for the appearance of increasingly urbanized spaces and structures, but for urban systems as the dominant of globalized socioeconomic/ sociocultural relationships and cities to be understood as *"places of spatially extended socioeconomic relations"* in their role for globalized socioeconomic networks (Amin and Thrift, 2002). The resulting occurrence is strongly influenced by the emergence of economic, social as well as cultural globalization, networking, and the building of complex multiscale organizations of an urban-industrial society.

With all of that, we most significantly recognize that a resulting overall ecological impact of this transformation is leading into existential threats to both the entire socioeconomic system as it is now and the underlying balance of natural ecosystems.

The warnings in this regard are not new, even if they reach a new quality of public discussion and fundamentally concrete fears at the time of finalizing this dissertation. Even before the repeatedly promulgated milestones of the description and the prognosis of unsustainable developments, such as the "Silent Spring" (Carson, 1962) or "The Limits to Growth" (Meadows et al., 1972), there are earlier decidedly scientific works about the existence-threatening quality of the global socioeconomic change and its ecological consequences, for example by Fairfield Osborn (Osborn, 1948, 1953) or William Vogt (Vogt, 1948)[3].

[3] One reason why these early works have been almost forgotten could be the fact that apart from the analysis of the ecological effects of industrial civilization and the global population developments - taken up by the later "Population Bomb" by Ehrlich (1968) - those authors advocated ideas of eugenics as "solution strategy", as Desrochers and Hoffbauer (2009) suppose. At the time (in the first half of the twentieth century) this was a widespread and almost symptomatic "attitude" among scientists and the emerging Neo-Malthusians.

According to a now almost unmanageable accumulation of academic publications of the last about forty years, within the coming decades dramatic changes will continue and, in many cases, intensify unsustainable cascade effects in human-environment systems. It is already and will even more be crucial how social and economic systems deal with the changes in terms of sustainable development and how we get from the currently predominant critical effects toward new ground-breaking opportunities. Some of the contemporary understandings of this connections will be summarized below against the motivation and subsequently incorporated into the wider strategic and narrower research-oriented context of this dissertation.

17 years ago, the United Nations published the Millennium Ecosystem Assessment (MA) (Reid et al., 2005). Over a period of four years more than 1,000 scientists had compiled the first systematic overview of the global environmental status. The results showed drastically that all global development trends run counter to the goals of sustainable development. 15 of the 24 global ecosystem services measured during the MA were in a state of advanced and/ or persistent destruction, leading to the finding that the Earth is in a state of severe degradation. Here the term “ecosystem services”, in its most common definition, refers to the benefits people or society derive from ecosystems from local to global scale (Alcamo et al., 2003). Since the beginning of the millennium, the term has become a key concept at the interface of natural and social science environmental research (compare: Costanza and Folke, 1997; Daily, 1997; Chapin III et al., 2010; Noorgard, 2010; Ekins, 2011; Abson et al., 2014; Poppy et al., 2014).

These “services” of ecosystems describe provisioning functions, goods, and commons, such as the production of energy, food, and water; regulating functions, as the control of climate and diseases; supporting functions, such as nutrient cycles, oxygen production and carbon dioxide fixation; and cultural functions, representing spiritual and recreational benefits (Daily, 1997; De Groot et al., 2002). This underscores the overall aspiration of the concept, which goes beyond the basic provision of usable resources, but brings together key catalysts of natural and economic processes, the protection of all forms of infrastructures and the expression of values for social coexistence as fundamental to well-being and prosperity.

In addition to the summary report of the MA (called “Ecosystems & Human Wellbeing: Synthesis”) and sub-reports for various more detailed analysis areas, a “Business and Industry” sub-report had been published to address issues of the economy to push forward crucial implications with respect to root causes (“Challenges”) and needed solution pathways (“Opportunities”).[4] This sub-report formulates takeaways of the MA for various business actors

[4] http://www.millenniumassessment.org/en/

in developing and industrialized countries as well as global companies and, above all, clarifies two basic critical constellations:

1. the fundamental dependence of economic value creation – including all wider understood societal benefits – on the functions of nature capital and a resulting high socioeconomic vulnerability if those functions are disturbed,
2. the massive damage to the functioning of the natural household, which is based on current economic/ industrial practices, patterns, and framework conditions. This has been particularly the case since the centuries of industrialization, the “big acceleration” in the second half of the 20th century and the economic catching-up processes of developing and emerging countries in the recent decades (Steffen et al., 2015a).

Until today, 2022, a steadily rising number of reports and scientific studies make clear that this overall development has become more acute (Rahmstorf and Schellnhuber, 2012; Steffen et al., 2015b; DellaSala et al., 2018; Steffen et al., 2018) and shows new hitherto little-calculated complex repercussions of global ecological change in terms of cumulative effects with respect to climate change, biodiversity loss, oceans warming, geochemical cycles, loss of agricultural land or deforestation (Lawrence and Vandecar, 2015; Rasul and Sharma, 2016; Urban, 2015; Frölicher et al., 2018; Resplandy et al., 2018; Cheng et al., 2019). The Earth's ecological system and the corresponding socioeconomic sub-systems show non-linear dynamics in form of complex cumulative and emergent effects that cannot be described in causal relationships and the (up to now) predominantly applied methodologies (Reid et al., 2010, Schellnhuber and Wenzel, 2012). Global climate change studies have termed tipping points that result in total regime shifts and unpredictable cascade effects (Lenton et al., 2008). Recent studies show that time windows to avert irreversible consequences are narrowing further (Steffen et al., 2018; IPCC, 2018, 2019, 2021).

It is this complex dynamic behaviour that makes sustainable development extremely difficult and requires new knowledge in terms of contents, strategy, and methodology.

In terms of transformative efforts within the academic world, sustainability-oriented science has provided some valuable outputs about the effects of the socioeconomic system, in concern of “planetary boundaries” of socioeconomic activities, and a “safe operating space” of the humanity to be respected or be re-attained (Rockström et al., 2009; Steffen et al., 2015b).

In political realms, despite international proclamations, programs and partly also (theoretically) binding agreements – such as the 2015 Paris Agreement –, radically effective levers in the socioeconomic system are not activated to reverse the trend. Scientific findings about the earth system status stand in strong contrast to political decisions (Geden, 2016; Spash, 2016; Victor et al., 2017; Allan, 2019; Hagedorn et al., 2019). At the same time, the United Nations Sustainable Development Goals (SDGs), also passed in 2015, appear as an almost exclusively political level of governance transformation and lack a nested structure and system approach that would be necessary both for an adequate understanding of sustainability and its operationalization in alternative systems (Glaser, 2012; Pongiglione, 2015; Hak et al., 2016; Krumme, 2016; Breuer et al., 2019; Koch et al., 2019).

What risks result from an ineffective ability to (re)act and deficient concepts of necessary change? It is expected for the coming decades that effects of global ecological change in combination with the world's sociodemographic and socioeconomic developments will face increased existential resource stress in numerous regions in the world, including critical shifts in primary production and the availability of essential natural resources and ecosystem services (Beddington, 2009; Wheeler and von Braun, 2013; IPCC, 2014; Rasul and Sharma, 2016; IPCC, 2019). On global scale it is predicted that by 2030 the world economy will need to produce around 50 % more food and energy, together with 30 % more fresh water compared to the reference year 2015, whilst mitigating the acceleration of climate change and adapting to its impacts (UNDESA, 2015).

These developments will harmfully influence the performance of economies in terms of their productivity and stability, supply effectiveness and security of the populations, socioeconomic prosperity and ecological integrity (IPCC, 2014, 2018, 2019). Regional tipping point scenarios show a high likelihood of supply bottlenecks or even deadlocks in the life supporting systems of the affected societies (IPCC, 2013, 2014, 2019). Beside the regional effect, this also bears risks for the security of globalized supply chains and would hinder the affected economies in a broad range of their further development capacities (Ghadge et al., 2020).

Overall, these effects increase uncertainty in local, national and international governance and supply systems and fuel anticipations about an existential crisis in social and economic systems. Conflicting problem cascades are to be feared, which can lead to (mass) migration of people and in the worst case to political and economic destabilization and conflicts (Diamond, 2005; Reuveny, 2007; Zhang et al., 2011; Scheffran et al., 2012).

The flow of the "Environment-Conflict-Hypothesis" into the narratives of the so-called "Climate Wars" or "Water Wars" as a direct causality has been contested in the scientific literature of Empirical Geography and Political Sciences for more than a decade (Raleigh and Urdal, 2007; Theisen et al., 2011; Gleditsch, 2012; Salehyan, 2014). Today we can state in a more differentiated manner that the drivers of climate change as factors in a complex process can result in unsafe and destabilizing interaction with local resource systems if, for example, a low development level plus undemocratic and marginalizing social structures also exist (Koubi, 2019¸ Mach et al., 2019; Ide et al., 2021). Recent studies from water-stressed areas in the MENA (Middle East and North Africa) region show an increased high level of problem pressure (Ash and Obradovich, 2020; Schilling et al., 2020). Aside from the discussion about uncertainty and the likelihood of potential effects, the general statement of Scheffran et al. (2012) must be given a high argumentation weight, when they say that equilibria are shifting due to climate change on a level unprecedented in human history and when they conclude:

"There is reason to believe that such a change might overwhelm adaptive capacities and response mechanisms of both social and natural systems."

Perhaps an increase in uncertainties beyond the specific and feared scenarios is finally the most problematic consequence for local as well as global social systems, in view of the necessary planned countermeasures that are to generate the "safe operating space" for humanity.

The situation is critical, above all because of several preceding decades of a lack of determination to find and implement mechanisms of radical reversal, but also of missing consistency and speed of implementation in the case of commonly agreed measures that have already been found. This exacerbated situation can unpleasantly be illustrated by the covenant of the signatory states of the Paris Agreement that, in view of the avoidance of uncontrollable devastating systemic effects, on a development goal of *"well below 2°C, while allowing for the possibility of 1.5°C"* of global warming, without having known a specific suitable development scenario (UN, 2015). This scenario was postulated posthumously by the IPCC as the mission of the conference over the following two years and published as a special report three years later (IPCC, 2018).

In addition to the necessary goal of a largely climate-neutral global economic and social system (to be reached between 2045 and 2060), compliance with the 1.5-degree limit also requires the active removal of carbon dioxide by the second half of the century at the latest, termed "negative emissions" (van Vuuren et al., 2013; Fuss et al., 2014; Anderson and Peters, 2016). The 2018 IPCC report describes scientifically sound measures that must be taken on the way under the premise of subordinating all other development goals under the primacy of climate protection in a short time (Rogelj et al., 2015). This includes the simultaneity of measures that, taken individually in their own, appear doubtful in the face of the inconsequence, inconsistencies and inefficiencies of recent decades and reveal the total failure of global climate and sustainability related policy since the 1992 Rio Conference (Lawrence et al., 2018).[5]

In addition to the academic community and the even older demands of initiatives within the civil society to initiate radical reversals, there are also increasing numbers of influential voices in business and finance. The fact that apart from averting primarily ecological and societal damage, the matter of inseparable company related consequences and a threatening macroeconomic crisis (Zhang et al., 2011; Meadows and Randers, 2012; Stern, 2014), is probably the main reason why the CEO of the world's biggest asset management and investment company, BlackRock's Larry Fink, wrote in 2018 to the world's leading companies to extend their corporate governance strategy, accounting and planning methods fundamentally: in addition to shareholder value, they should include the entire stakeholder value of all those involved in the economic process (Fink, 2019). What at first might seem like a statement in the "spirit of the times" is more: it is the clearly worded departure from Milton Friedman's "shareholder-primacy governance" (Friedman, 1970/2009) which since the 1970s has clearly defined the common mindset of the economics scene and the financial markets (Lipton, 2018). In the face of global crises and increasing instability such a strategy could take responsibility for a sustainability-focused societal course and relational stakeholder-driven corporate governance.

1.2 From the Crisis to a Challenge for Sustainability Related Research

1.2.1 Specifying the Challenge

If we assume that the above-described change of perspectives is consistent and regardless of whether economic and political leaders are fully aware of the imminent consequences of such requests, we must confess that an alternative socioeconomic system lacks a fundamental consensus on its theoretical foundations (Dolderer et al., 2021), but also the further necessary operative anchoring for a needed implementation and maintenance of alternatives (Haas, 2004; Loiseau et al., 2016).

Unsustainability is a global phenomenon which, in its manifestations, is based on core structures, processes and, above all, values, understandings and economic practices in

5 Combined with disruptive "clean" technology innovations the scenarios take into account a number of extremely ambitious measures, such as an immediate coal exit, 25 newly built nuclear power plants per year, intensive global cooperation and a historically unprecedented global forestry program. This would have to provide a net afforestation gain globally of about half of Germany per year (resulting in a net forest gain of the area of Europe in 2050) (IPCC, 2018).

socioeconomic systems. On the one hand, it is important to characterize which core identities of our society and our economic system are addressed. In this context, both urban and industrial imprints of unsustainability play a fundamental role without being the subject of explicit and purposeful transformative discourses in the mainstream academia.

Environmental change is leading to complex shifts at the global scale and different interconnected levels of organization of Social-Ecological Systems (SES) (Andrews-Speed et al., 2012; Vervoort et al., 2012). A fundamental problem of enabling effective sustainability transformation structurally is the lack of perception and implementation of system integrations of necessary factors of the problem (and of solutions). From an academic standpoint and against the background of a needed transformative authority of scientific knowledge and concepts, a disintegrated status of scientific knowledge provides only incomplete attempts for solutions. But what are the actual “strong” mechanisms and functional structures of the unsustainable global system? In practice and scientific research, attempted solutions relate predominantly to traditionally perceived individual components (e.g., sustainability problems in the production sector, a carbon-based industry, a lack of necessary consumer responsibility, disadvantageous corporate development strategies, problem constellations in the city and urbanization processes, supply systems that are not adapted to climate change, etc.). However, in fact these elements and domains are not separable but inherently functionally connected. The control and governance systems also correspond to this fragmentation and are generally unsuitable to take up helpful cross-connections and implement them in targeted change processes.

About any necessary detail solution, humanity is confronted with problem-interdependencies. A – still reductionist – systemic triangle of non-linear dynamic relationships is formed by the behaviour of fundamental factors in the categories of:

- *Global Environmental Change* (concerning ecosystem/ climate stability and complex regime shifts, e.g., the continuity of further essential ecosystem services, including particularly a future availability of essential water, food and energy resources),
- *Global Sociodemographic Development* (urbanization, total population growth, interdepending resource consumption pattern, rates and footprints),
- *Demand and Supply for Welfare/ Wellbeing,* which is largely subject to a predominant logic of quantitative economic growth (centrally food, water, and energy supply, coupled with complex material flows from production sources to consumption sinks and emerging new local, regional and globalized patterns).

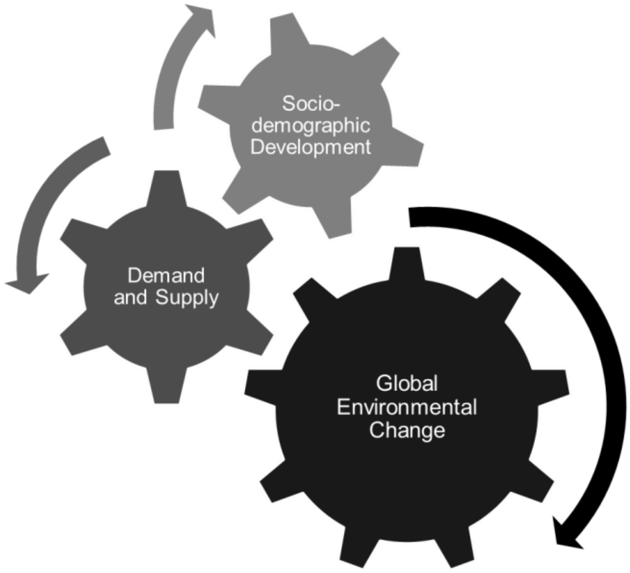


Figure 1.1: Global Problem Dynamics: Interplay of Environmental Change – Sociodemographics – Supply/ Demand

The principal interaction of the three categories of global problem dynamics is shown in Figure 1.1. The least category of demand and supply for the human welfare/ wellbeing either plays up to now a subordinate role in the public and academic perception of the problem, or it is understood primarily as a subsequent constellation of the two other "main" categories of global change. In fact, it is a driving factor and root cause, because many of the mechanisms of the global ecological crisis are rooted in the predominantly industrial patterns, spatial arrangements, and modes of functioning of the third category (Satterthwaite, 2009; Wiedmann and Lenzen, 2018; Krumme, 2019). The requested natural resources are finite and according to the current economic use limited in time (Rockström et al., 2009; Steffen et al., 2015b). The regeneration capabilities of the basic ecological systems have already been exceeded (Barnosky et al., 2012; Hoekstra and Wiedmann, 2014; Rockström and Klum, 2015). Despite all the progress achieved so far in material efficiency and material substitution in various industrial sectors, the past decades have seen a steady rise in the material intensity, meaning the absolute amount of recovered raw materials as well as the total turnover of used materials (Wiedmann et al., 2013; Giljum et al., 2014; Dahmus, 2014). It can be assumed that the non-sustainable use of natural resources, in particular fossil fuels, will become significantly more expensive and/ or increasingly societally intolerable soon (Payne et al., 2009; Daggash and Dowell, 2019).

At the same time, we see that the supply functions of the society with commodities (like food), specialized products (like IT-products or any kind of machines), basic resources (like water or energy resources) up to societal commons (such as space or air) suffers from the instabilities caused by unsustainability and become increasingly vulnerable (Keating, 2013; Andreoni and Miola, 2015). That is particularly true for teleconnection supply chains of a radically globalized market system, where industrial production sources and consumption sinks are far distantly located (Moser and Hart, 2015). The established socioeconomic system reacts vulnerable against the pressures of global environmental destruction and is under risk to maintain its broad based “functions of supply and welfare”. For the background of global urbanization and demographic transformation the resilience in supply systems will increasingly be decisive to run growing worldwide urbanized systems.

The other way around: The worldwide industrial value creation patterns and its spatial distribution and organization of the modern socioeconomic system (from material extraction, design and production, distribution, to consumption and use) are currently standing for a delicate texture of economic processes that is causing unsustainable resource consumption (Wiedmann and Lenzen, 2018). The supply mechanisms and the way how the system is planned and managed within the economic/ industrial system up to the consumer is a major trigger for the energy/ resource consumption and ecological footprints that accompany and facilitate product, resource lifecycles and consumptive lifestyles (Hoekstra and Wiedmann, 2014; Hoekstra, 2015).

Taking into account that it is urban life and economy that cause between 75 and 80% of global greenhouse gas emissions and consume approximately 75% of the world's natural resources, but nominally take up around 3% of the land surface and a little more than 50% of the total world population, it is obvious that the ecological crisis is an urban crisis (Bai, 2007; Marchal et al., 2011; Cajot et al., 2015; Worldwatch Institute, 2016). It is also true that those urban centres are the hearts of the globalized industrial knowledge economy and account for 80% of global GDP, and are hotspots of education and innovation (Acuto and Parnell, 2016; Wigginton et al., 2016)

However, the figures raise fundamental questions as to whether our conception of the urban is at all appropriate. This concerns specifically the huge disproportionality of effects of the settlement area and the resulting global ecological footprint (Rees and Wackernagel, 1996; Wackernagel et al., 2006).

In fact, there is no great confusion about where the main fields for transformation should be addressed and implemented, but how. Particularly how key areas of transformation are linked to each other in guiding conceptual frameworks stays widely unclear.

Even further: If transformation has to be a system approach, how can such a system approach be consistently theorized and then effectively implemented in terms of new alternative systems patterns and operations? What kinds of methodology and knowledge are helpful and suitable on the way of sustainability transformation?

As a central challenge, we can state that the solution pathway must include the defragmentation of the problem systems on the levels of understanding, governance, and operations. System-oriented considerations allow us not only to recognize problematic cascades and rebounds, but also, on the contrary, the dynamics of change. At the same time, however, such system approaches must provide the necessary resolution of details (complexity) to not only develop well-intentioned principles, but to bring about concrete improvements. As always in systems, there will be essential levers that can initiate the dynamics of change. These levers are hardly just technological, organizational, or social innovations, but combinations of all. Once essential levers have been identified, it is important to concentrate on them and set priorities for action in “condensed tasks”.

1.2.2 Meeting the Challenge

It is precisely the interlocking of urbanity and industriality understood as a driving dynamic, that leads to an economized understanding of the globally dominant urban systems of the recent (unsustainable) transformation. Amin and Thrift (2002) build their “re-imagining of the urban” on such functional descriptions with cities as nuclei of complex networks of socioeconomic relationships and connections and emphasize the urban-industrial nature of globalized value creation systems.

It is the urban-industrial processes and network relationships that are fundamental to an explanation of the patterns of unsustainability. According to this understanding, the urban-industrial represents the needed starting point for new understandings, sustainability-oriented research and transformation efforts.

Without the urban dimension, the specificity of the industrial is inconceivable, and vice versa. In contrast to the historical beginnings of industrialization in a non-globalized society that was still predominantly rural at the time, urban and industrial effects are now closely interwoven. Industrialization has made global urbanization possible, and the “urban society” creates new images of the “industrial society”. Geography articulates these interlocking functionalities and entangled structures in the context of Economic Geography. However, in its mainstream, Geography still focuses on less systemic considerations of sustainability as in Urban

Geography (for example in Heineberg, 2016) or in Economic/ Industrial Geography (for example in Haas and Neumair, 2008; Braun and Schulz, 2012).

In the context of the challenges of sustainable development, questions arise about the future characteristics of the urban and/ or the industrial, or in our understanding the urban-industrial. Although there are few approaches to a more systemic understanding of the urban, as by Amin and Thrift (2002), the question of the future orientation and conception of the industrial is less recognizable, and even less visible in an entangled systematic view of the urban-industrial up to now.

Just like "urban", what is commonly considered to be "industrial" today, must be reinterpreted against the background of sustainability assessments. If today there is still an understanding of the industrial as processes that extensively use extra sources of capitals and energy, but also a consolidated organization, to enhance economic productivity in terms of economies of scale, potential for change toward sustainability must be shown for further advanced definitions and interpretations. This also applies to looser associations of production, new forms of organizations and system consolidation, governance values and rules and the decentralization of supply units in new structures in the sense of a new industrial revolution (Rifkin, 2016). For example, small business structures, traditionally less considered in Industrial Geography, Industrial Sociology, or Industrial Economics, would find their way into newly interpreted industrial supply systems through system-wide service innovation. This establishes new more open understandings and designs of what will be or can be "industrial" in the future.

The industrial assets traditionally considered in connection with the extraction, treatment and processing of raw materials and semi-finished products as well as the production of goods, are reinterpreted in the sense of system-wide sustainability-oriented services. The assets are in principle retained in the resulting alternative networks, but in new organizational structures, possibly beyond the classic large industrial companies, but with regard to various functional (perhaps more heterogeneous) business entities with the aim of consolidated sustainable (industrial) goods production and supply.

The goal of a needed transformation is to bring such urban-industrial socioeconomic patterns, processes, and functions into synchronization with the patterns, processes and functions of natural capital, by – as the ecological economist Robert Costanza puts it – creating mutual benefits and long-term stability of the interactions in-between the socioeconomic system and the natural capital system (Costanza, 1996). From a simplified anthropocentric perspective, it is therefore crucial to deal with providing products, vital services, commodities, basic resources and commons that are either supplied directly by natural ecosystems or that go through a complexity of various stages in the socioeconomic system thereafter. The principal of an integral connection between the spheres of the socioeconomic and the ecological must always be maintained in the future to reach a long-lasting stability of the balanced functions between them (Costanza, 1996). The urban-industrial perspective creates a new interpretative option regarding the evaluation of existing structures and processes, but also describes a possible frame for innovative transformation structures and actions.

Based on the above explanations, we can principally identify two problem considerations, which offer new perspectives on fundamental solutions, respectively the needed research for sustainability:

1. It is important to consider more deeply ***systemic patterns, routines, networks, and cause-effect dynamics of and within socioeconomic subsystems*** that are supposed to be the source of adverse developments regarding ecological stability and – as destructive feedback – destabilizing the socioeconomic functions themselves.

Specially to understand the global network society, drivers and effects of urbanisation, and the associated changed characteristics of the world economic system, considerably scholars on the interfaces between Geography and Social Sciences/ Economic Science have generated valuable progress in the academic knowledge, such as Taylor (1999) or Castells (2005). However, their references to sustainable development stand still in the background (Rees, 2002; Lambin and Meyfroidt, 2011). At this point, there are gaps in the academic knowledge and in the mainstream of practicable sustainable development strategies.

2. It is important to consider more substantially and comprehensively ***supply and welfare functions in socioeconomic systems*** and to integrate natural capital with its ecosystem services functionally with the socioeconomic sphere into an overall system understanding.

This latter requirement is not new, but it is continuously subject of past and ongoing research and poses still considerable conceptual deficits (Daily and Ehrlich, 1996; de Groot et al., 2002; Farber et al., 2002; Liu et al., 2013; Starik et al., 2016). The general question of coupling ecological and socioeconomic systems into a "sustainable whole" under new industrial conditions and global urbanization arises particularly about basic supply, such as of water, food and energy. Within the last decade, the focus has been progressed to works that deal with the critical interdependence of the three basic supply areas, named the Water-Energy-Food Security Nexus (WEF Nexus) (Bazilian et al., 2011) (see 1.4.6 below for further explanations). So far, research results have concentrated on causal interdependencies between the individual areas or show increasing supply uncertainty for the critical resources (Bazilian et al., 2011; Hoff, 2011; Vermeulen et al., 2012; Scott et al., 2015; Schipanski et al., 2016; Sohofi et al., 2016). Theoretical foundations, principles for transformation designs and alternative routines, patterns and goals are widely missing.

When it comes to the sustainability related meaning of supply and welfare functions beyond the narrower function of “the delivery of something”, it helps to consider supply and welfare functions as part of the “Theory of Dynamic Systems” of Willems (1972). This rises the discourse to a sophisticated theory level and maps out values and functionalities that are crucial to welfare, maintenance, and development of socioeconomic civilization. Up to now, a so understood supply and welfare function has been significantly underrepresented both in practice and in the theoretical debate in research for sustainability.

In order to transfer a more holistic idea of supply and welfare functions into a more concrete transformation context, the connection between spatial-structural and economic-ecological-functional characteristics of systems is a fundamental requirement. It is noteworthy that with respect to the modes and networks of a globalized socioeconomic system and its production and consumption patterns, the earlier-mentioned correlation of global un-sustainability and urbanization/ industrialization trends is centrally fixed within the spatial and functional organization of value and supply chain structures and the mechanisms of their operations levels and services (Krumme et al., 2011; Krumme, 2016).

Alternative planning makes progress in the associated perception of future sustainable demand, production and supply necessary. The geographical referencing starts with the terminal ends of sources and sinks relationships, makes further consideration of more complex interconnected spatial subsystems for sourcing, production, distribution, and consumption necessary.

A further combination needed is an integrated system view offering an illustration of the concretely tangible occurrence of such dynamics over interrelated (sub-)structures and the responding counter measures of Sustainable Operations Management (SOM) (Kleindorfer et al., 2005).

1.2.3 Relevant Research in, between and across the Disciplines

Academic knowledge relevant to the context described still appears to a large extent in disciplinary accentuated literature. In the case of the present research, this is Geography. Especially in the context of the sustainability effects of socioeconomic structures and comprehensively conceived supply systems, it is more specifically both Environmental and Economic Geography. Since the work is interpreted from Geography in the context of a modern Sustainability Science, the interfaces between Geography and Ecology/ Environmental Sciences are just as interesting as to Economics and Management Science and specific areas of Social Science.

In all mentioned academic disciplines corresponding research has partly established connecting elements to Sustainability Science, partly not. Some activities perform within the boundaries of their traditional understanding of the discipline, others have started expanding their research subjects and already place efforts in the context of neighbouring disciplines. Also, some of the disciplines show developments and a transformation of their research strategies and methodological profiles over time. Since this makes the description of a state of research complex and opens the need to consider several levels of academic positioning in research and corresponding literature, the following chapters will break down the state of research in an orderly manner:

Chapter 1.3 is primarily devoted to topics and discourses within disciplines, and to the role of disciplines and their research profiles against the background of the challenges described above. In the case of the dissertation presented here, these are Geography, Ecology/ Environmental Sciences and Economics/ Management Science. The disciplinary contexts addressed here are of course not rigid, but already show numerous overlaps with Sustainability Science. However, it is worthwhile to examine centrally relevant fields of work, methods and research strategies from a disciplinary perspective. On the one hand, they are important for understanding the context; on the other hand, they represent significant development impulses for Sustainability Science in terms of the history of science (and looking to the future), which should be appreciated and explained. With respect to disciplinary contexts and their natural connections in-between the named directions, classical disciplinary developments can initially also be identified as relevant, and which often lead to interdisciplinary working contexts, debates and self-positioning of the academia.

Chapter 1.4 then presents the fundamentals and research advances within the framework of Sustainability Science, which are essential in view of the thematic narrowing and challenge outlined. Here, too, the following applies: of course, individual scholars are rooted in their disciplinary origins, but do work predominantly in the interpretative context of Sustainability Science and are interpreted this way above all in their research communities.

Over the last few decades an increasingly influential Sustainability Science has established itself internationally, which has both created its own highly ranked scientific publication formats and has found entry into the most renowned scientific journals worldwide. The sphere of activity deliberately goes beyond the scientific community and integrates all other social sectors in addition to academia, understood as transdisciplinarity.

Overall, inter- and transdisciplinarity have become characteristics of sustainability-oriented research. Here the starting points of research projects or their methods should also be understood in an inter-/ transdisciplinary context, since pure disciplinary approaches often produce shortcomings, as it will be explained in the coming subchapters.

All in the following chapters contained considerations of existing research literature are implicitly and, in some cases, explicitly and extensively anchored in the cumulative individual publications of this dissertation but are summarized here for the purpose of gaining an overview and a broad strategic connection between the single publications.

1.3 Developments of Related Research in a Disciplinary Context

1.3.1 General Remarks

Against the above-described challenge (1.2) scientific nuclei from Geography, Ecology/ Environmental Sciences, Economics, and Management Science, are considered as different, yet still merely separated, but also as compatible building blocks within the presented research.

In the following it is explained in which way and with which approaches or methods the disciplinary schools deal with system-oriented solutions for sustainable development, particular regarding socioeconomic issues. Specific content has been sought that relates the supply and welfare functions (from 1.2.2) to strategies for sustainable development, as an aspect which is considered central to this dissertation.

Since this dissertation is situated within Geography, different research strands of Geography are pointed out in this context and substantial research activities that occur in or even shape Geography.

Significant building blocks of a bigger emerging interdisciplinary solution knowledge come with regard to the issues addressed from Geography scholars, in particular impulses from the newer Environmental and Economic Geography (as well as the Environmental Economic Geography), but often in a transition with blurred dividing lines to Human Ecology, Environmental Sciences and various research strands of Economics. Geographers, Environmental Scientists and Economists work here in the overlapping contexts of human-environment interactions, Social-Ecological Systems (SES) as well as sustainability transitions of the socioeconomic system.

1.3.2 Alignments of Sustainability-oriented Research in Geography

1.3.2.1 Human-Environment Interactions

Geography through the knowledge of system structures of physical and social provinces anchored in spaces and scales, determining complex functionalities, is undoubtedly of high general relevance for sustainability transformations. Another characteristic is at the centre of the meaning of the entire canon of Sustainability Science: Research on human-environment interactions. Although Physical and Human Geography have divided over a long period (Porter, 1978), principally Geography is a science that bridges natural and social parameters and holds a particular interdisciplinary force to understand human-environment interactions in all its facets (Holt-Jensen, 2018; Fu, 2020). There is an impressive breadth of research in the tradition of human-environment interactions, standing in the core of the geographical research (compare: Chapman, 1977; Turner, 2002; Harden, 2012; Grindsted, 2013; Walmsley and Lewis, 2014).

In addition, the implementation of alternative solutions in the light of sustainability first and foremost requires a spatial order in the sense of social, economic, technological and infrastructural configurations and their respective planning and development (Holt-Jensen, 2018; Fu, 2020). As Holt-Jensen (2018) and Fu (2020) point out, for modern Sustainability Science the geographical profile is an essential support to map, analyse and understand human-environment interactions at different scales, beginning with the effects of globalization on a planetary transformation stage in terms of the Anthropocene, over contextualization of sustainability in the regional set up, to very local concretions of problems or innovations as well as in the interdependence of all mentioned scales.

Tuan (1991) asked the question what the intellectual character and core of Geography is and concluded that in the centre stands “the study of the Earth as the home of people”. In this meaning, “home” encompasses all physical, economic, social, psychological, and even moral issues that belong to the environment with which “people” in all their organizational forms, abundances, distributions, cultural expressions, and socioeconomic activities interact (Tuan, 1991).

Basically, geographical studies by countless scholars document over a long period of time until today how humans interacting with the environment have affected ecological, biogeochemical, physical, social, and economic features of the planet on all scales (compare particularly here: Porter, 1978; Slocombe, 1993; Yarnal and Neff, 2004; Judkins et al., 2008).

Strong impulses for the sustainability discourse relevant to this dissertation originate to Environmental Geography, with specific contextualization of the "global urban challenge" (Seto et al., 2010, 2017) and Economic Geography, with the concept of Environmental Economic Geography (EEG) (Braun et al., 2003; Bridge, 2008; Hayter, 2008; Braun et al., 2018, Fastenrath and Braun, 2018) and particularly connect to the "Geography of Sustainability Transitions" (Markard et al., 2012; Hansen and Coenen, 2015; Truffer et al., 2015).

1.3.2.2 Geography and Human Ecology

To understand Geography in the contexts of modern Sustainability Science a key lies in historically old interwoven nature between Human Ecology and Geography. The human-environment interface has been in the core of Geography even before the human factor was integrated into the "natural science" of Ecology. Consequently Porter (1978) sees the roots of Human Ecology in Geography, and not in Ecology. There is early evidence for his statement: Boas (1887) described Human Ecology as part of Geography as "cosmographical", – to draw comprehensive and integrated pictures of the relations people have with the natural environment factors. Barrows (1923) saw Human Ecology as the unifying future impulse for Geography to find a common position of geographers. Geographers in the tradition of Human Ecology have been early focusing on core relevant topics of sustainable development, such as (a) population pressure and limits to growth, (b) adaptive evolution of sociocultural systems under change, (c) environmental perception and natural hazards and (d) political economy worked in the sense of economic criticism (Porter, 1978). Zimmerer (1994) elaborates questions and working approaches in which especially Human Geography can be inspired in terms of content, strategically and methodologically by System Ecology in the sense of a "New Ecology".

Over time it has been steadily criticised that Geography as a "system science" has deficits with respect to methodology and research profiles in order to fulfil this role (Stoddart, 1965; Porter, 1978; Baerwald, 2010; Fu, 2020). As Porter (1978) explains in detail, this is due to the reductionist tendencies of an "environmental determinism" until the 1950s, and then – also counterproductive – the deepening of the trench between Human and Physical Geography afterwards. Human Geography with many sub-denominations, such as Cultural Geography or Economic Geography, moved closer to the Social Sciences and Economic Science, whereas trends on Physical Geography advanced into the fields of Physics with Climatology or Geomorphology.

1.3.2.3 Environmental Geography

As one unifying force, modern Environmental Geography deals with the discussed core identity of Geography in the best sense of a syn-discipline, accentuated as such by Porter (1978). Following Duram (2018), Environmental Geography explains humans and the natural environment in interaction and needs to include physical and human features in an interconnected understanding. The resumption of interdependency research between people and the environment on the one hand and on the other hand in the sense of nested space hierarchies of modern contemporary Environmental Geography (as by: Castree et al., 2016) or Human Ecology (as by: Marten, 2010) took place both from progressive elements within Geography as well as out of Ecology.

Since the 1980s, Environmental Geography has intensified with all references to global change on different spatial scales with regard to climate change (Ackerly et al., 2010), resource systems (Johnston, 1983; Mitchell, 1989), urbanization (Knox, 1994; Seto et al., 2010), regional sustainable development (Nijkamp et al., 1990; Brunckhorst and Reeve, 2006) and also globalization dynamics (McCann, 2008; MacKinnon and Cumbers, 2014; Murray and Overton, 2014), while the latter has been worked on from both an economic and environmental geographers perspective.

1.3.2.4 The Geography of Sustainability Transitions

In today's sense, sustainability-relevant references depict all shades of Geography. Research on sustainability transitions, as in many other classic scientific disciplines, such as in Economics, Social Sciences, Educational Sciences, is an emerging and increasingly influential field as the "Geography of Sustainability Transitions" (Coenen et al., 2012; Markard et al., 2012; Hansen and Coenen, 2015; Murphy, 2015; Truffer et al., 2015).

Hansen and Coenen (2015) base their approaches for this emerging research field primarily on the elaborations of Economic Geography. For the research of sustainability transitions, perspectives of Environmental Geography are integrated, besides the strengthening of further interdisciplinary interfaces to Economics, Social Sciences, Ecology and Psychology.

The Geography of Sustainability Transitions is referring to the Multi-Level-Perspective (MLP) of Geels (2002, 2011) to explain processes of innovation. According to Geels, MLP defines three central, different, interrelated levels for the analysis of socio-technological transitions. First, there are strategic niches outside of the existing regime that can act as incubators. Second, the regime itself represents an established mainstream assemblage of practices and actors. Third, there is an overarching socio-technical landscape in which chronic, exogenous, and most importantly, slow changes affect the regime.

Hansen and Coenen (2015) claim that terms of place specificity must be assigned in relation to global network phenomena as a key research task for sustainability transformation. According to Truffer (2016) as well as Truffer et al. (2015), this requires that scale references be displayed as scale hierarchies from local to global and that a Geography of inter-organizational relationships is related to this multi-scale for sustainable development, for example in companies or in value creation networks between them. This can be related to the characteristics of functional network constellations on specific scale levels, for example in vertical or horizontal cooperation (or both) between value creation partners or their stakeholder networks, e.g., with regard to regionalized supply scenarios of cities or in the sense of local value creation communities. In addition, it means that the actual "jumps" between the scale levels in the sense of the nested organization are mapped, analysed and researched regarding transformation needs and potentials.

1.3.2.5 Global Telecouplings

Some works connect scales in a functional way to core problems of sustainable development by associating the local on a world scale. Seto et al. (2012), Liu et al. (2013) and Friis et al. (2016) – with primarily an Environmental Geography background – focus on socioeconomically induced environmental impacts in the sense of teleconnections of urban centres in the world and superregional scales. They raise the question of global "telecouplings" for sustainability. Telecouplings are assigned to transformation solutions based on global (and not just local) connections as points of attack. Many of the teleconnections and their multilevel environmental impacts concern material or energy flows – mostly as part of value or supply chains – that are triggered by global trade patterns, and more deeply by worldwide economic dominance structures. It becomes clear that supply and connectedness represent a key issue for sustainability. In the context of sustainable supply alternatives – but not only – alternative spatializations play an essential role. At this point, for an adequate examination Economic and Environmental Geography naturally must come together and, in view of the holistic sustainability issues, inevitably lose their sub-disciplinary character (Hayter, 2008).

1.3.2.6 Environmental Economic Geography (EEG)

After a long phase of conceptual disruption, in the recent past through Environmental Economic Geography (EEG) some progress can be seen that opens space to reconnect the economic with the natural environment conditions (Hayter, 2008; Fastenrath and Braun, 2018), rediscovering Economic Geography in the sense of Wagner (1960) as *“the human use of the Earth”*.

With references from Evolutionary Economics and Evolutionary Economic Geography, Hayter (2008) combines some elements as the initialization of an EEG agenda by favouring an evolutionary institutionalism approach as a basic understanding. His open and adaptive concept of institutions caprices itself on the level of regions as a central institutional development axis for sustainable reorganization of resource and land use and value creation systems. In the centre of progressive developments is his idea of the Techno-Economic Paradigms (TEP), whereby he refers in the sense of Kondratieff's “Long Waves” to the “Green TEP” as a socio-technological, industrial sustainability innovation era.

Fastenrath and Braun (2018) built on the fundament of the above-mentioned Geography of Sustainability Transitions (Coenen et al., 2012; Markard et al., 2012) for a more strongly sustainability guided conception of EEG. Their research is dedicated to understanding of sustainability transitions and to strengthen open collaborative settings for innovation and transformation in the direction of sustainability and beyond the mainstream pattern of business-driven technology innovation. What is striking is the noticeable transformative character, which does not only remain in the analytical-descriptive role, as it is still typical for contemporary Geography scholars. At the analytical level, they develop an (albeit related) alternative to Geels Multi-Level-Perspective for understanding innovations in processes of sustainability transition. Fastenrath and Braun (2018) combine historical and subsequent “pathways” (in political-institutional and technological settings), “changed practices” (taking into account learning conditions and progress aversions) and “actor networks” (across all stakeholder groups).

1.3.2.7 Local to Global: Scales and Networks

Generally, it is noticeable that a majority of the trendsetting sustainability-related scholars in Geography either favour the concept of the region as a coordination, planning and management entity for sustainability transformations (Hayter, 2008; Coenen et al., 2012; Truffer and Coenen, 2012; Truffer et al., 2015; Boschema et al., 2017) and/ or pronounce the particular “urban” significance for sustainable development strategies (Seto et al., 2012; Braun, 2005; Seto et al., 2017; Affolderbach and Schultz (2018); Fastenrath and Braun, 2018) or connect even both. It was Ullmann already in 1953 who considered the connections between urban settlement and industrial economic areas to be just as important for (that time) modern Geography as the characterization of the areas themselves (Ullmann, 1953).

Bruce Braun makes the urban strategy particularly strong (Braun, 2005). He sees environmental considerations as a priority for geographic research and calls for a breakdown of classic, above all, locally perceived effects of human economic and social areas, for the "city". The main question raised is whether "urban" in this context is primarily a structural description of the "city" or a quality of (globalized) connectivity.

Regarding the urban multiscale and networked qualities, already postulated by Friedmann (1986) in his world city hypothesis:

"… the form and extent of a city's integration with the world economy and the functions assigned to the city in the new spatial division of labour will be decisive for any structural changes occurring within it".

Economic Geography has developed concepts for analysis and mapping of globalized socioeconomic and particularly industrial networks, but these works have until now little contributed to questions of sustainability transformation.

The global commodity chain (GCC) framework (Gereffi and Korzeniewicz, 1994) is used to understand interrelated functions, operations, and transactions that produce, distribute, and globally consume commodities. GCC emerged as an alternative global network approach in contrast to national small-scale analysis in Urban and Economic Geography (Derudder and Witlox, 2010). In terms of a "world system analysis" GCC relates economic (urban) network centres to their role as financial, information, and trade nodes. In terms of local to global sustainability issues worldwide, urbanization can be interpreted as a downstream result of urban-economic functions within those global networks (Derudder and Witlox, 2010; Hesse, 2010), which appears then also true for its interconnected unsustainability effects.

The related concept of Global Value Chain Analysis (GVC) (Gereffi and Fernandez-Stark, 2011) also shows such relevant features. GVC refers to organisations, roles, and activities involved in the production of goods and services, and their delivery, distribution, and after-sales activities, particularly when these activities need to be coordinated across large global distances (Antràs, 2020). It encompasses a wide range of activities required to bring a product to the end user in terms of its conception and design, resources required, product marketing, and sales issues among others. International trade and value creation networks have been analysed with GVC. Clearly there are some intersections – and interdependencies – with the physical-operative supply chain. Although GVC are touching upon crucial sustainability issues, first works came late and are still rare (compare Ponte, 2019; Chen et al., 2021).

Building on the above, the Global Production Networks (GPN) open up to new, multi-dimensional perspectives on complex production and value-added networks and the multi-factor structures that condition and change them (Henderson et al., 2002; Coe at al., 2008). GPN has thus made a significant contribution to the further development of empirical and theoretical research into globalized socioeconomic networks in Economic Geography. The older tendentially more linearistic, structuralistic approach of the GCC is fundamentally criticized, but on the other hand references are made to the value-adding, corporate-relationship-driven characteristics of the GVC.

In recent years, the GPN model has developed through intensive discourses – and sometimes very heterogeneous directions – to a new level, “GPN 2.0” (Yeung and Coe, 2015), which Coe and Yeung (2019) present in a differentiated way in a special issue of the Journal of Economic Geography on the perspectivation of GPN concepts. For example, after questions about the understanding of the structurality and spatialization of socioeconomic disparities have been discussed for some time, assets and functionalities related to the environment and climate change are also part of GPN 2.0 (Franz et al., 2018). Structurally, GPN 2.0 has many starting points for system considerations and for interdisciplinary work, which seem interesting in the understanding of this dissertation. However, one may critically add that this also comes late, after a system-oriented sustainability science was already formed in the 1970s and 1980s and the analytical aspect also predominates GPN 2.0, transformative orientations are hardly recognizable, and the systemic nature of sustainability is not taken up.

1.3.2.8 Regions as Governance Institutions for Sustainability

In addition to global networks, references to regionalization have implications for sustainable supply. However, Geography deals with the term “region” in a complex way: First, for a “regional view” scale is not a direct defining feature. More fundamentally, regions are determined regarding structural similarities (i.e., the tendency of homogeneity in the space of the features represented) or functionality (i.e., those with regard to the dependence of individual structures in the spatial context) (Braun and Schulz, 2012). Depending on the resolution of the analysis and the level of abstraction, this can include very different levels of scale, so that Geography deals with both large-scale subdivision units such as the world regions (as an agglomeration of structural features of several countries) and, in extreme cases, with commuter movements to a city from the rural settlement area.

Although we can identify that the regional in the sense of “midscale spatial extent” (with very relative connotations) is in the foreground for specific sustainable development options, the other way around, however, it cannot be concluded per se that regionality is synonymous with advantages for sustainability. With regard to the key meaning of supply, however, it is indisputable that in comparison to global transactions in value-added networks (e.g., through transport and energy consumption or correlated carbon emissions), a certain beneficial sustainability effect can be demonstrated (Wiskerke and Roep, 2007; Hudson, 2007; Wiskerke, 2009; Paloviita, 2010). However, without further integrated consideration of temporal patterns (e.g., seasonality in food production) and resulting system structures and processes (based on complex system behaviour) or even the inclusion of macroeconomic performance or concrete downscaling to business models, conclusions cannot claim to be generally valid.

Following Coenen et al. (2012) as well as Truffer et al. (2015) the role of regions should preferably gain explicit emphasis in the core of multi-scale innovation and transformation. Apart from the Geography of Sustainability Transitions, in contemporary Geography above all analytical orientations are well represented, but hardly any transformative focus with respect to regional development. Regarding the process categories of Geography addressed are special geneses of endogenous regionalization (Hudson, 2007; Scott, 2016), which has little in common with the transformative approach of sustainable regional development. This is more evident in the planning sciences, however, often then with the participation of geographers (Nijkamp et al., 1990; Haughton and Counsell, 2004; Counsell and Haughton, 2006; Innes and Rongerude, 2013).

Assuming that regional planning and transformation approaches are highly relevant in the context of the problems dealt with here, it must be stated that at this point the scientific impulses in the sense of “Regional Sustainable Development” (RSD), as by Nijkamp et al. (1990), are surprisingly patchy and do up to now not represent a strong consistent research orientation in Geography. This key role of regionalization is noticeable for planning contexts such as for nature conservation and natural resource management (Miller, 1996; Krumme, 2006), regional metabolisms (Newman, 1999; Newman and Jennings, 2008), eco-civic regions (Brunckhorst and Reeve, 2006), regional ecotourism (Barkin and Bouchez, 2002), or increasingly with the focus on regional food systems (Wiskerke, 2009), including the re-localization of businesses and the resulting effects, e.g.in the field of Transport Geography (Sonnino and Marsden, 2006).

Promising strategies with respect to regional boundaries and patterns for the implementation of sustainability solutions are interwoven within the concept of “Bioregions” (Miller, 1996; Krumme and Ajathi, 2006). Here, features of the human-environment system are integrated into a comprehensive synthesis of a set of physical, ecological and sociocultural or socioeconomical features within a regional boundary, that can serve e.g., the balancing of economic uses and the preservation of natural capital or the resilience against impacts of climate change.

1.3.2.9 Unclear Relationships: Geography and Sustainability Science

Fundamentally, however, the above explanations make clear how decisive spatial scales are for the sustainability transformation and how relevant Geography is principally for answering core questions in this context. We see that the qualitative connection of factors in socioeconomic-ecological contexts and the associated demographics, economic patterns, scaling and functional-spatial networks are not only an aspiring research subject but are rather crucial for the strategic positioning of Geography within Sustainability Science and for profiling a future Geography itself.

However, and despite this undisputable relevance and a lot of pertinent work in the sustainability context, as Fu (2020) puts it:

> “*Current knowledge [of Geography] on the relationship between humans and the environment and the methodologies for studying this relationship are inadequate to solve the transdisciplinary questions in Sustainability Science.*”

In a bibliographical analysis, Fu shows and criticises, that geographers tend to position themselves on a more blurred “policy level” when it comes to sustainability issues than when it comes to more specific questions of management and planning for the transformation (Fu, 2020).

Overarching and connecting significant research dimensions, transdisciplinary and even transformative scientific efforts must be concerned with the comprehensive understanding between natural capital and socioeconomic systems as well as the mutual feedbacks between the spheres, which are connected through various structures and functional characteristics on multiscale levels.

With the key objective to reveal the mechanisms of human-environmental system dynamics, Fu proposes five interactive research areas for an improved system-oriented Geography research and methodological profile:

1. geographical processes
2. ecosystem services and human wellbeing
3. human-environmental systems
4. sustainable development
5. geo-data and modelling

Fu expresses that in this way Geography can become an “interdisciplinary condensation” point for neighbouring disciplines in the social and natural sciences and generate entrainment effects for research into sustainability.

The question is whether the “condensation” lies *within* Geography (and thus Geography would be an important enabler of other sciences), or whether rather the condensation lies *between* Geography and the other disciplines. The latter means that ultimately solutions from different academic perspectives, knowledge histories and methodological skills can be processed synergistically to find solutions with respect to the variety of concrete transformation problems.

At this point, however, it must be clear that for a synergistic connection between Geography and Sustainability Science, it is more the boundary work in the sense of the interfaces to neighbouring disciplines than the sharpening of the “core” that brings Geography forward in terms of methods and content.

It can be reasoned that the demand for an inter- and transdisciplinary as well as transformative profile is in principle supported by (at least parts of) the geographic community itself (compare next to Fu, 2020; Hayter, 2008; Baerwald, 2010; Wainwight, 2010; Pretorius and Fairhurst, 2015; Fastenrath and Braun, 2018, Schwanen, 2018; Zimmermann and Zimmermann-Janschitz, 2020). In its constitutional disposition, this is necessarily congruent to other disciplinary starting points in favour of system-oriented inter-/ transdisciplinary Sustainability Sciences, such as from Economics (Common and Perrings, 1992; Costanza and Patten, 1995; Baumgärtner and Quaas, 2010), Political and Social Sciences (Forsyth, 2004; Loorbach, 2007; Avelino et al., 2016; Kanie and Stevens, 2019), Environmental Sciences/ Ecology (Wu, 2006; Wright, 2007; Chiras, 2009) and in the high levels of maturity of independent schools of thought in Sustainability Science itself (Clark, 2007; Kates, 2011; Lang et al., 2012, Brandt et al., 2013; Nagatsu et al., 2020).

At this point, methodological innovations for a transdisciplinary workspace have emerged in the last decade, such as “transdisciplinary knowledge co-creation” (Mauser et al., 2013) or “transdisciplinary knowledge claims” in the interplay of environmental problems, spatial hierarchies, and governance systems (Buizer et al., 2011).

It is also common ground in specific “established” transdisciplinary research contexts such as the (against the presented background highly relevant) urban studies (Ramadier, 2004; Goebel et al., 2010; Despres et al., 2011; Gurr and Walloth, 2014; Rizzo and Galanakis, 2015; Salama, 2019) and partly but with increasing significance in supply chain management studies (Sahamie et al., 2013; Stindt et al., 2016; Melkonyan and Krumme, 2019).

Here we have reached a threshold where new research on the interfaces between modern Geography, Environmental and Social Sciences as well as Economics have begun to operate in a common understanding of Sustainability Sciences. The submitted dissertation starts at these points.

1.3.3 The Ecosystem Approach and the Ecology-Geography Interface

1.3.3.1 Impetus from System Ecology

The fact that ecosystems do not exist in isolation but rather function as units in a nested order of landscape metasystems, means that any activity or change in any part of a geographical space is likely to affect the functioning of other parts interconnected with it and could influence upper and lower scales and the functions occurring (Krumme, 2006; Bell, 2012). We could say that this is just as true for natural ecosystems as it is for social, socioeconomic or even technological/ infrastructural systems. If so, it illustrates the tremendous value of ecological thinking for understanding and designing any form of systems, and thus the importance of Ecology for sustainable development beyond its own original domain, the natural household (Korhonen, 2004b; Potschin and Haines-Young, 2006; Marten, 2010).

Systems Ecology (SE) as a part of Ecosystem Science can be seen as an application of general systems theory to ecological systems, including human agents and their activities (Odum, 1994). At the heart of the system-ecological approach is the idea that an ecosystem is a complex system that has emergent properties. SE focuses on interactions and interdependencies within the nested hierarchies/ scales of ecosystems. In particular, SE deals with the question of how the functioning of ecosystems can be influenced by human factors in a positive or negative sense and has therefore high significance for application for sustainable development (Graedel, 1994; Vogt et al., 2015).

A central feature of SE is the general application of energy flow principles to all systems of all sizes. The protagonist of this approach was Howard T. Odum. He established the energy flows as a system language and as a tool to create system diagrams and flowcharts (Odum, 1983). On such a basis, ecological energetics aims to uncover those principles that describe the bias of material flows through the “consuming” levels within ecological networks. The most well-known are the energetic connections between solar energy, the building of biomass as primary production and the subsequent cascades of a food web of different consumption levels and on each stage resulting closed loops for primary production.

Similarities to conceptions of sustainability in economic production and consumption systems are – as mentioned – obvious and SE influenced a number of research activities in this area, with emphasis in agricultural production and supply systems, particularly for food networks (Gliessman, 1990; Seyfang, 2006), but also (other) industrial systems (Korhonen, 2001; Lehtoranta et al., 2011).

1.3.3.2 System Resilience

On a theoretical basis, SE deals intensively with the circumstances under which studied systems are stable or unstable over the long term or which configurations, patterns, and essential elements as well as the resulting effects of structural properties cause them. This includes many of the work done about resilience of Social-Ecological Systems (SES). Scholars of SE have researched system resilience at an early stage (Holling, 1973; Fiering and Holling, 1974; Holling, 1987). Factors influencing regime change as well as those preventing regime change were examined (Gunderson, 2001; Walker et al., 2004; Folke, 2006; Folke et al., 2010). The ability to resist a regime change is fundamentally understood as resilience (Holling, 1996). With respect to resilience, there are strong links to the social learning agents” and the system-wide knowledge on the governance of resilient SES (Carpenter et al., 2005; Folke et al., 2005; Hahn et al., 2008).

Resilience-based strategies have found their ways into social systems (e.g., social and community forms; compare Timmermann, 1981; Davidson, 2010), corporate development (Fiksel, 2006; Sheffi, 2007), to psychology (Masten and Reed, 2002), health research (Zautra et al., 2012) and technological infrastructure (Vugrin et al., 2010).

Until the present day, the integration of resilience into organizational and operational problem issues as “resilience design” represents an important research direction and demonstrate the importance of SE for the modern scientific discourse on sustainability (Fiksel, 2003; Pettit et al., 2010; Fiksel, 2015).

1.3.3.3 The Ecosystem Approach and its Socioeconomic Dimensions

Academic literature in Ecosystem Science has since long pioneered the exploration of primordial natural ecosystems into the functional interrelationships with human systems (Odum, 1971, 1997) and is especially with respect to Odum (1983) and Costanza et al. (1991) responsible for the blossoming of Sustainability Science (see chapter 1.4). In Conservation Biology and Human Ecology, the “Ecosystem Approach” (EA) celebrated a career for integrating resource use and conservation of natural resource ecosystems (Grumbine, 1994; Miller, 1996) and established important links into sustainable development. For a consistently further elaborated and defined EA, disciplines outside Ecology have also integrated the understanding of ecosystems. Particularly Geography can look back on a long-time tradition here. This indicates a close scientific connection of broad common spectrums of Geography to Ecosystem Science.

In collaboration with at that time numerous highly regarded researchers, Robert Leo Smith (1972) gave a comprehensive early outline of EA as framework with one of the pioneering books of the modern Human Ecology: “The Ecology of Man: An Ecosystem Approach”. Smith and his supporters followed the agenda to connect different problem areas of human civilization with environmental awareness and ecological systems thinking, including ecosystems management, urban systems, demographic development, food chains, energy systems, mining, and water use.

Before, Stoddart (1965) compiled several arguments as to why an ecosystem or an “ecological approach” can be methodological and principled for Geography. In addition to many points of reference to Physical Geography, as well as arguments that anticipate the later clearer relationship between Human Ecology and Environmental Geography, he primarily developed orientation for a structured understanding and analytical processes from the properties of ecosystems as well as from the significance of ecosystems for progress and applicability of the General Systems Theory (GST). Stoddart points out a considerable potential for system considerations in Geography, since the “space” as an integrator means that more complex system contexts appear to be naturally interwoven than, for example, temporal relationships in the historical sciences. The close link to the early work of E.P and H.T. Odum from System Ecology is striking. However, Stoddart's approach is limited to the consolidation of analytical skills in Geography and does hardly extend to the beginnings of the environmental movement that began at the same time.

In practise studies of ecosystems and their socioeconomic management have gained stronger momentum since the 1970s and 1980s. A very visible example was the initiation of the United Nations “Man and the Biosphere” (MAB) programme, which saw a sustainable interplay between the need to protect natural ecosystems on the one hand and sustainable socioeconomic uses on the other hand, understood as an inclusive but spatially and functionally well-organized whole (UNESCO, 1972). At that time, MAB created biosphere reserves as “living laboratories” of the functional and spatially zoned entanglement of protection and use of natural capital. However, the spatial claim alone remained local or regional and aimed not at the viability of globalized industrial economies, but at locally adapted primary production systems and settlement developments apart from the effects of social, infrastructural and economic urbanization and its global impacts. Despite the integrative character, there are no directly derivable upscale effects. Since then, a mainstream of many complementary approaches has emerged mainly in the field of nature conservation and the utilization management of ecosystems (e.g., fishery, forests, lakes, small scale farming, etc.) (compare: MacKenzie, 1996; Silberstein and Maser, 2000; Busch and Trexler, 2003; Vogt et al., 2013).

The 1990s integrated the EA in finding a balance between nature conservation, spatial planning and economic development. Smith and Maltiby (2000) define the EA:

"… as a strategy for management of natural resources that promotes conservation and sustainable economic use in an equitable manner."

Miller (1996) as spatial planner and conservationist connected the EA to bioregional planning as an:

"… innovative framework for achieving harmonious and mutually dependent sustainability of society and the environment, that focuses on human and natural systems at regional scales across inter-generational time periods".

For Miller, the bioregional scale means a geographical space that contains several nested ecosystems which are characterised by its landforms, vegetation, both biodiversity and human populations, including human economy, culture and history.

The boundary with regard to the transfer of EA into broader system questions of sustainable development was broken at the end of the previous century by a group of scientists around James J. Kay (Kay and Schneider, 1995; Kay et al., 1999; Waltner-Toews and Kay, 2005; Waltner-Toews et al., 2008). The work of Kay and colleagues combined knowledge of the traditions of ecosystem science, bio-cybernetics and complex systems thinking to create progress in the sense of sustainable development for changes in research as well as in practice. Their understanding of the EA is transferable to different kinds of natural, human, and technological systems. To rid them of misunderstandings of too much belonging the EA to the management of ecosystems, the concept was named more abstractly as "Self-Organizing Holarchic Open Systems" (SOHOS) (Kay et al., 1999). This refers to what Barrows had earlier asked for in 1923 as a "motivating theme" and "organizing concept": SOHOs are both content-strategic orientations, in which they visualize, order and connect system components in new methodological processes to enable sustainable developments, but they also represent an approach how science can be enabled to re-contextualize and reposition research for sustainable development.

Even if the range of applications of the EA became more consistent on the one hand, and on the other hand widened, an initially higher level of abstraction was necessary for the conceptual progress. Kay and his colleagues derive behavioural descriptions from systems from non-equilibrium thermodynamics and structured processes via holons, propensities and canons, information, and attractors (Kay et al., 1999). The goal is on the one hand to model an impact system, but then also to map forecasting with regard to sustainability options. “Sets of narratives” are used here in the form of scenarios to depict morphogenetic causal loops, autocatalysis, and multiple possible development pathways. Based on participatory processes in sustainability projects, preferences and choices are taken into account, which can be effectively connected with suitable forms of adaptive management, monitoring and organization of governance. Kay interprets the approach as momentum of post-normal science (Funtowicz and Ravetz, 1995) and develops a heuristic framework including a step-by-step guide for implementation and decision making.

We can conclude, the state of the art of EA is comprehensively relevant for academic theory formation and practical application in the sense of sustainable system solutions and their (adaptive) management and further development. The results of this research and development (also in specific reference projects) were finally published after the death of James J. Kay in 2004 by a comprehensive team of authors in the book “The Ecosystem Approach – Complexity, Uncertainty and Managing for Sustainability” (Waltner-Toews et al., 2008). So far, however, the diffusion into sustainability practice has not been convincingly strong, even if the approach holds considerable potential.

1.3.4 Related Research from Economics, Management Science and Social Science

1.3.4.1 General Remarks

Since we – as explained – consider supply and welfare functions in the sustainable interplay of natural and socioeconomic systems, the knowledge about production, consumption, and supply systems, including structures and services that drive and organize them (in a mostly market-oriented manner) must be included in more detail. This thematic spectrum has mostly been elaborated in research within Economics, Business Administration/ Management Studies and partly in Industrial Engineering.

1.3.4.2 Sustainable Supply Chains

Supply Chain Management (SCM) represents a well-established area of knowledge, highly accepted in research and practice and rich of experience since the 1980s (compare: Simchi-Levi et al., 1999; Chopra and Meindl, 2007; Christopher, 2016). Generally, the term supply chain simplifies complex structures and processes of networks of suppliers: manufacturing plants, retailers, supporting companies involved in various design, procurement, storing, shipping, selling, or servicing processes (Sheffi and Rice Jr, 2005). Respectively is SCM the integration of business processes across the supply chain. SCM evolves through several stages of increasing intra- and interorganizational integration, coordination and cooperation activities of design, planning, execution, control and monitoring along supply chain structures and flows with the objective to effectively synchronize demand and supply (Cooper et al., 1997).

Sustainability concerns are not taken into consideration in classical SCM and began to play a stronger role in research in the late 2000s and 2010s in terms of Sustainable SCM (SSCM).[6] SSCM puts the supply chain into a wider corresponding strategic frame in association to the three dimensions of sustainability: ecology, economy and society (Linton et al. 2007; Carter and Rogers, 2008; Seuring and Müller, 2008; Lieb and Lieb, 2010; Crum et al., 2011; Brandenburg and Rebs, 2015). The noble aim is to qualify SCM based businesses for the sustainability challenge in the 21st century and support the needed transformation into a green economy. With respect to this aim Linton et al. (2007) make clear that sustainable supply chains must explicitly include by-products of the supply chain and consider the entire lifecycle of a product. Seuring and Müller (2008) identified three distinctive features of SSCM: to take into account a wider range of issues (and therefore the concept refers to extended system boundaries of the supply chain), to deal with a more comprehensive set of performance objectives (thereby considering the environmental and social dimension of sustainability beside the economic performances), and to increase the amount for cooperation among partnering companies.

However, in its conceptual core the achievements widely remained restricted to a modification of the well-known SCM strategies by relating structures and operations to external social or ecological factors. SSCM up to now has not been related to “strong sustainability” models of the contemporary Sustainability Science (Krumme, 2019). An in the sustainability relation recommendable contextualization to macroeconomic modelling (as existent in Economic Geography) remained until recently unexplored, although debated in the literature (Vermeulen

6 In a contemporary more open definition SCM includes the acquisition of all needed services from the point of origin (sourcing and manufacturing) to the point of consumption and as far as possible back loops towards a (secondary) resource base and (re-)production facility (closed loop supply chain management: CLSCM). This definition can be considered the first tempt towards integrating sustainability contexts into SCM since the connection with operations within a circular economy is given.

et al., 2012; Thorpe and Fennell, 2012), and was finally co-published by the author (Melkonyan et al., 2019)[7].

Although not in the focus of mainstream SCM research, in fact, a sustainable supply chain concept can act as an integrator with respect to consumption and production (Mangla et al., 2017; Govindan, 2018; Krumme and Melkonyan, 2019). Innovation toward a sustainable supply system, including trade and logistics, must be closely interwoven with the routines of the everyday social practices of people as Reckwitz (2002) and Shove et al. (2012) make clear. Contemporary literature has explored some perspectives of SCM to sustainable consumption (Choi et al., 2012; Luthra et al., 2016) and/ or sustainable production (Geldermann et al., 2007; Burritt and Schaltegger, 2014).

However, a stronger integration into the cores of Sustainability Science or a state-of-the-art contextualization with the research findings of Sustainability Science is still missing (Krumme, 2019).

1.3.4.3 Sustainable Consumption Interfaces

Research coherent with a Sustainability Science interpretation of production, supply and consumption settings is concentrating on trigger systems of consumption and consumptive lifestyles or demands of our society as a whole and puts a stronger emphasis on qualitative shifts in terms of “sufficiency” instead of quantitative gains in “efficiency” (Princen, 2003; Figge et al., 2014; Spangenberg and Lorek, 2019). Intensively discussed in research for sustainable consumption, the qualitative shift at the demand side is needed for a sustainable economy (Jackson, 2005; Alcott, 2008; Seyfang, 2009; Lorek and Spangenberg, 2014). This puts the collective instead of the individual needs as a societal interest in the centre of a socioeconomic transformation process. Literature on sustainable consumption formulates this necessary qualitative shift also in a more institutionalized manner in consumption routines of non-renewable resources (Gilg et al., 2005; Thøgersen, 2005; Barr and Gilg, 2006; Marchand and Walker, 2008; Mont et al., 2014).

Within this background, lifestyles encompass broader activities and values that do not involve resource consumption alone (Mont, 2007). We define lifestyles as the recurring overall context of a person’s behaviours, interactions, opinions, knowledge, and judgmental attitudes (Hradil, 2005), whereas consumption is the process of buying, consuming, and disposing.

[7] This publication is part of the cumulative dissertation.

It seems obvious that sustainable consumption so understood has direct functional links to SCM. Likewise, the more comprehensive concept of sustainable lifestyles displays multifold interactions regarding the continuous expansion of logistics services. These expansions are being linked to shifting consumer requirements through among others increased individualisation and pluralistic behaviours as root causes within the modern socioeconomic system (Krumme et al., 2015).

It is remarkable that sustainable consumption research appears largely absent from research on the supply side, particularly with respect to SCM and logistics services (Krumme et al., 2015; Melkonyan and Krumme, 2019). Contextualizing logistics services with sustainable lifestyles as an integrated concept compared to sustainable consumption was a research gap until some fundamental research portrayed here as part of this dissertation started. Although publications on SSCM generally consider these socio-ecological effects and make them the starting point for conceptual innovations (Seuring and Müller, 2008; Carter and Rogers, 2008; Carter and Easton, 2011), the consumer was not identified as a central driver. “Demand-oriented” strategies related to logistics and SCM do only recognize demand in terms of more or less individualized consumer need fulfilments. Demand chain management (DCM) is linking marketing with SCM but still with a one-directional view to more effectively shape the sales to consumers by identifying consumer demand needs as niches to optimize SCM and marketing measures with the goal to increase business competitiveness and company profits (Jüttner et al., 2007).

Also, the other way around, research on sustainable consumption and sustainable lifestyles (compare Jackson, 2005; Schrader and Thøgersen, 2011; Hicks, 2013) is not considering aspects of logistics or SCM. Only if the reduction of transports (and its negative environmental impacts) plays a role (Hansen and Schrader, 2001; van Acker et al., 2013; Reimers, 2013), the approaches more generally appeal to “buy locally” to avoid long distance transports and correlated greenhouse gas emissions. However, these considerations often come from a one-sided perspective of mobility as only one driver of sustainable lifestyles (Backhaus et al., 2012) and rarely by including more comprehensive system configurations of the entire supply chain. More comprehensive, multifactorial, including other important ecological factors, social aspects, and the interdependencies of both are being significantly underrepresented (Faße et al., 2009).

Lifestyle and consumer research is devoted to a large extent to questions of transmission how sustainable patterns of production and consumption can be brought up successfully in society as part of transformation research. This involves i.e., what kinds of social, business, and technological innovations are needed, and how should stakeholders be involved to transform paradigms and practices for sustainable development (Liedtke et al., 2013b; Laschke et al., 2015). The research results show that greater user integration in the creative processes of product and service design, as well as in production (associated with the term “prosumer” (Kotler, 1986)), and greater participation in the repair or reuse of products (in the sense of a circular economy, sharing economy, or collaborative consumption) have great potential for both users and sustainability traits (Liedtke et al., 2013a, 2013d; Blättel-Mink, 2014; Chen et al., 2015; Arnold, 2017). A central challenge of sustainable product innovation is therefore the greater involvement of people as “system agents” in the various stages of product life cycles.

Methodologically, living labs, which enable interaction and integration of all parties involved in product life cycles, are increasingly coming to the fore, and based on experiments, empirical foundations are being delivered for sustainable product service systems (PSS). Besides product design, customer services within the product life cycle play a significant role, which allows for products that trigger more sustainable action through new product characteristics, product use alternatives and further correlated service businesses supporting sustainable consumption, e.g., in the form of transformational products (Liedtke et al., 2013b, 2013c; Laschke et al., 2015). Within a product lifecycle numerous supply chain structures and services are involved and display levers to enhance sustainability on the consumer side by translating structural and conceptual lifecycle alternatives as consumer-tailored service operations and to support sustainable consumer behaviour. However, lifestyle research also means evaluating sustainable patterns of consumption against the background of people’s everyday reality. Here, research on sustainability assessments, as well as time use and rebounds, can provide valuable clues as to how unwanted negative effects could be reduced or avoided (Liedtke et al., 2014; Buhl and Acosta-Fernandez, 2015).

1.3.4.4 Correlations of Production and Supply in regard to Sustainability

System designs that relate material and energy flows from production facilities and spatial production clusters to ecosystem models and thus perform fundamental work for the circular economy relate the named disciplines stronger to natural science and also to applied technical proveniences. This research province is highly influenced by Industrial Ecology (see chapter 1.4.3). However, in the respective research focusing on correlation of production and the supply chain usually different further accents are set. Here, for years, the avoidance of greenhouse gases and the design of carbon-efficient product lifecycles (Weidema et al., 2008; Wiedmann and Minx, 2008) and supply chains (Sundarakani et al., 2010; Benjaafar et al., 2012; Cariou et al., 2019) have made up a large portion of the relevant literature. Against the background of this dissertation this context is undoubtedly a fundamentally important aspect, but it is not sufficient to create a comprehensive understanding of the interrelated dynamics of sustainable production, supply and consumption systems at all.

Evidently water and energy are cross-oriented key issues with respect to commodity production and along their supply chains and therefore represent critical factors for the sustainability of products within a lifecycle consideration (Huijbregts et al., 2010; Liu et al., 2020). With respect to sustainability-relevant co-factors and SSCM comparatively few works have been published. According to Ercin et al. (2011) the development of highly water-efficient management systems does enclose a more comprehensive product lifecycle assessment (LCA) as well as a supply chain perspective. Gerbens-Leenes et al. (2009) published helpful work of assessing water footprints for renewable biomass sourcing. As Boulay et al. (2013) point out, “water aware” and “water efficient” supply chains of products and connected services are needed, monitoring the water use from the source to the sink and determining “end to end” water lean management systems. This is principally analogous to the role of energy inputs along supply chains in terms of goods and services, although measurements of energy footprints are less investigated than cases of carbon or water footprinting. Valuable examples are given for the energy footprint of bottled water (Gleick and Cooley, 2009).

An important research focus is represented with respect to lifecycles of food products, due to energy and water inputs after the primary production, e.g., in further processing, distribution, storage or use. Here a strong lever appears through “virtual” water and energy inherently covered in every food product (Hoekstra and Hung, 2002, 2005; Huijbregts et al., 2008; De Benedetto and Klemeš, 2009).

Both in the context of the effects of climate change and in response to shifting customer demands on production conditions, the food sector has become the centre of sustainability-oriented research and community-organized alternatives. With respect to sustainable urban, localized, regional, and decentralized agricultural food production and supply patterns (Connelly et al., 2011; Melkonyan et al., 2020) integrated land management can contribute to key factors of a sustainable economy, the security of supply and the balance of interests (groups) in the region, as well as to the safeguarding of ecosystem services in the long term (Penning de Vries et al., 2003). Furthermore, urban farming initiatives unambiguously demonstrate that urban integrated production and local actors, structures, and services can help mitigate supply shocks and shape local food sovereignty (Grewal and Grewal, 2012; Barthel and Isendahl, 2013; Specht et al., 2014).

In addition, an increasing number of consumers are becoming prosumers: they are involved in initiatives such as community farming, urban farming, and other grassroots cooperatives, which have been establishing themselves as start-ups (Gonzalez, 2017; Plieninger et al., 2018; Davies and Legg, 2018). Such social innovations, most of which occur at the local level, are critical to addressing present and future societal challenges, and represent interesting strategic niches for solution (and business) upscaling.

1.3.4.5 Resilience of Production and Supply Systems

Product lifecycles and supply systems will become more vulnerable against changing environmental regimes, respective disruptive events and chronic stresses (Hanke and Krumme, 2012), significantly related to the Water-Energy-Food Security Nexus (Bazilian et al., 2011; Stein et al., 2014). The WEF Nexus is extensively subject to interdisciplinary research, presented in chapter 1.4.6. For the backdrop of global environmental change further progress in the resilient availability of water, food and energy for the growing (urban) sinks pose new challenges for modern businesses and SSCM (Hoekstra, 2014; Hoekstra and Wiedmann, 2014).

In literature the direct link of supply chain resilience (SCRES) to climate change risks stays surprisingly weak (Krumme, 2019) as well as the SCRES community generally appears disconnected to the research on resilience concepts in Sustainability Science (Wieland and Durach, 2018). Nonetheless, SCRES has become considerably more important in the recent decade (Pettit et al., 2010; Jüttner and Maklan, 2011; Wieland and Wallenburg, 2013; Tukamuhabwa et al., 2015). However, most research in SCRES still focuses on intrinsic vulnerability factors of supply chains, much less on external links to sustainability in general (compare: Tukamuhabwa et al., 2015; Donadoni et al., 2016). Concrete alternative service models do not exist either (Levermann, 2014; Beck and Villarroel Walker, 2013). Just general knowledge lacks, and respective research challenges have been detected and food systems particularly are recognized as critical area (Benedikter et al., 2013; Miller et al., 2013; Levermann, 2014; Paloviita, 2015).

1.4 Related Research in Sustainability Science

1.4.1 General Remarks

Against the background of the emerging paradigms of science as a transformative societal force and as a self-concept of science, fundamental understandings and definitions of

Sustainability Science are summarized in the subsequent subchapters regarding the most influential sources.

Sustainability Science today relates to elaborated theoretical foundations on common problem backgrounds and to the scientific understandings about overall problem constellations of (un)sustainability. One can identify further strategical and conceptual adaptations to those problem backgrounds, that are taken up through a common lens by an inter- and transdisciplinary set of scholars, including research strategies, methodologies, and new collaboration forms with non-academic stakeholders of the sustainability transformation.

The literature reflected in the following subchapters is largely based on this inter- to transdisciplinary canon of contemporary Sustainability Science or represents essential branches of development towards it. Nonetheless, the researchers cited here also belong to their disciplinary communities, but it is noticeable that scholars from several disciplines contribute to joint fields of work and refer largely to the concepts of Sustainability Science.

To clarify this programmatic reference, the first subchapter presents the basic understanding of Sustainability Science. The next subchapter is dedicated to the early development drivers of Ecological Economics and Industrial Ecology that are particularly important in the context of the presented research of this dissertation.

Then the following subchapters are focusing on different cores of the unsustainability problem constellations as interdisciplinary recognized common grounds. As principal frame, to describe the radically changed condition of the planet, the concept of the “Anthropocene” is used.

Afterwards, to better identify and understand existing problems, factors of global sustainability are briefly explored. Reference points on the fundamental nature of sustainability issues are developed through the concept of the tragedy of the commons (ToC) and research in the framework of social-ecological systems (SES). Following the given wider interpretation of the supply and welfare functions between the environmental and socioeconomic spheres (as explained earlier), a focus is on nexus perceptions, especially the Water Energy Food Security nexus discourse.

Further explained key drivers explicate overriding global socio-demographic or socio-technological developments, such as urbanization and thereby triggered shifts in the characteristics of our socioeconomic system, relating to the challenges stated in the beginning of the introduction. Finally, a special emphasis is given to the metabolism of cities as one of the root causes of global unsustainability taken up in the respective research summarized there.

1.4.2 Sustainability Science: General Understandings and Paradigms

In this research, a thematic state of the art has to be reflected to the state of Sustainability Science, since this emerging “container” of a progressive research is aiding as a possible integrator and as a transformation oriented academic arena, that still needs vital enrichments of its body of theory, knowledge, strategies and methodologies.

Therefore, research contributions that examine sustainability contexts and contribute to sustainable development should also necessarily underwrite the corresponding further development of Sustainability Science itself. Beside research topics and methodological progress this refers also to the self-conception and working modes of academia as stakeholders and promoters of sustainable development.

Sustainability Science has emerged since the 1980s as a pulsating field of system-oriented research and developed until now a core research agenda as well as an increasing flow of results published in some of the leading journals of the academic world (Kates et al., 2001; Clark and Dickson, 2003; Komiyama and Takeuchi, 2006; Clark, 2007; Kajikawa, 2008; Lang et al., 2012; Kajikawa et al., 2014).

Sustainability Science, as described in the Proceedings of the National Academy of Science of the United States (PNAS) by Kates (2011):

“…is an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability.”

Efforts for sustainability require a strong systemic emphasis on interdependencies and interconnections within a systemic perception of problems. An obstacle for these expansions, leading to an increase on the level of detail, heterogeneity, but also needed definitions of integrative frames upon formerly disintegrated fields of research, is that research subjects as well as approaches and technical language between the disciplines appear often “foreign” to each other. Moreover, barriers between a more “traditional” understanding of science and a transformation-oriented understanding of science have to be broken in terms of Sustainability Science. Research tasks have been evolved through the interplay between a descriptive-analytical and a transformational mode. The first is concerned with analysing problems in complex and dynamic human-environment systems, whereas the second conducts research on solutions to those problems (Wiek et al., 2012).

State of the art sustainability knowledge as the knowledge to achieve sustainable systems has emerged while Sustainability Science matured as cross-sectoral and transdisciplinary "post-normal" research (Funtowicz and Ravetz, 1995, 2003; Ravetz, 2006) in contrast to the rather increasingly fragmented "mainstream" academia (Sterman, 2012). The transformative part of this science has been incorporated from the beginning and is as strong as the analytical scientifically justified (compare: Funtowicz and Ravetz, 1995, 2003; Ravetz, 2006). This applies above all to a strong Anglo-American-influenced established research community of Sustainability Science, which has particularly spread mindsets not only to the Anglo-American region, but also in Scandinavian countries, the Netherlands, and to a large extent in Oceania.

This matured Sustainability Science has not been comparably successful in Germany so far. Here, Sustainability Science does not take effect as a top-ranked innovation path of science, but is still subject to a fundamental discussion about "transformation research" (i.e., research examines the transformation) and "transformative research" (research that itself has a transformative effect) (compare: Schneidewind and Brodowski, 2013; Strohschneider, 2014; Grunwald, 2015; Schneidewind, 2015; Strunz and Gawel, 2017). This debate is internationally unique, since the transformative part of Sustainability Science – as mentioned – has long been constitutionally accepted and successfully anchored, but only outside Germany.

The concept of sustainability itself and its practice orientation have been widely discussed, producing more advanced concepts than the ubiquitous policy related Brundtland "definition" on sustainability (Brundtland et al., 1987) or the business inclined triple bottom line (TBL, Elkington, 1998), as well as sophisticated scientific discourses about constitutional frameworks and theories (Ayres et al., 2001; Ekins et al., 2003; Neumayer, 2003; Dietz and Neumayer, 2007). Today a number of advanced conceptualizations are available (Kay et al., 1999; Ravetz, 2006; Kajikawa, 2008; Xu et al., 2014; Liu et al., 2015; Steffen et al., 2015b), yet rarely applied outside the expert communities.

Principally the findings of Sustainability Science bear momentum for concrete developments, strategies or investments being taken in socioeconomic systems. Based on the results of system sciences (Mesarovic et al., 1970; Findeisen et al., 1980), Costanza and Patten (1995) argued early that a *nested hierarchy organization* of systems must be considered over the ranges of space and time to avoid failures, costs and further risks. Accordingly, Sustainability Science bases errors or success of systems related to the understanding of nested system hierarchies and system resilience (Hahn et al., 2008; Folke et al., 2010; Steffen et al., 2015b).

Sustainable development findings with respect to system resilience (Folke, 2006) and social-ecological systems (SES) (Ostrom, 2009) had a big influence on the analysis as well as for the alternative solutions and finally how to achieve sustainable systems.

Beddoe et al. (2009) argue that sustainability transformation will occur through an evolutionary process that people can direct and control and seed the evolutionary redesign of the current socio-ecological regime to achieve sustainability. Finally, the socioeconomic stakeholders of a system must participate in the change of the system itself. All efforts for sustainable development must ideally reach a consensus on the desired characteristics which are consistent with the relationships between socio-ecological subsystems in the hierarchy (Costanza and Patten, 1995). These efforts should be based on participatory approaches (Kasemir, 2003; Lafferty, 2006; Ghai and Vivian, 2014), adaptive management (Gunderson, 2001; Tompkins and Adger, 2004; Norton, 2005; Walker et al., 2006) and applied in modes of collaboration and joint knowledge production (Hegger et al., 2012; Lang et al., 2012) in a non-technocratic but comprehensive transition process (Elzen et al., 2004; Kemp et al., 2007).

1.4.3 Ecological Economics and Industrial Ecology

Ecological Economics (EE) is a transdisciplinary field of academic research that deals with the dynamic interrelation between human economics and natural ecosystems. EE brings together different disciplines and combines them within the natural and social sciences. Starting since the 1980s, work in Ecological Economics (Costanza et al., 1991) has been an early special synthesis already beyond traditional economy, space or environment related research communities and academic disciplines and can be identified as a development milestone for the transformation of academia toward sustainability. The results represent far-reaching impulses for understandings of Sustainability Science today.

On the one hand, EE was formed and initially positioned within Economics by merging with the content and understanding of the Ecosystem Sciences, as an alternative school of thought and as criticism of the assumptions and approaches of traditional environmental and resource economics (Costanza, 1991; Costanza et al., 1991; Ropke, 2004). On the other hand, we could possibly also argue, that by incorporating economics into the consideration of ecological thinking, EE was developed (Costanza et al., 1991; Costanza and Daly, 1992; Rees, 2003; Wiedmann et al., 2006).

EE scholars have been mainly responsible for “strong sustainability” models as opposite to mainstream weak sustainability models. Strong sustainability refers to long-lasting stability of the concerned systems in terms of critical capital and particularly the non-substitutability of natural capital through technology (Costanza and Patten, 1995; Ayres et al., 2001; Ekins et al., 2003; Ekins, 2014). Another key aspect among others, but of relevance to the presented research, is the traditionally strong integration of issues of consumption into EE, with borrowings from social theory, psychology and anthropology, as well as the emergence of new communication methods from practice (Ropke, 2005; Ropke, 2009).

Resulting from the systems understanding of System Ecology, EE thus stands in strong contrast to the neoclassical economics and managerial studies (Pearce, 1987; Illge and Schwarze, 2009). Prominent EE scholars deny the possibility of a simple decoupling of resource consumption and economic productivity from economic growth. They argue for a comprehensive but differentiated view on a variety of capitals forming a sustainable system nested organization and under limitation of ultimate qualities of natural capitals stocks and flows to be preserved (Daly, 2005; Beddoe et al., 2009; Jackson and Senker, 2011; Costanza et al., 2016). Consequently, alternative economic models are conceived against the growth orientation, such as “Steady State Economics” (Daly, 1991).

Industrial Ecology (IE) as another influential school of thought, uses ecosystem principles and associated energetic organization to translate and open them for almost every alternative industrial purpose. IE established the first studies of industrial processes as open-loop systems, in which physical and financial resources are invested, degenerate into waste and, via open loops, become inputs for new processes (Korhonen, 2001; Korhonen, 2004a, 2004b; Nielsen, 2007). Pioneer works are prototypes for leading innovations in a circular economy.

Within IE, Systems Ecology thinking inhabits powerful implications for fundamentals in economic and sociotechnical systems with a general shift from a dominant efficiency paradigm towards needed resilience guidance. Following this research, simply lean, eco-efficient and energetically optimized resource systems do not lead to sustainable improvements, since they cannot meet needed flexibility and adaptability in terms of an “in vivo” fluctuating environment (Korhonen and Seager, 2008; Fiksel, 2015; Korhonen and Snäkin, 2015). In the longer term they may be inefficient due to lower persistence in their economic performances and thus bring new risks and additional costs. To reach resilience the broadening and diversification of the resource base and its structures and functions within socioeconomic systems are important. The diversity and presence of multiple and also redundant elementary structures, as reserves or buffers, ensure ancillary services, even if conditions change drastically and/ or if key elements fail (Folke et al., 2002; Folke, et al. 2010; Brown and Williams, 2015). In the industrial context some authors are exemplifying the “efficiency vs. resilience paradox” on the basis of comprehensive value chain and material flow networks of and in-between firms considering sourcing, production, supply and consumption sub-structures (Zhu and Ruth, 2013; Chopra and Khanna, 2014) and derive new policy recommendations rooted in IE (Deutz and Ioppolo, 2015), which is quite close to the hereby presented research.

1.4.4 The Anthropocene and the Planetary Boundaries

The Anthropocene describes a scientific diagnosis as well as one of the most influential concepts in Sustainability Science of the last decades, according to which a new geological age has replaced the Holocene (Syvitzki et al., 2020). This new earth epoch signifies the absolute dominance of humankind over the forces of the natural environment; an earth-historical novelty in which a single species represents this decisive power (Crutzen, 2002, 2006; Steffen et al., 2007).

However, it can be stated that the concept of the Anthropocene describes not just a dominance of humans over all the essential features of the planetary natural balance, but above all effects that bounce back on humans in a negative, threatening way. Building on this analysis, science raises the question of absolute, non-negotiable “planetary boundaries”, ensuring that humanity continues to exist and preventing serious global environmental change, termed a “safe operating space” (Rockström et al., 2009; Steffen et al., 2015b).

Effects of the Anthropocene can destabilize basic ecosystem services as well as complex value creating economic networks. Many of these effects are entangled in complex dynamics, often not fully understood scientifically, and thus constitute barriers to rapid “simple” solutions.

In research consensus is given for interlinked thinking and action and to come up with precautionary integrated solutions. Liu et al. (2015) are advocating stronger systems integration in the view of the root causes and functions but also in terms of needed methodologies and their frameworks. Finding and activating these integrated system levers of sustainable development would have to be preceded by a comprehensive reconfiguration of not less than the bios of our socioeconomic system, and, above all, change the habitual routines of global urban-economic networks with respect to all its scales (Rees, 1990; Costanza et al., 2017).

1.4.5 The Tragedy of the Commons and Social-Ecological Systems

All current approaches, strategies and proposed actions of a desired sustainable development are referring to a core set of problems, which describe subject-related affairs of global unsustainability. This planetary status is rooted in conflicting and ineffective designs of socioeconomic utilization systems of the natural capital and its ecosystem services (Holling et al., 1998; Holling, 2001; Ostrom, 2009).

The interplay of ecosystems with socioeconomic utilization systems, the resource pools, products, value-added levels, and system services between them is highly intertwined with the "Tragedy of the Commons" (ToC) (Holling et al., 1998; Thiele, 2016). ToC is a social science and evolutionary-theoretical model of understanding that freely available but limited (natural) resources – the commons – are not used efficiently and show a high vulnerability against overuse, which is ultimately threatening the users themselves. This causality can be understood as the root of sustainability problems at various scale levels, from local to global effects.

The underlying dilemma has been known for far longer than the scientific contributions of recent decades suggest. Garrett Hardin (1968) extended the originally by William Foster Lloyd (1833) described problem of the ToC and introduced it into resource economics. According to Hardin, as soon as a resource is fully available to everyone, everybody will try to generate maximum individual returns. This works if the resource is not exhausted. However, as soon as the number of users, or the intensity of use, increases above a certain threshold, the ToC becomes evident: Users continue to maximize their individual yield by contrasting the common interest of conserving the resource. The costs of depletion are borne by the community, not by the benefiting individuals. For the individual, the current profit is perceived to be higher than the delayed long-term cost, which explains a lack of intervention. Consequently, however, everyone contributes both to his own and to the ruin of the community. According to Hardin (1998) ToC is an *"inevitable fate of humanity"* if the acting parties try to counter (over-) exploitation of resources alone in a technological and reactive manner while the archetypal system behaviour remains misunderstood. He argues that rather a fundamental change of perspective is necessary, which should replace individualistic, disintegrated solutions with community-oriented and integrated regulations.

In general, we can argue that a recalculation of current global environmental problems to ToC produces an incomplete picture, even though fundamental features of the problem are depicted. A major contention argument is that the limitation of resource uses is not solely determined due to the lack of the availability of resources, but also through the inability of compensatory systems to absorb the wastes generated, including greenhouse gas emissions. In fact, the climate system sets tighter limits to resource utilization than the general availability e.g., fossil fuels (IPCC, 2014, 2018).

Elinor Ostrom considered the ToC from an institutional economic point of view in "Governing the Commons: The Evolution of Institutions for Collective Action" (Ostrom, 1990). According to her, promising solutions to the problem of local commons would be based on the point that the affected individuals manage the resource in the framework of a suitable institution, which is based on the self-organization of the participants. For the establishment of an appropriate agreement both a credible self-commitment of the participants as well as the establishment of effective control and monitoring mechanisms in a governance approach are necessary. Such institutional arrangements at the cooperate community level are often more successful than central government control or pure market mechanisms because local knowledge and process ownership can be used more effectively to conserve the use of resources in the long term (Ostrom, 1990, 2009).

From Ostrom's point of view there are more solutions to the problem of commons as suggested by Hardin, but also as in traditional economic theory in general. In particular, she insists for a reassessment of the scope of the theory that emerged from Hardin's article. Between the extreme forms of a government model (with a “benevolent dictator”) and an enterprise model (with a “profit-maximizing entrepreneur”) a multiplicity of collective and collaborative forms of use exists in the reality, which should be considered. How these designs can look has since that become an important research question with previously unseen societal relevance regarding sustainability issues (Hinkel et al., 2014; Abson et al., 2017; Miller and Wyborn, 2018).

From a systems theory perspective, the ToC is the result of positive feedback mechanisms, which lead to a reinforcing behaviour (Sterman, 2012). This means that the positive feedback has a reinforcing effect on itself: the more the common good is used, the scarcer it gets – and the scarcer it gets, the stronger the competition from the users for the remainder. This leads to a downward spiral in the end: The common good is almost or completely consumed and competition results into conflict. If the survival of the users depends on it, it is also endangered.

Based on this missing mutualism between the socioeconomic and ecological system compartments, there is meanwhile rich interdisciplinary accentuated research of Social-Ecological Systems (SES) (Walker et al., 2004; Folke, 2006; Cumming, 2011). Berkes et al. (2000) use the concept of SES to emphasize that the demarcation between social systems and ecological systems is artificial and arbitrary.

Ostrom’s “SES Framework” contains much of the evolving theory of shared resource pools and collective self-governance from her institutional economics work from the 1990s (Ostrom, 2009). For management processes within such institutional frames, this means that they are made adaptable and flexible to counter uncertainties and surprises and to build up a system-based ability to adapt to changes. It is therefore vital that SES are being continually tested, learned, and developed to deal with changes and uncertainties (Carpenter and Gunderson, 2001; Folke et al., 2005; Folke, 2006).

1.4.6 Nexus Behaviour and Urbanization Dynamics

Scholars from different backgrounds have been discussing a multitude of aspects of integrated solutions or are taking different perspectives. However, a focus of research since the 2010s refers to the increasingly vulnerable areas of primary production and general resource availability, which are characterised and controlled by dynamic complex relationships as “nexus behaviour” (Liu et al., 2018). Highlighted have been the specific interdependencies between food, water and energy supplies and the dwindling security of these vital resources, especially under conditions of global environmental change, particularly climate change (Ringler et al., 2013; Rasul, 2014, Rasul and Sharma, 2016; Keairns et al. 2016). The functional interconnectedness of inflicting core factors strongly connected to risky regime shifts are recognized as “Water Energy Food Security Nexus” (WEF Nexus) and is representing an issue highly ranked on the international sustainability research and development agenda (Bazilian et al., 2011; Bogardi et al., 2012; Allan et al., 2015; Rasul and Sharma, 2016; Scott et al., 2015; Smajgl et al. 2016). Climate change was the foremost motivation from the very beginning of the discourse on the WEF nexus and is intensively discussed by several authors (Scheffran and Battaglini, 2011; Beck and Villarroel Walker, 2013; Howells et al., 2013; Rasul and Sharma, 2016; Scott et al., 2015). The WEF Nexus approach can be considered as a way to frame the interdependent challenges of water, food and energy as well as the natural resources that underpin those systems to align policies for the reduction of trade-offs and to generate co-benefits for sustainable development (Stein et al., 2014). This applies to the preservation of the performance of basic ecosystem services, the functions for value creation and supply within the socioeconomic system and the handling of the complex dynamics between water, energy and food as a determining force.

The cited WEF Nexus literature is having an emphasis in complex problem descriptions or assessment studies. State of the art still lacks in dealing with the nexus elements in a consolidated manner and a stronger emphasis on the exploration of lever mechanisms to reduce supply risks and to enhance supply security. At this stage Ostrom’s SES framework represents promising principles for dealing with nexus dynamics to achieve higher supply security (Stein et al., 2014). Generally, the WEF Nexus demonstrates the interconnectedness of the factors in SES and shows considerably how far we have moved away from delimited traditional scopes of demand, production, and supply mechanisms. It has become impracticable to execute autonomous assessments for sustainability in a particular industry or a socioeconomic sector without occurring broader repercussions in manifold functionally contiguous fields (Fiksel, 2006).

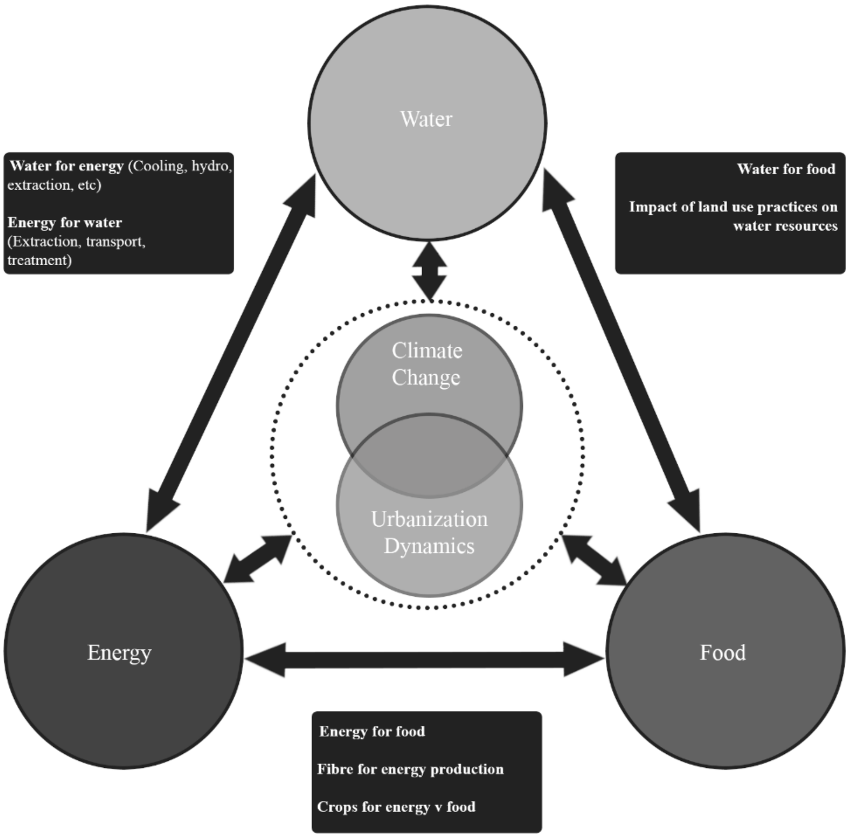


Figure 1.2: WEF Security Nexus and Climate Change/ Urbanization Dynamics (modified from Smith-Gillespie, 2014)

According to the previous understanding, urbanization has developed to be not just a main feature, but a driver of the Anthropocene. Urbanization thus not only generates an increase in urban space, but also determines global economic and ecological systems as an increasingly urbanised global system as the “Urban Planet” (Elmquist et al., 2018). The global urban networks are fundamentally shifting global source-sink relations, are causing unsustainable macro-scale teleconnections (Seto et al., 2012; Liu et al., 2013). Besides climate change, urbanization dynamics[8] must be weighted as a root cause of climate change and as a key driver for the WEF Nexus, since urbanization triggers a new quality and quantity of energy, water and further resource demand rates (Sassen, 2009; Bettencourt and West, 2010). This exponential hunger for resources in relation to urban growth curves and resulting emissions can be explained by the theory of “non-biological scaling behaviour” (Bettencourt and West,

[8] Understood as regional demographic development in absolute terms of population growth, combined with urbanization effects with increased resource consumption due to dependent lifestyles in urban systems.

2010). Basically, the theory explains the positively increasing network effects of cities and metropolitan regions, which, among other things, increase demand for energy and resources.

Conversely, urban systems are highly vulnerable against climate change due to their extreme supply dependency next to geographical exposition and typical urban environment qualities (Newman and Jennings, 2008; Newman et al., 2009). Several authors highlight the extreme dependency of urban systems with all global economic implications from those functionalities and industrial life support systems capable to preserve water, energy and food supply as well as to the connected enabling mechanisms within the urban metabolism (Sassen, 2009; Krumme et al., 2011; Beck and Villarroel Walker, 2013; Villarroel Walker et al., 2014; Biggs et al., 2015; Smajgl et al. 2016).

Figure 1.2 above illustrates the interplay of the WEF Nexus with climate change and urbanization dynamics.

1.4.7 Perceiving the Sustainability of Cities by Metabolism Models

The Urban Metabolism (UM) has been an important orientation for the sustainability transformation of cities since the 1970s. First described by Wolman (1965) in Scientific American, the concept at the time was primarily dedicated against the background of material or oriented towards energetic in- and outflows of cities and describes a holistic budgetary approach to make material and energy flows visible for an entire city. UM experienced an upswing in application to some American and European cities in the 1970s[9]. It was not until the 1990s that UM became a key contribution to urban transformation in the course of sustainable development (Baccini, 1996; Newman, 1999). In addition to the mere analysis of energetic or material inflows or outflows, UM serves as a modelling option to design cities in a resource- and energy-efficient manner, to provide indicators for alternative urban development strategies, to introduce information and control levels and to strengthen comprehensive considerations of the city as a system on the physical-technological side. UM is thus compatible with other approaches to the sustainability transformation of urban systems, e.g., in Social, Spatial, Economic or Environmental Sciences. They all represent system elements that have an influence on the UM or shape it from the ground up (e.g., consumption by the urban population in the social sciences, modification of the ecological properties of the city in terms of ecology, quality and quantity of the energy and material requirements or their control presented in economics and the influence of urban structure and spatial planning in Spatial

[9] This has expanded significantly to date and applications can be found in many cities around the world, e.g. Melbourne, Sao Paulo, London, Rotterdam, Stockholm, Cape Town, Beijing, Brussels, Lugano, Barcelona, Uppsala and others

Sciences). Viewed as a whole, the interplay of the disciplines enables work on the "sustainable urban organism", for which the UM represents the basis. In the 1990s, system boundaries were spatially expanded to include the regional environment or the "urban hinterland" and the conscious control of regional material and energy flows, or the enabling of regional cycles for an increase in self-control and reduced dependency (Baccini, 1996; Newman, 1999). The discourse about the "city and its region" or "urban-rural relations" or "city and hinterland" is a never-ending thread in respectively participating expertise areas (Jacobs, 1984; Dickinson, 1998; Newman, 1999; Davoudi and Stead, 2002; Newman and Jennings, 2008; Hoggart, 2016).

In the last decade extensive application references to the methods of modern urban planning have been worked out and documented for various case studies. System-theoretical references are included in the application (Niza et al., 2009; Kennedy et al., 2011; Broto et al., 2012). Finally, the EU-funded BRIDGE project enabled clearer documentation and comparability regarding mapping environmental and sustainability goals (see Chrysoulakis et al., 2013). At the same time, new technical solutions are available, especially in information and communication technologies (ICT), the resulting networking and collaboration of all relevant urban stakeholders, and in the sense of the further development of "Smart Cities". For example, a project group at the Royal Institute of Technology in Sweden brought together ICT, smart city technologies and UM for smart city districts in Stockholm and published them as "Smart Urban Metabolism" – SUM (Shahrokni et al., 2015a, 2015b). Individual stakeholders and stakeholder groups (citizens, companies, local government) communicate transparently with each other and with the UM about material and energy flows, or directions, locations and consumption of resources and energy.

Within the analytical frames, the city's classic system boundaries are shifting to reduce the city's dependence on external resources and to increasingly think in terms of circular, highly decentralized and self-regulating supply alternatives. Girardet (2014) argues, cities must move from a linear metabolism (depending on imports) to a cyclical metabolism. Urban-metabolistic models therefore show a close but not yet sufficiently elaborated relationship to the modern ideas of sustainable resource management of the "Cradle to Cradle" concept by Braungart and McDonough (2009) and/ or the idea of "Biomimicry" and "Management Bionics" by Benyus (1997).

The at this point conceptually relevant approaches of industrial metabolism (IM) (Ayres, 1989; Ayres and Simonis, 1995) have existed parallel to the developments presented for a long time, although the conceptual similarities are great and go back to common origins. Work on IM largely originates from the theoretical framework of Industrial Ecology (as presented earlier) and serves primarily to record and display material, energy and, increasingly, data flows to be able to assess the environmental impacts of (mostly local) structures of economic systems and to enable political target control. Many of the elaborations place a (regional or local) energy and material flow management centrally and thus serve a predominantly technical focus. At this point, criticism can be justified: against the background of natural metabolisms of ecosystems and building on the knowledge of Systems Ecology (see above), social actors and their institutions would fully be integrated. A conceptual bridge here is formed by the socio-metabolic regimes approach derived from research into human-environment interactions and social metabolisms (Fischer-Kowalski and Haberl, 1998). However, the regimes remain at a high level of abstraction and could not be fully translated into more concrete transformation designs up to now.

1.5 New Coordinates in Sustainable Development related Research

1.5.1 General Remarks

The following explanations contain central coordinates for enriching future sustainability research. Beyond the “state of knowledge” from the disciplines and contemporary sustainability science explained before, the aspects help to address the challenges defined at the beginning in a more targeted manner and, above all, in accordance with their systemic character. The aspects are considered in the research of the cumulative chapters 2, 3 and 4 and are further developed there. The present chapter can be understood as a strategic overall orientation, which is then further condensed in the dissertation concept (afterwards) that describes the framework of the cumulative work in an operationalized form.

First, fundamental anchoring of sustainability science in terms of systems science is discussed. The theoretical interdisciplinary substructure of the general systems theory and outstanding representatives of different disciplines are considered (1.5.2). A more specific transfer is then made in the direction of a further strategic upgrade of the ecosystem approach (1.5.3).

New pathways of Sustainability Science must reflect the multilevel organization of the problem and serve effective levers for system-wide changes. So to speak, they should focus on “system tipping points of a transformation”. Such tipping points of the transformation would be “transformative domains”, i.e., areas that can have a systemic effect in favour of a change process to a multiscale sustainable socioeconomic system. These domains describe basic system connections of the “old” unsustainable system, but also levers to facilitate processes of change around a dynamic effect in favour of a “new” sustainable system. As we learn from Ecosystem Science and Cybernetics, these domains stand in close relationship to “system services”, since structures are addressed, and functions are operationalized.

A promising assumption in this context is thinking in terms of supply (source) and demand (sink) relationships makes core interdependencies of unsustainability and sustainability tangible. As explained earlier, processes of global multiscale urban-industrial systems are root causes of the global ecological overshoot and resulting regime shifts. Implications (in terms of gaps and coordinates) of such a new sustainable development related research with respect to several more specific research directions are explained in the subsections 1.5.4–1.5.9.

1.5.2 Systems Thinking from the Baseline

In his “Guide for the Perplexed” Schumacher (1978), is pointing out that finding solutions for many pressing problems, depends on identifying the context of larger concepts and issues wherein they are integrated. Ultimately therefore a progress in problem solution relates to an expansion of the “classical” fields in the academic disciplines for those who would like to come to sound solutions. We can basically conclude that stronger inclusion of knowledge, theories and methods of systems thinking in sustainability references is crucial. However, how this is implemented in a specific programmatic way must be worked out. In analogy with the increase in detailed information on the acquisition of knowledge through the microscope, the French system theorist Joel de Rosnay called the necessary “upscaling” and “synscaling” of the perspective on fundamental, cross-sectional functional relationships the “macroscope” (de Rosnay, 1975). The idea of the macroscope is followed by various considerations in social and economic systems, such as in companies or in the city (de Rosnay, 1975).

Approaches that sharpen a “Sustainable Systems” profile are therefore also explicitly considered in the selection of the cumulative contributions to this dissertation. This applies to already earlier mentioned diverse works in general system theory, applications in relevant contexts of sustainability orientation such as the applications of system dynamics in industrial, urban or resource systems, e.g., from Forrester (1961, 1968, 1997) or Sterman (2000, 2012), as well as newer methods that support the co-creative production of system knowledge. Such methods enable the identification of disadvantageous or advantageous system behaviour amongst system stakeholders and agents, coming from different backgrounds, motivations and with differing interests. Through collaborative participation structures, transformation designs can be extracted from “thought silos”, path dependencies can be identified and questioned, and realistic alternatives of then promising future designs can be made possible such as through Participatory Systems Mapping (Sedlacko et al., 2014), or CANVAS-oriented methods (Wigboldus et al., 2020). Further progress is dependent on an evolving discourse between disciplines and worlds of experience in the transdisciplinary space.

In addition to the closer references to the presented research already mentioned, such as the system dynamics school of thought, the Ecosystem Approach, and general systems theory, contributions from the wider systems theory context are also relevant. The pioneering work by Niklas Luhmann is not directly contextualized in this dissertation due to specific orientation with respect to Geography, Environmental and Management Sciences. Nevertheless, it is easy to develop references to Luhmann's Sociological System Theory (Luhmann, 1984), because he contributes several aspects from a sociological-philosophical point of view, to which – due to its universal nature fundamentally relevant – references to sustainability transformation exist. On the one hand, generally the concept of social “autopoiesis”, i.e., the genesis and self-referentiality of social organizations as an obstacle to transformation efforts in systems, can be named. As early as the 1970s and 1980s, Luhmann worked intensively on the question of the responsiveness of modern societies and their organizations regarding ecological hazards and differentiates between actions, ability to react/ act and communication and its rules (Luhmann, 1986). At this point, too, references can be made, since Luhmann's concept of communication is based on a complex representation of relationships in the social system.

De facto, this results in system properties as a relationship building in the system. According to James J. Kay, the EA also places the system-forming and system-maintaining relationships between elements that result into functions at the centre of considerations, instead of defining the system from the physical structure (Kay et al., 1999). The highlighting of functions through communication and interaction is an essential basic positioning of a future-oriented transformation effort. The “fitting” structure follows. Conventional planning often asks what structure should be designed, built, or transformed to serve a particular “purpose”. Sustainability transformation, however, has to proceed the other way around and is therefore very anchored in the universal system-theoretical considerations presented: It has to find new structures through desirable functions and the underlying relationships and interactions. The difficulty of this communication or interaction structure is also dealt with by Luhmann by speaking of the “improbability of communication” (Luhmann, 1986) but also elaborating the increase in probability (albeit on a meta level). This “relationship work” is based on all collaborative processes in the sustainability transformation in a more fine-grained manner, in a way that methods to facilitate understanding and the flow of communication as well as about key terms (boundary objects/ boundary work) are a necessary component (McGreavy et al., 2013; Koehrsen, 2017).

Less considered in the academic debate, in the "Economy of the Society" (Luhmann, 1988) and in his monetary value theory and the classification of money as a communication medium, Luhmann gives further guidance, e.g., in concern to ecological economics. With regard to the monetarization of "natural capital" and critical discussions about ecosystem services and their "pricing" ("capitalization of nature"), his theory illustrates interesting orientations, how monetization can be lifted out of the "suspicious" capitalist canon in order to be able to integrate prices in the sense of communication for the creation of environmentally sensitive value creation networks.

Also, outside the direct spectrum of this dissertation, but also relevant to its context, is the work of Peter Senge, whose influence on management organizations through the transfer of system thinking is highly interesting (Senge, 1990). This applies to perspectives via "learning organizations", since here strategies of learning and adaptive management as well as the strategical development of organizations can be transferred to complex organizational forms in sustainability transformation processes and open new ways of institutionalizations for the adaptive governance of sustainable development.

1.5.3 Further Valorising of the Ecosystem Approach

Scientifically an Ecosystem Approach represents a naturally coherent structure of elements and parameters to create a synergistic, self-organizing sustainable functioning whole through dissipative structures (Kay et al., 1999). "Accuracy of fit" and interdependencies for generating emergence in quite complex and dynamic networks are fundamental for this kind of understanding.

Today, an Ecosystem Approach often stands generally for a broader ecosystem-based thinking or design. Transmissions are available in different directions. The "ecosystem" has become established as a transfer of prototypical system organization from natural systems to business, technology, cities, and other artificial systems. The basic understandings of interdependencies, feedbacks, emergences and synergies in nested organizations, modelled on natural ecosystems over the past five decades, have increasingly found its way into the modern social or economic world, e.g., as "industrial ecosystems" (Lowe and Evans, 1995), "business ecosystems" (Iansiti and Levien, 2004), "innovation ecosystems" (Adner, 2006), "digital ecosystems" (Nachira et al., 2007), "knowledge ecosystems" (Clarysse et al., 2014), "data ecosystems" (Jarke et al., 2019) and finally "entrepreneurial ecosystems" (Acs et al., 2017; Stam and van de Ven, 2021).

Even if the conceptual substance of these approaches, measured against such definitions as given by James J. Kay, do fluctuate between the “metaphorical” use of the term “ecosystem” and more profound conceptual understandings, we must attest great progress in the various research and development areas mentioned above. Data and software ecosystems in computer science and business informatics and innovation ecosystems in management science (and most recently the amalgamation of these two approaches) show considerable scientific content here. Originally natural ecosystem properties in terms of architecture and composition, factor interdependencies, emergence of effects, self-organization, system control as well as susceptibility to errors or system resilience and learnability are clearly recognizable in the literature cited and the further networked scientific communities.

Rowe (1992) developed definition approaches and principles for the application of the EA for forestland management (so far only received attention there), which can be transferred to general applications of the EA. Rowe is arguing that taking an EA means that people and their institutions shift the focus from parts to wholes, from the “interest” to “capital”, from the elements at the earth's surface yields to “three-dimensional ecosystems” that produce wanted revenues. He also stresses the importance of encouraging partnerships to reach sustainability, but also raises the question “what kind of common understanding is needed to form closer liaisons and alliances” (Rowe, 1992).

To come up with comprehensive solutions due to – in nowadays terms collaborative and cooperative – structures does not lie in increased technical understanding at the level of managing resources. As Rowe (1992) argues, the kind of understanding that is necessary lies on an “ecosystem level” transcending and integrating the formerly separate resources. If well understood, an ecosystem view by following Rowe:

> “*… leads everyone involved toward a comprehensive ecological perspective on people and resources.”*

In a contemporary understanding, one could state that the EA is a framework under which “ecosystem-oriented activities” operate. Building on this, the EA provides the links for ecological, social, and economic aspects of an area or a system in question in order to achieve a long-term stability and balanced “benefit” in the sense of system resilience. The meaning of “ecosystem-oriented activities” is hereby multifold and makes an EA:

- adopting a system view of human-environment interfaces by recognizing complexity and interdependencies and by respecting the finite capacities of ecosystems
- based on scientific knowledge of the functioning of ecological systems.

- facilitating participatory involvement of stakeholders as the driving force for sustainability transformation.

However, the question must be asked whether the congruence between the organization of ecological systems and the desired sustainable socio-economic systems is complete on a theoretical basis, i.e., the transfer of the “lessons learned” of Systems Ecology is sufficient.

Here it is, where the EA seems to have conceptual deficits: there is no doubt that Ecology's essential functional mechanisms are also to scale above the regional area, as global climate models can clearly illustrate. Principally, it can be stated that ensuring functionality is in the vitality of regional and local systems, which develop “bottom up” into a functioning whole in a “nested organization”. For developing sustainable integrated solutions, it is important to note that Ostrom's SES frameworks (Ostrom, 2009), while leveraging local governance and knowledge systems, may have strong rewards in avoiding sustainability disadvantages and gaining benefits explicitly through a local management level.

In the socioeconomic sense, however, the human economic system has developed mechanisms that are not local, but explicitly global. They are to be viewed per se in the sense of global sourcing and global added value creation and reveal a deficit about macro- or global scale transfers in the theory foundations in Sustainability Science. A nested organization of the complex system – as displayed in the EA – must therefore be conceived to capture the aspect of global interconnectedness and to form the foundations for a global sustainable economy. In this sense, an EA must also be conceptually expanded: On the one hand, it must be possible to think and plan scales beyond regions. On the other hand, it must take up the complexity of value-added functions of modern business and social life.

The following research aspects continue the thought, in the narrower framework of EA and in the broader context, in research questions related to the research presented here.

1.5.4 Holistically understood Supply and Welfare Functions

The Millennium Assessment addressed the issue of the status of the functionality and availability of basic ecosystem services that are “supplied” as socioeconomic uses to humankind. The dependent economic system provides products and services for basic supplies as a societal function as well as for economic value creation. The supply and welfare function – understood in this superordinate sense – is again central to our context.

From Ecosystem Sciences, we know that most services supplied at the local scale depend on the nestedness with upscale regional and/ or global functional mechanisms to maintain these functions (Odum, 1994; Jorgensen, 2012). Under natural conditions, this nested organization leads to a self-regulatory whole (Kay et al., 1999; Holling, 2001; Waltner-Toews and Kay, 2005). Nowadays socioeconomic systems disturb those natural structures and functions, not least because they are structurally different, leading to functional errors to maintain overall and long-term system functions for finally both economic and ecological services (Costanza, 1992; Berkes and Folke, 1994; van den Bergh, 1996). This seems especially true when socioeconomic performances are grounded in neoclassical economic conceptions (Gowdy and Erickson, 2005; Rees, 2019).

A general problem is that social or economic compartments of the actual SES are perceived fragmented and are therefore organized and "optimized" in a disintegrated and consequently ineffective manner, that has to be changed to find sustainable solutions (Costanza et al., 1991; Folke, 2006). As Holling (2001) has decidedly broken down, the translation of ecosystem theory – so to say: An Ecosystem Approach – into SES theory and implementation practise would lead to key points of solution designs through features of nonlinearity dynamics, multiple scales, emergence of collective functions, self-organization through functional hierarchies, feedbacks, and loops.

1.5.5 The Global Space of Flows and its Operation Services

Texture and patterns as well as general performances of the socioeconomic system have changed fundamentally against the backdrop of globalization, urbanisation, and the widespread use of information technologies in a virtually condensed world (Castells, 2011). Castells describes the most fundamental change in characteristics as a *"dominance of the Space of Places by the Space of Flows",* labelling a major paradigm shift in the functioning of the globalized, highly urbanized and industrialized socioeconomic system (Castells, 2002, 2005, 2011).

To follow Castell's argumentation, on the one hand, mechanisms of action lie in the cultural, social and economic potentials of change in communication and information systems and their technologies. The power of virtualization and the associated changes in the physical world, however, in the main phases of industrialization, in particular during the great acceleration after the Second World War, led to a fundamental structural shift and reorganization of production, labour and consumption. In the result, this fundamental restructuring triggers a mostly urban-determined global ecological footprint through demands and supply dynamics (Wackernagel et al., 2006; Grimm et al., 2008; Lambin and Meyfroidt, 2011; McHale et al., 2015; Moore, 2015; Rees, 2019).

Even if Castells' analytical statement is 20 years old, it has not lost its topicality. More importantly, however, it lacks the transformative component in terms of sustainability research. Up to now it is unclear how to turn Castell’s observation into a transformative setting of sustainable global development.

1.5.6 Global Sustainable Supply Systems and their Urban-Industrial Context

The growing proportion of urban populations and downstream resource agglomerations are fundamentally shifting global source-sink relationships and are generating macro-scale teleconnections (Seto et al., 2012, Liu et al., 2013). In the macro-scale context of shifts in global sources and sinks linked by supply chains, urbanization and industrialization are of particular (and interlinked) importance (as explained).

We know that these effects are strongly associated with industrial – corporate-driven – value creation patterns and appear as a functional urban-industrial amalgamation (Liu et al., 2015; McHale et al., 2015). Globalised industrial value and supply chains correspond to a global urban demand system, which requires structures and services for bridging global teleconnections and built-up structures, functions, and services of a complex worldwide supply and value creation networks, which essential conditions and performances are represented and modelled by among others Global Production Network (GPN) Approaches.

The question would be how a monitoring and assessment system would have to be designed, e.g., to map out transformation paths using complex scenarios and to design concrete strategies for action in favour of sustainability transformation. How new designs of a global urban-industrial system could look under changed circumstances, and how the different manifestation levels and standards of urbanization, has so far left unanswered. Research designs are correspondingly weak or non-existent.

1.5.7 Expanding System Boundaries with an Urban-Industrial Metabolism Approach

The significance of metabolistic concepts and models is obvious for sustainability and system considerations. In the context of urban sustainability, they have a decades-long tradition in science, but primarily from the perspective of the individual city and only secondarily about the relationships in the “supplying” and interlinked network structures. Sustainability-related studies of higher-level networks within the global urban system are not available. Works such as Baccini and Brunner (2012) in their “Metabolism of the Anthroposphere” do contextualize cities and urbanization, but do not deal specifically with the urban or the urban-industrial “Space of Flows”. In the context of the present dissertation, a synthesis of the urban and industrial metabolism concepts is necessarily derived from the problem analysis as well as anticipated “integrated” solutions.

New operating and organizational principles for sustainably transformed cities, including the network relationships within the globalized urban or urban-industrial system are currently not available. A synthesis of the technology term Sustainable Urban Metabolism (SUM) as “smart” with economic, ecological and social system factors of metabolism in the sense of the more comprehensive “sustainable” requires an opening of the underlying technology interpretations.

A model of a “Sustainable Smart Urban Metabolism” can make use of valuable preparatory work (see Shahrokni et al., 2015a, 2015b). Approaches to the further development of frameworks that guide action in the sense of Social-Ecological-Technological Systems (SETS) can play a significant role to conceptually reinterpret cities. Central areas of innovation, such as digitized urban production and urban consumption could be reorganized on this basis. This could apply to spatially re-urbanized/ regionalized production as well as to solutions that emphasize relationships between the city and the surrounding region as well as urban-industrial distant telecouplings. At this point it becomes obvious that expanded urban metabolism approaches naturally lead to a synthesis of urban and industrial metabolisms into integrated urban-industrial metabolism approaches as a perspective for transformative research.

1.5.8 Innovative Contextualization of the Supply Chain and Logistics Services

The manifestation of an alternative socioeconomic system lacks the necessary operative anchoring in its future supply networks as part of a global sustainability governance system (Haas, 2004; Baily and Caprotti, 2014; Loiseau et al., 2016). Despite the conceptual achievements that exist, such an alternative system is little implementable because it lacks scale-comprehensive rules and operational principles beyond *and* beside the questions of organization between the hierarchies of scales. Concretely the sectors of production, supply and consumption would have to be tackled in an integrative way and be conceptually innovated under internalization of sustainability relevant assets.

Castell's description of the dominance of the Space of Flows implicitly points to a world of logistically operationalized networks of information and material flows, and dynamically corresponding production, labour, consumption and value-added systems. In Economic Geography, the world of globalized value and supply networks, also under integration of trigger and maintenance services in the understanding of e.g., modern logistics value-added and information service systems open to some research arenas (Hesse and Rodrigue, 2004, 2006; Yeung and Coe, 2015; Coe and Yeung, 2019).

As a central concept, the “supply chain” represents a backbone and a mediator of contemporary and future-oriented structures and developments in the economy. The “logistical determinant” could also be viewed as an access point for system transformations. Based on the understanding of logistics and SCM as a comprehensive facilitator of complex economic relationships and value-added processes, questions arise about the “transformative supply chain” and about system services in logistics, which, after supply chain and value chain integration, also take up the “system service for the sustainable economy”. The proactive role of transformative supply chains and system services for changes in the entire economic system has been underestimated (Melkonyan et al., 2019). Approaches require further elaboration, research, and evaluation in practice (Krumme and Melkonyan, 2019). In perspective, design options for globalized sustainable value creation and supply networks are formed from this, on the one hand via the level of regulatory frameworks, on the other hand via the research and development of new archetypal business models.

1.5.9 Blended Research between Production, Supply and Consumption/ Lifestyle

One directly related pillar of a more progressive course is the combination of strategies for sustainable logistics and SSCM with those for sustainable consumption and lifestyles, seeing the consumer and the economic and ecological impacts of lifestyles as a terminal and deterministic force of a supply system (Krumme et al., 2015; Melkonyan and Krumme, 2019).

The earlier explained two-sided research gap between supply chain services and the (un)sustainability of lifestyles is not just remarkable but represents an unused potential for concrete sustainability transformations. Considering qualitative (also radical) shifts in lifestyles and consumption represent one of the most important strategies to reduce the overall resource consumption and the related ecological footprints (Ekins, 1993; Spaargaren, 2003). Enabling sustainable lifestyles, thus, depends to a significant extent on the processing of the interdependencies to emerging services in complex supply networks. Taking logistics and SCM as important counterparts and enablers of the needed shifts in terms of sustainable consumption represents a high degree of the understanding of system dynamics for a future sustainable economy.

1.6 Dissertation Concept

1.6.1 Research Subject and Research Goal

Based on the challenge from 1.1. and 1.2. as well as using the coordinates of new sustainability-related research (1.5), the research subject of the conception, justification and application of the Sustainable Urban-Industrial Supply Systems is processed by applying and expanding the Ecosystem Approach.

Based on this, the research goal is to combine different key couplings between natural capital, production, supply, and consumption in the sense of a "Production Supply Consumption Ecosystem" (PSC Ecosystem). Theory formation and empirically based findings are to be transferred into new sustainable transformation designs.

The author advocates three main general research objectives on this basis:

1. *To enrich concepts on the course of Sustainability Science through theory formation for a transformation guided progress toward sustainable PSC Ecosystems.*
2. *To validate various PSC Ecosystem solutions based on that enriched theory in practise in different but interconnected real life spatial and methodological settings.*
3. *To design new improved capabilities, transformative macro- and microscope structures and system service archetypes for orienting organization, governance, and operations on multiscale levels with respect to PSC Ecosystems.*

These main objectives correspond to the three cumulative publication-based parts of the dissertation: *Theory Formation (Chapter 2)*, *Empirical Analysis (Chapter 3)*, and *Transformation Designs (Chapter 4)*.

1.6.2 Strategic Research Agenda

In view of existing network-oriented approaches, especially in Geography, we need more evidence-based research to test and generate innovations in concrete transformation settings. In the context of the (eco-)system-based new concepts described in the cumulative part of the dissertation, the emphasized recourse to existing methods of system dynamics and empirically oriented research settings, such options are shown. It is important that, on the one hand, Sustainability Science integrates geographical approaches more closely. On the other hand, however, Geography should be more determined in the integration of research strategies, concepts and methods, e.g., from Management Science (such as from supply chain management) and the joint processing of interfaces.

In the understanding of Sustainability Science, a strategic positioning is important, which combines scientific analysis of problems, their conditions and relationships, with the further development of theoretical substructures for solutions and suitable, implementable transformation impulses for the practice. For content orientations and contexts, this means above all methodologically that the phases of analysis, conceptualization/ modelling, as well as implementation of practical solutions and transformation piloting show a strong coherence and are operated in a coordinated manner (temporally, functionally, and often also physically and spatially).

The understanding of the 3 cumulative chapters (Theory Formation, Empirical Analysis, Transformation Designs) is therefore not sequential-linear but circular-iterative. This means that the order of the contributions in the chapters 2, 3 and 4 builds interrelated content blocks (partly reflected by the publication date of the articles). In this course of the underlying research, initially basic theoretical concepts for example have been refined or on the basis of empirical results/ concrete transformation designs – or the other way around: theoretical advances have had again improving meaning for e.g., transformation designs.

The scope and interplay of the three chapters with cumulative contributions are shown in Figure 1.3 below.

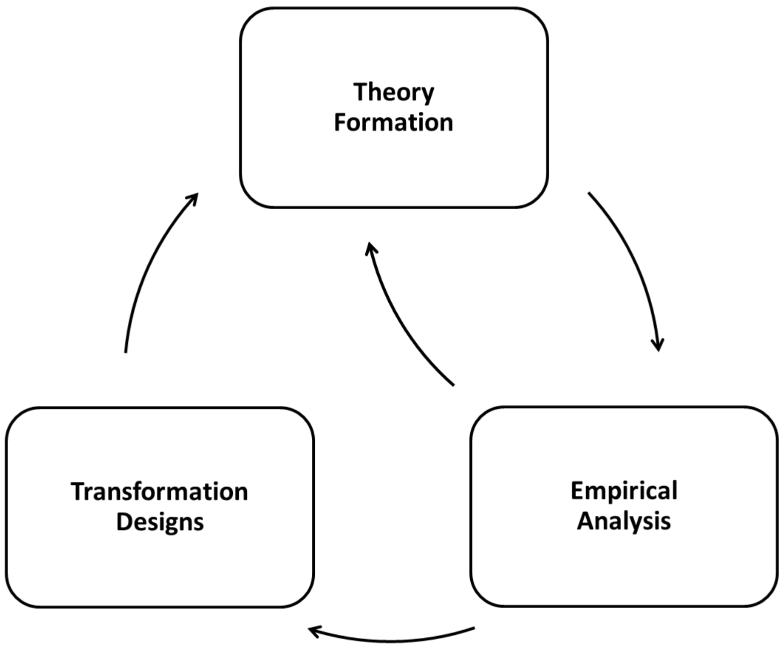


Figure 1.3: Scope and Coherence of the Transformative Research Strategy

The three basic elements act as transformative research through their interaction, but each shows different strategies in the transformative orientation:

1. Theory Formation as part of a classical, but interdisciplinary academic approach
2. Empirical Analysis as part of the analytical part of transformation research
3. Transformation Designs as part of a transformative research approach

Progress in inter- and transdisciplinary Sustainability Science must meet the requirements of conceptual rigor, goal-oriented problem analysis and the identification of realistic transformation potentials. It requires the combination of progress in different academic schools and must attempt to unite them in a strong theoretical fundament of a system approach. In the cumulative parts of the dissertation, based on the research agenda research questions (see below) are specifically addressed. The scientific work of the three cumulative parts is deliberately highlighted in an interdisciplinary and transdisciplinary manner, especially in the case of results developed by multidisciplinary teams of researchers. The common basis is “Sustainability Science”, the disciplines are Geography, Environmental Sciences, Economics, Management Science (with a specialization in supply chain management) and Industrial Engineering.

Against this strategic background and the explained coordinates from 1.5, the work brings some central proposals into a focus of a 5-points research agenda:

1. Building on the preceding argument, namely that a significant problem pressure as well as a potential for solutions exists on the lever of the supply systems and welfare-generating mechanisms, the concept of the supply chain is an innovative and powerful element in a research strategy. This lever of sustainability transformations via the explained systemic considerations was not considered in this connotation until the research on which this dissertation is based. The literature and practice refer largely disintegrated to the “traditional” framework of company-related supply chain management issues.
2. If this is assumed, it must be answered what the basic characteristics of the system are to be considered in functional and structural terms, e.g., via the structure of supplying sources and consuming sinks in an extended spectrum that in the area of the sources incorporates issues of natural capital and integrates lifestyle considerations of our society at the sinks.
3. A system description of the underlying relationship must be created, as it does not exist in the underlying academic literature in this connotation. Such a system description

must be related to the drivers of globalization, industrialization, and urbanization. Which new, possibly linked meanings of the “urban” and the “industrial” in the transformative sense would move into the foreground of sustainability considerations?

4. Within the mentioned extended system scope, empirical research cases should be accentuated in concrete structural and spatial relationships that take into account various central issues of possible innovation. On the other hand, these research cases should be able to take up and to present system effects (for example with regard to the challenges of climate change and changing consumer expectations) in their methodology and actively involve system agents/ stakeholder groups into the investigation process.
5. Transformative supply chains, adapted regulatory frameworks, and the development of system services relate to deeper mechanisms of action in value chains, which in the second instance can lead to alternative spatializations of alternative structures and functions. The investigation puts an emphasis on transformation potentials in these system services and system structures under specific (future) conditions (e.g., emerging capabilities, consumer empowerment, circular economy, digitization). Here, the work is based on a fundamental retention of the general market economy conditions but changes the roles and relationships between the individual system agents (service providers, consumers, producers) via scenarios.

1.6.3 Research Questions

The above 5 points can be condensed into ***research questions (RQ)***, which are primarily dealt with in the cumulative chapters of the dissertation and secondarily discussed again in the final chapter of the dissertation in the overall context and with regard to the value of the results for the scientific community and with regard to the overall transformative potential.

Guiding research questions to be found within the cumulative parts of the dissertation are:

RQ A: How must concepts of Sustainability Science be expanded and changed to present suitable theoretical building blocks for an Ecosystem Approach (EA) to rationalize sustainable Urban-Industrial Supply Systems?

Sub-questions are:

a. *What potential building blocks from the System/ Ecosystem Sciences can be used to further develop “Strong Sustainability” concepts here, especially with respect to the background of resilience theory?*

b. *Which structural and strategic compartments do integrated models of sustainable urban-industrial supply systems contain, and how are they arranged and connected to one another?*
c. *How can considerations of supply systems and their supply chain management (SCM) services be expanded to fundamentally change the demand-supply dynamics of unsustainable socioeconomic stings in urban-industrial systems?*
d. *Which levels and scales must be found and how do they mesh to represent a nested urban-industrial supply system that meets the requirements of Strong Sustainability?*
e. *How and via which cross-functional urban-industrial functions can sustainable integrated systems of production, supply and consumption be represented in terms of production supply consumption (PSC) ecosystems?*

This is mainly subject to **Theory Formation** (Chapter 2).

RQ B: How can the interactive parts of a PSC Ecosystem change individually and in relation to each other, to facilitate ambitious sustainable solutions, particularly with respect to demand-supply dynamics?

Sub-questions are:

a. *Through which processes and methods can stakeholders of the status system and the transformation process acquire system and transformation knowledge, for themselves but also in a knowledge community with other sector groups involved?*
b. *How can necessary mind-shifts and new behaviour among consumers as a system driver be achieved and communicated between organizations, companies and consumers?*
c. *How can Supply Chain Management (SCM) act as an integrator/ coordinator of sustainable functions in PSC Ecosystems and guide transformation processes?*
d. *Which sustainability gains with which scaling effect are mobilized in which way by changed PSC Ecosystems?*

This is mainly subject to **Empirical Analysis (**Chapter 3).

RQ C: Which system-inherent transformative levers can be identified to enable and to strengthen system changes toward sustainable PSC Ecosystems?

Sub-questions are:

a. *What are dynamic capabilities of stakeholders as system agents, especially business and service providers, for sustainable PSC Ecosystems and how can these capabilities be strengthened?*
b. *How and with what qualities can new system service archetypes be described, which map and support the requirements for a system change towards cross-scale nested sustainability and the resulting system service operations?*
c. *What are the most effective socioeconomic dispositions and development scenarios with respect to resulting conditions, frameworks and strategies to transform PSC systems and those services that support the systems sustainable integrity and further adaptivity?*

This is mainly subject to **Transformation Designs (**Chapter 4).

1.6.4 The Ecosystem Approach as a Research Rationale

As advocated by various scholars in Geography (Stoddart, 1965; Porter, 1978; Truffer, 2016), Ecology (Odum, 1983; Rowe, 1992) and contemporary Sustainability Science (Kay et al., 1999; Soto et al., 2008; Liu et al., 2015), the present work connects several previously separately processed fields of research and transformation by using an EA as a strategic frame. Environmental and Economic Geography, as well as related areas of Environmental Sciences, are becoming more capable of correspondence with various further fields in Economics-related research in the field of services, business and supply chain management as well as of consumption.

The connection between natural capital, (industrial) production, supply chain structures and services (including retailing) and consumption patterns/ consumption habits and lifestyles represents an overall connection recognized in the context of the dissertation. It is characterized by the interdependencies and structural interfaces between those areas. Such multiple systemic connections lead to an increase in complexity beyond individual connections and thus to emergent dynamics.

In addition, as part of the published research work (especially in Chapter 3: Empirical Analysis) system dynamics are shown using causal loop diagrams (CLD) and subsequent stock and flow diagrams (SFD) and simulation techniques.

The idea of using the EA is dependent on the application of system-compatible methods (as explained earlier), and above all on the integration of the areas, interfaces, interdependencies and emergent system dynamics in a common conceptual framework: The PSC Ecosystem. This should allow alternative system constellations and system designs to be presented better and more clearly, but above all to deliver a holistic frame of reference for sustainability transformation.

A few basic premises can be assumed here and provide us with a better understanding of the above shown interdependencies and dynamics:

The demand structure, qualified as “urban sink” in Chapter 2, is at the centre of different perspectives. On the one hand, structures and services (as shown earlier) are interrelated to consumption, in that not only the demand structure triggers supply, but services and structures of supply (via sophisticated logistics services) also enable certain qualities on demand, as for instance in E-commerce (Krumme et al., 2015; Melkonyan and Krumme, 2019). Lifestyles within society play an important linkage function. On the one hand, they determine consumption habits and consumption patterns (constantly also changing due to various basic influences, such es technological progress, sociodemographic development, etc.), and on the other hand, they also create a targeted structure of services in the supply chain.

To increase sales and consumption in a growth-centred economy, this also works the other way around: new (recently often digital) technologies and the resulting performance assets in the supply chain are changing qualitative and quantitative features to such an extent that other consumption patterns can emerge. To the extent that this happens “downstream”, the environmentally disadvantageous consequences “upstream” simultaneously increase. Chapter 2 and Chapter 3 deal with the investigation of these two-sided interrelated dynamic system effects.

A conceptual substructure is required, which relates system and sustainability theoretical parameters to the underlying core questions, but also actively reflects on priority development trends of the resource-consuming socioeconomic overall system, such as global urbanization or the industrial shaping of the production-supply-consumption system. Beside more precise views on the typology of resource consumption sinks as “urban”, a sources view would distinguish not only typical industrial production and service capacities, but also capacities which are “sources for the sources” as part of the natural capital in form of ecological resources and/ or ecosystem goods and services (ESGS) (Costanza and Daly, 1992; Rees, 2003; Wiedmann et al., 2006).

The EA can embed the categories of ecosystem functioning (natural capital base ESGS) and of socioeconomic value-added systems (sourcing, production, supply, consumption) into a holistic ecosystem model. The depicted connection of the PSC Ecosystem can also be viewed as a specific resolution of a fundamental human-environment interaction or as social-ecological system (SES). Since Ostrom's SES, however, have not yet found complete transfer into the total nested organization complexity of globalized socioeconomic networks and corresponding ecosystem settings, an advancement through an EA to draw this line is representing a valuable conceptual progress. Moreover, research on the transfer of the EA to sustainable development can be used to describe, justify, explore, and translate integrated ecological, social, and socioeconomic structures into concrete and tangible transformation designs. An EA has not yet been applied to the socioeconomic context of production, supply, and consumption.

Used in such a way, the EA does not only concern a functional coupling of natural ecosystems with the benefiting socioeconomic system and its governance rules as it is also envisioned by the SES framework (Ostrom, 2009). More important, the structural and functional arrangement of all corresponding elements, irrespective of their origin (ecological, social, economic) would have to be treated inclusively, according to the organizational principles of ecosystems, namely: dissipative structures, nested hierarchical organization, extensive self-organization, and resilience orientation. This corresponds to the EA definition as by Kay et al. (1999) and places ecological and/ or socioeconomic system elements between natural capital and resource consumption into a common frame of reference.

Fundamental orientation is given by the models of "strong sustainability" (Neumayer, 2003; Ekins et al., 2003; Dedeurwaerdere, 2014) instead of referring to mainstream definitions with poorly systemically integrated categories of natural capital, social capital, and economic capital, such as the popular triple bottom line (TBL) of Elkington (1998).

An EA-based research rationale should consider the following dimensions, against the backdrop of a nested systems organization understanding:

1. *Representation of Real-World System Functions:* The conceptually linking of functionally interacting domains, which together represent higher-level emergent system purposes, here: Natural Capital, Production, Supply and Consumption for a "Supply and Welfare Function".
2. *Representation of Real-World System Structures:* The manifestation of these addressed functions by corresponding multiscale structural and spatial patterns.

3. *Suitable Methodological Dimension:* The research approach must be methodologically suitable to reflect and check system properties.
4. *Participatory Research Mode:* The stakeholders of the system should be actively involved in the research activities in terms of knowledge co-creation.

As clarified earlier, the central question about the form, quantity, patterns and consequences of unsustainable consumption of resources is no linear response to consumer demands, but an emergent system property, that has its roots in all the components and their positive and negative feedback loops (i.e., self-reinforcing mechanisms) at their interfaces and further differentiated complex system behaviours.

Due to the dynamic interrelationships, necessary system changes on the path to a sustainable economy can not only be addressed one-sided from the provisioning production and supply dimensions but must be socially supported by a corresponding demand dimension of consumption and lifestyles (Melkonyan and Krumme, 2019). To enable the integration of the subsystems, the question of how to shape which integrating and cross-oriented system services must be addressed.

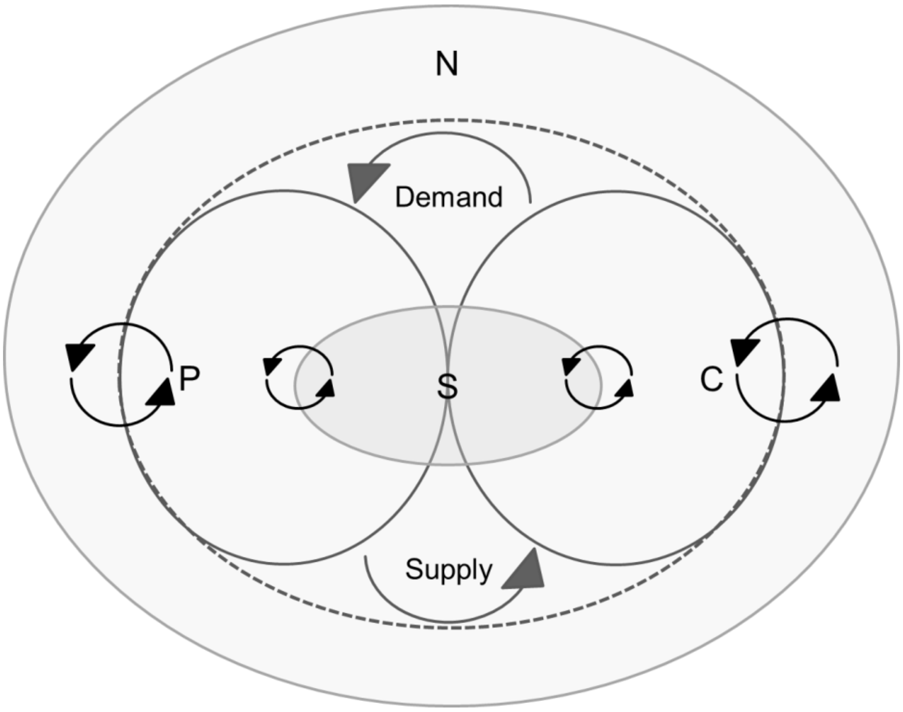


Figure 1.4: Simplified PSC Ecosystem (N=Natural Capital; P=Production; S= Supply; C= Consumption)

Since the overriding and integrating function to be addressed is supply – defined in terms of the provision of resources/ products and needed information and services –, the desirable transformation goal in the PSC Ecosystem would refer to a synchronization of the natural capital stocks and flows and the emerging carrying capacities with the de facto corresponding cascade chain from sourcing and production to consumption within the socioeconomic subsystem. Figure 1.4 shows a schematic draft of the PSC Ecosystem.

A question is how the integrative momentum of the supply and welfare function of a sustainable socioeconomic system can be achieved. Since the tracing back of unsustainable resource consumption to a primary demand represents an inadmissible simplification of the researched reality, the central dispositions of research must clarify in which constellation of specific qualities and quantities determine a dynamic interaction and how. More differentiated interpretations must follow, which aim downstream at the specific effectiveness of factors on the demand side and provide information about the way in which upstream assets in value and supply systems, e.g., through marketing or enabling service qualities, can influence system behaviour. The latter would be an indication that service offers in the interaction between natural capital, production, supply and consumption as system services represent options to change the system performance in a sustainable way.

In today's globalized socioeconomic system, such enabling economic services are highly determined by the logistics business (Logistics Service Providers, LSP). LSP effectively combine production, distribution, retailing and consumption through to the use and return of products and “facilitate” a sustainable life cycle and value proposition of goods and products. We can deduce that rearrangements of this functional conglomerate of natural capital, production, supply and consumption would be key for sustainability transformations.

In addition to the knowledge about the leverage of the interplay of natural capital, production, supply, consumption and lifestyles, the embedding in an overall conceptual framework is decisive. This must be considered in an effective transformation design and addressed at least in the essential basic positions and coordinates.

A finally effective sustainability transformation agenda would among others be based on such (*A) applicable and comprehensive strategical frameworks*, which is not available yet. Without it we miss a concreteness level of *(B) necessary alternative Sustainable Operations Management* (SOM) in the sense of Kleindorfer et al. (2005). The interplay via a suitable governance organization between these two classical levels of strategy (A) and operations (B) – or strategical and operational management – represents a decisive step to win more substance for sustainable development.

1.6.5 Methodological Dimension

All parts of the cumulative dissertation describe the methods used explicitly in the respective individual publication, but all these approaches are embedded in an overall methodological concept.

The extent to which there are complex emergent interactions as well as transformation options through system services between demand, supply and production is a research subject that can only be dealt with suitable methodological consideration of the dynamics of complex systems. As explained, the research presented uses conceptual dispositions of the EA in the narrower sense of Kay et al. (1999) as a strategic model and organizational principle. The EA interpretation of this work draws on some basic system theory understandings, such as that of Bertalanffy (1950, 1968) and Bossel (2007).

The approach used in this dissertation is based on a perception of the “real-world” existing problems as and in a nested systems hierarchy. The existing complexity needs practically to be reduced as part of a research and transformation-oriented work.

First this makes the exploration of different interdependent content and/ or scale organisational levels necessary in individual parts of the research, but also a working concept that logically connects these parts. Individual works (here publications in the cumulative sense of the research) are housed as part of research design at different levels or connect individual levels with each other.

Secondly, it is purposeful to generate conceptual models guided by theory as an extended understanding and to consider the decisive system dynamics (sketching reductionist system boundaries, structures, and simplified dynamics, based on conceptual modelling and qualitative system dynamics).

The entire research presented, but particularly starting with Chapter 2 “Theory Formation” is based on systems thinking. System thinking (ST) as a strategic-methodical approach means the application of mixed methodological set ups and tools to master complexity and dynamics. ST “thinks” in processes, relationships, and functional hierarchies as well as resulting emergences and feedbacks instead of in single states and linear causalities (Checkland, 1981; Meadows and Wright, 2008). On this basis, conceptual theory building (CTB) is used as a structured exploratory procedure. CTB adopts on the basis provided by Meredith (1993) and Wacker (2008). The conceptualization phase is an iterative process involving extensive reading, additional collection of literature, synthesis, and refinement of the framework via structured discussions with scientific scholar groups of the respective research project over a period from 2015 to 2019 (under additional use of shared CITAVI resource groups and joint data pools). The way to accomplish conceptual frameworks and model building consists of an integration of collected/ selected journal articles, summaris(ing) the common elements, contrast(ing) the differences, and – most important – extend(ing) the work.

The approach of extensive literature analysis was based on the methodology of integrative research review (Cooper, 1989, 1998). According to Hsia (2015), the review process was executed as a qualitative meta-analysis, oriented on the state of research in Sustainability Science with strong references into the connected disciplinary contexts (Geography, Economics, Environmental Sciences, Management Science, Social Sciences). The reviews used Thomson Reuters (preferably Web of Science) as well as Elsevier (preferably ScienceDirect) databases under use of CITAVI software in facultative consolidation with a Google scholar search. An extensive database of the relevant literature was developed in CITAVI software for the further work process.

In accordance with Meredith (1993), chapter 2 provides elaborations on conceptual frameworks and models, presented in text explanations, as illustrated models and via mathematical derivation and justification. Central results in chapter 2 are presented with the inclusion of metabolism models. Metabolistic modelling has its origins in in urban metabolism (Wolman, 1965; Kennedy et al., 2011) and Industrial Ecology (Jelinski et al., 1992) and is gaining importance not only in the context of this work, but recently also in a variety of related contemporary research (compare e.g., Shahrokni et al., 2015b; Meirelles et al., 2020; Palme and Salvati, 2020).

Chapter 3 implements the system-theoretical orientation in stakeholder- and case-specific settings as empirical research. The application of system dynamics (Forrester, 1968, 1994) and participatory systems mapping (PSM, Sedlacko et al., 2014) played an important role throughout all the included research. PSM was applied in stakeholder-workshops and innovation platforms. The results were consolidated in causal loop diagrams (CLD) and partly as stock and flow diagrams (SFD) as a basis für further simulation and instrumented measurement. In addition to PSM, as another system-guided method business model CANVAS (Osterwalder et al, 2011; Joyce and Paquin, 2016) for the analysis and exploration of business models and their success-related factors was applied. Structured expert interviews have been carried out as further method.

In addition, extensive surveys were carried out in the investigation of the system-driving role of consumption/ consumers and in lifestyle research. Target group-specific communication scenarios have been the qualitative basis for the surveys. To interpret the results, the "Stages of behavioural change" (Prochaska et al., 1992, 2002) were included into the interpretation and classification of the results.

Chapter 4 shows the peculiarity that participatory methods were also used here. In one context, applications of PSM are based on approaches to understanding dynamic capabilities (DC) theory. The participatory research design served in different formats for multi-stakeholder information acquisition: group discussions, scenario workshops and questionnaires. Evaluations for transformation designs are subject to a mixed method approach, depending on the specific research objective. Exploratory Modelling and Analysis (EMA) has been applied in computational experiments to study and guide business practises. The STEEP (Sociological, Technological, Environmental, Economic and Political) method was used for scenario development and analysis.

1.6.6 Cumulative and further Structure of the Dissertation

The published cumulative contributions come either from the direct or extended research context of the project "Innovative Logistics for Sustainable Lifestyles" (ILoNa), funded by the Federal Ministry of Education and Research of Germany in the Socio-Ecological Research of the program "Forschung für Nachhaltige Entwicklung" (FONA) between 2015 and 2018 (Krumme et al., 2015). In the cumulative parts of the dissertation, the role of Klaus Krumme in the development and the relationship to the ILoNa project (either directly or in a further context) is broken down for each individual contribution.

The results of the research in the individual publications are interpreted in the context of each publication. The "Sustainable Supply System" and the integration of production, supply and consumption play a key role. In the sense of "building blocks", results are synthesized in the final part of the dissertation afterwards (chapter 5) and discussed and interpreted about the overall research and transformative progress.

In addition to stimulating the further development of Sustainability Science, the focus is on a closer look at Geography, more precisely: on Environmental Economic Geography (EEG). In the concert of Sustainability Science and especially for the EEG, concrete research perspectives for a sustainability-oriented Geography are to be shown. Suitable interfaces between Geography/ the EEG and the Environmental, Economic and Management Science are to be emphasized. Moreover, the strategic role of Geography to enable progress in the larger context of inter- and transdisciplinary Sustainability Science is discussed.

To generate a better clarity, each of the three following chapters initially contains a short synopsis (including remarks), which crystallizes and classifies the respective focus of the contributions on the topic of the chapter. In addition, information about the genesis of the contributions and the role of the author Klaus Krumme in the scientific context are explicated. Important publications (e.g., in the context of scientific conferences) prior to the publication and cooperation with the co-authors are also discussed to specify the originality of the contributions and the role of the author.

2 Theory Formation

2.1 Remarks and Synopsis

Central system terms in Ecosystem Science and Systems Theory still require a stronger transfer to new models of understanding with regard to socioeconomic systems and their sustainability transformation. This applies to interpretations of long-term stability through flexibility, adaptability, system dynamics and system complexity, which largely find anchor points in resilience research. Models of the nested organization complexity of natural systems are addressed repeatedly when it comes to the conceptualization of sustainable development (compare Costanza and Patten, 1995) but have so far not been sufficiently considered in the theoretical foundations. Targeted realignment in practice suffers from this fact.

Based on that, conceptual theory building is fundamental to justify and mobilize new research approaches. Otherwise, they have to offer the basis to be verified, falsified, refined, and further developed through empirical work approaches. An ecosystem understanding of the functional integration in-between the dynamics of natural capital, production, supply mechanisms and consumption in the context of social lifestyles for sustainable development is particularly dependent on a broad and comprehensive theoretical foundation. This provides target orientations and is to a large extent important as an interdisciplinary engine for further research efforts. The present work sets basic emphases here, all of which are defined against backgrounds from systems theory and Ecosystem Science.

The research is anchored in three parts, which stand in exchange with one another.

The first part (2.2) focuses on the theoretical foundations that arose from ecosystem theory and resilience research. The urban-industrial connection is broken down, resilience-oriented sustainability strategies are condensed and – as the most important conceptual theory formation – the main features of the Social-Ecological-Technological Systems (SETS) are introduced. The respective paper represents one of the first scientific publications on the SETS worldwide and is cited accordingly in the sustainability community, most recently in the Proceedings of the National Academy of Sciences (PNAS) (Cosens et al., 2021).

The second part (2.3) is dedicated to the theoretical-conceptual perspectives and extensions of Sustainable Supply Chain Management (SSCM), as a central subject of this dissertation. Conceptual gaps between SSCM and “Systems of Sustainability” (in the sense of the system concepts of Sustainability Science) are pointed out. A guide to an expanded definition of SSCM is given. A mathematical definition of a “strong sustainability” understanding of the supply chain is introduced and descriptive elements of this theoretical foundation are worked out. The work refers to an earlier conference contribution, especially in the orientation towards knowledge standards and system thinking of Sustainability Science:

Hanke, T., & **Krumme, K.** (2012). *Risk and Resilience in Sustainable Supply Chain Management – Conceptual Outlines*. 10th International Logistics and Supply Chain Congress: Sustainability in the Era of Global Crisis, Istanbul, Turkey.

In the third part (2.4), the two basic works are brought together for a first theoretical synthesis of “Sustainable Urban-Industrial Supply Systems” (as “header article”). The understanding of strong sustainability is crucial for the development of a “Multi-Domain Framework of Sustainable Urban-Industrial Supply Systems”. For this purpose, beyond the two basic articles beforehand, the conceptual-theoretical connection of “urban-industrial” problem effects and possible solutions is condensed. The article takes up different results especially of the last cumulative part of the dissertation (Chapter 4: Transformation Designs), especially the “Lead Sustainability Service Provider” (6PL) to be contextualized with the Multi-Domain Framework.

2.2 Sustainable Development and Social-Ecological-Technological Systems (SETS): Resilience as a Guiding Principle in the Urban-Industrial Nexus (Krumme, 2016)

The following chapter presents a peer-reviewed article by the author of this dissertation accepted for publication in the *Journal of Renewable Energy and Sustainable Development*, published 2016. Any reference to this chapter should be cited as:

Krumme, K. (2016). Sustainable Development and Social-Ecological-Technological Systems (SETS): Resilience as a Guiding Principle in the Urban-Industrial Nexus. *Renewable Energy and Sustainable Development*, *2*(2), 70–90.

Abstract

This conceptual paper focuses on the connection between system resilience and sustainable development. Setting an inclusive frame and beginning with stating the nature of complexity related to the sustainability challenge and the resultant uncertainty of planning and management within socioeconomic domains, the article describes the demand for a system approach and emphasizes the importance of a resilience-oriented approach to sustainable development, including the provision of correlated conceptual frameworks, as opposed to an efficiency paradigm.

The first part of the article mirrors on a systematic collection, assessment and reflection of scientific contributions alongside sustainable development/ sustainability strategies, resilience thinking and especially combinations of both with system theory/ nested systems theory, using a qualitative integrative research review method. Sources principally consider progressive explicitly interdisciplinary directions of the scientific community, evolved through the recent decades as Sustainability Science. The scientific state of knowledge is contextualized with sub-chapters of introduction, problem statement, and demand profile for problem solutions as well as system resilience as point of reference.

The central focus of the second part is on urban and industrial spheres of un-sustainability as well as their functional inter-connectedness as a main potential driver for progress in sustainable development. Elements of rooting sustainable development in a stronger consideration of an urban-industrial nexus proposed here are suggested for a consideration of resilience to describe more appropriate system constitutions and intra-connections as well as better system boundaries for assessments and innovative solutions. For the guiding of a more inclusive view of system agents inside the urban-industrial nexus, expansion of Social-

Ecological Systems (SES) towards Social-Ecological-Technological Systems (SETS) as guiding resilience-based framework is proposed. The urban-industrial nexus and SETS are considered as a basis for new research directions of Sustainability Science.

Keywords

Sustainable Development, Sustainability Challenge, System Thinking, Resilience, Systems Integration, Urban-Industrial Nexus, Social-Ecological Systems (SES), Social-Ecological-Technological Systems (SETS), Sustainability Science

2.2.1 Background

As an epochal contribution to the future of the world, the international community recently adopted their SDGs, the *"Sustainable Development Goals" (Sachs, 2015; United Nations, 2015)*. To produce practical and measurable progress towards sustainability, 17 goals have been identified as SDGs covering all critical ecological, social and economic issues corresponding to sustainable development and a number of grand global challenges. Although they differ in an improved level of concreteness, the SDGs stand in the tradition of the former Millennium Development Goals (MDGs) and the Rio Process (Sachs, 2012). The aim is to meet concrete objectives – which is of ultimate importance – while at the same time base progress on a safe operating space for humanity, respecting the planetary boundaries (Folke and Rockström, 2009; Rockström et al., 2009; Rockström and Klum, 2015; Steffen et al., 2015b).

The concept of sustainability and the practice oriented directions towards sustainable development have been discussed widely in the academic and non-academic world from many perspectives, producing different and also partly contradictory baseline understandings (Brundtland et al., 1987; Costanza and Patten, 1995, Elkington, 1997), up to sophisticated scientific discourses about the inner meaning of constitutional frameworks and theories (Ayres et al., 2001; Ekins et al., 2003; Neumayer, 2003; Dietz and Neumayer, 2007) and detailed refinements and advanced conceptualizations (Kay et al., 1999; Ravetz, 2006; Kajikawa, 2008; Liu et al., 2015; Steffen et al., 2015b). Apart from numerous understandings and definitions we can identify a consensus in a target orientation stating the "*goal of sustainable development is to create and maintain prosperous social, economic and ecological systems*" (Folke et al., 2002).

However, the way to achieve this ultimate goal remains untrustworthy and is not based on a deep consensual framework or a resulting sufficient agenda process. This cannot be changed by political conventions alone but needs deeper conceptualizations on its basis.

The objective of this paper is to serve this need by integrating consolidated scientific fundaments that are able to guide sustainable development concretely and reliably in form of a conceptual framework. A stronger system thinking perspective is favored to explore the beneficial relationship between concepts of sustainability and system resilience. A resilience anchored sustainable development of crucial drivers and functional leverage domains of the socioeconomic sub-systems would be of great advantage to improve the coordinates for sustainable development and to find more appropriate and deeper-rooted conceptualizations on the course. In this sense an elaboration on more appropriate system boundaries with respect to integration of crucial and powerful driver spheres of (un-)sustainability would be required. On such a foundation, outlines of guiding frameworks for assessment and development can be prepared or existing ones could be refined and extended. This would represent promising perspectives for those who are committed with a stronger progress for sustainability in science, society, economics and the public policy sector.

2.2.2 Methodological Overview

As the basis of the conceptual developments of this article stands a desktop literature review process, based on the methodology of *integrative research review* (Cooper, 1989, 1998) with the *aim of a hermeneutic synopsis of the approaches and findings, the generation of new problem overviews of major problem areas as well as related scientific propositions and solution proposals*. According to Cooper (1989) and Hsia (2015), the review process was executed as a qualitative meta-analysis, oriented on primarily the *state of research* on sustainability theory, resilience theory as well as both in combination (e.g. in the terms of Social-Ecological Systems frameworks, SES, by Ostrom (2009) and other system-related conceptions), and secondly on the *trends in research* in the field of sustainability theory, resilience and sustainable development and system theory derived approaches in this context. The review used Thomson Reuters (preferably Web of Science) as well as Elsevier (preferably ScienceDirect) databases under use of EndNote software in facultative consolidation with a Google scholar search. The search mode was restricted to key-terms in the context of sustainability and resilience in peer-reviewed journals with an explicitly visible interdisciplinary chorus of established modern Sustainability Sciences. Centrally important and meta-oriented forums of research publication, such as “Nature”, “Science” or “Proceedings of the National Academy of Science (PNAS)”, have been considered as far as topic(s) and author(s) are related to the first condition. The accompanying Google scholar search was also considering centrally important and highly cited book and policy paper publications if they stand in a contents connection to the peer-reviewed journal publications of the first instance.

An extensive database of the relevant literature was developed in EndNote software for the further work process. The integrative research review process was consisting of (1) problem and task definition, (2) data collection, (3) summaries and clusters, (4) evaluation of data points, and (5) analysis and interpretation. The integrative research review was then embedded into a *conceptual framework and theory building process* adopted on the basis provided by Meredith (1993) and Wacker (2008). The conceptualization phase is an iterative process involving extensive reading, additional collection of literature, synthesis, and refinement of the framework via structured discussions with scientific scholar groups over a period of 15 months (under additional use of shared EndNote resource groups).

Within the scope of this paper, literature findings and synthesis of the *state of research* are contextualized in a first step with the subchapters of introduction, problem statement, demand profile for problem solutions as well as system resilience as point of reference, considering specific propositions and demands according to the suggestions of Wacker (2008). In a second step *trends in research* in coherence with *state of research* are developed as *logical deduction* into the conceptual chapters of the urban-industrial nexus and the social-ecological-technological systems (SETS), principally oriented to Handfield and Melnyk (1998).

In accordance with Meredith (1993), this paper provides elaborations on conceptual frameworks, presented in text explanations and conceptual figures on the fundament of a number of interrelated scientific propositions which explain phenomena and/ or provide understanding of un-sustainability, sustainability/ sustainable development, system resilience, social-ecological/ economic-ecological interactions as well as sustainable economics/ ecological economics. The methodology to accomplish then conceptual frameworks and model building consists of an integration of a number of different journal contributions, summariz(ing) the common elements, contrast(ing) the differences, and extend(ing) the work in some manner (Meredith, 1993).

2.2.3 Conceptual Problems Coping with the Sustainability Challenge

Apart from complicated and counterproductive disagreements and unconsolidated ambitions in the political and economic arena, as characterized amongst others by Sachs (2016), the author can put forward three fundamental interrelated obstacles on the way towards sustainable development course corrections related to the status of research and practice:

A. *The academic world still shows divergent perceptions and itself has unconsolidated knowledge about sustainability as well as counter-productive self-conceptions still depending on disciplinary ways of thinking and research (Lawrence, 2015; Wilkinson* *et al., 2015; Alder, 2016). Sustainability Science as a newer and more inclusive school of academic acting based on Post-Normal Science (PNS) (Ravetz, 1987; Funtowicz and Ravetz, 1995) is still no mainstream in the academia and needs to become much stronger. The actual ineffectiveness of the traditional science system was already maturely described and is more striking the more complex the societal challenge gets (Funtowicz and Ravetz, 2003; Ravetz, 2006; Kläy et al., 2015).*

B. *Practical implementation in economics/ industrial, technological and social sectors suffers from the first obstacle and itself shows no "applied" approach to create really fundamental course corrections and radical alternatives within and across sectors to improve their performances towards sustainability (Shrivastava, 1995; Tonelli et al., 2013; Whiteman et al., 2013).*
C. *Beside the inappropriate non-consolidated or totally missing common referential background of respective actor groups, a low operationalization potential even of recognized references, irritated by supposedly blurred or misperceived concepts of sustainability, hinder a stronger but urgently needed progress in understanding, action and monitoring for sustainability (Dietz and Neumayer, 2007; Neumayer, 2012; Davies, 2013; Barkemeyer et al., 2014).*

The above obstacles are inherently connected to stakeholder groups, their explicit knowledge stocks, mindsets and abilities do correspond with the overriding complexity of the sustainability challenge itself: The economic, social and ecological dimensions of reality come out as closely coupled in their actual performances. Principally we have moved away from the bounded, controllable scope of traditional products and services to rather boundaryless, erratic realms of industrial, ecological and social system interrelationships (Fiksel, 2006). Climate change, urbanization, resource scarcity, and the causal dynamic texture of a globalized industrial economy are intermediate snapshots of a multifaceted regime shift but do generate further regime shifts in highly complex cascades and on various levels and scales of the social, ecological and economical organization of a transformed planet (Folke and Rockström, 2009; Hughes et al., 2013; Hoekstra and Wiedmann, 2014; Steffen et al., 2015). Each particular course of socioeconomic developments (e.g., expansion of cities, course of industrial branches, transition in energy supply), as parts of this complexity, is in conclusion highly volatile. It is noteworthy to understand that the widespread understanding of sustainability in terms of the "people, planet, profit" bottom line (Elkington, 1997) or the politically accented Brundtland-Definition of inter- and intra-generational justice (Brundtland et al., 1987) use social, economic and ecological spheres as reductionist categories and at last superficial perceptions of a much more complex reality. The politically influenced reductionist approaches on sustainability helped to introduce a new way of thinking and made sustainability quite popular but are not helpful to cope afterwards and consequently with the underlying complexity of the challenge as well as to operationalize strategies in and across sectors of our socioeconomic system.

In an effort to structure root causes of un-sustainability we can identify that human pressures on the planet are strongly associated with the *global duality of urbanization and industrial backgrounds in a functional amalgamation* (Seto and Satterthwaite, 2010; Ahern, 2011, Liu et al., 2015). Accordingly, both sustainable urban development (SUD) and green economy play central roles in the discussion on global sustainability transitions (Bugliarello, 2006; Jänicke, 2012). In both directions of discourse, the cross-cutting energy transition away from massive use of fossil resources towards renewable energy resources and closing of supply loops is a central agenda issue (Heinberg, 2004; Atkinson, 2007; Kaygusuz, 2012; Twidell and Weir, 2015). Taking up the overstretched capacity of the global climate system and its tipping points for risky regime shifts of the system and its ecological and socioeconomic interconnections, a really ***fast*** progress towards a renewable based industrial economy is now the decisive step (de Vries et al., 2007; Schellnhuber and Martin, 2014; Galil, 2015). As Negro et al. (2012) indicate, the transition process shows dangerously slow pace. Following Dangerman and Schellnhuber (2013), the slow pace of necessary change as well as some backfiring against sustainable solutions also belong to complex nature of systems and can be explained as a powerful dynamic *locked-in effect*, described by Senge (1990).

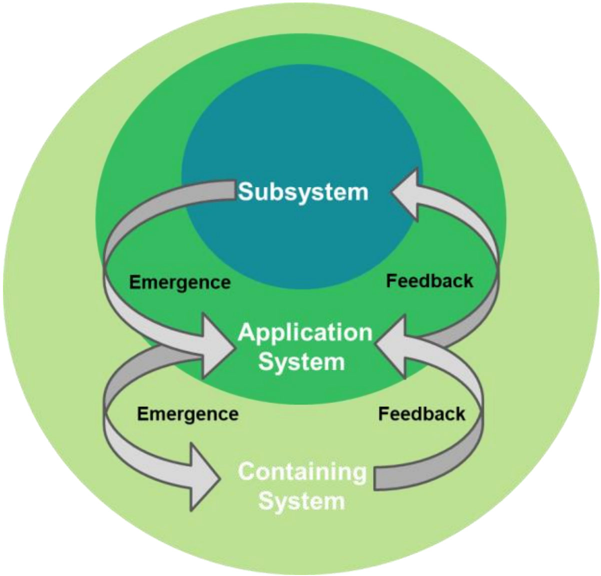
2.2.4 A Demand Profile for System Alternatives and Alternative Systems

The building of sustainable systems in the sense of integrating highly complex interplays of unsustainable domains is still ineffective and should be taken as a major motivation for progress in Sustainability Science (Clark and Dickson, 2003; Fiksel, 2006; Kerkhoff, 2013). Practically it becomes unfeasible to execute autonomous assessments and planning for sustainability in a particular industry or a social sector without being confronted with broader repercussions in manifold functionally contiguous sectors (Fiksel, 2006). It will become necessary to relate countermeasures and alternative solutions to the actual status quo of existing sectors in economical/ industrial or social life to transform current settings into new and better arrangements.

To effectively overcome the above-described disadvantages, affected stakeholders have to intentionally mirror the complexity of real-world systems in the achieved assessments and alternative countermeasures for sustainable development. Bearing in mind the above statements, the author can recapitulate as a first step for a profile of system alternatives and alternative systems demands enumerated hereunder:

A. *Academic as well as practical expertise need a more consolidated referential knowledge background of Sustainability Science, a solid basis on which interfaces can jointly be operated on in the sense of Post-Normal Science (PNS). This background must encompass a system understanding of problem(s) and their dynamics as well as a systemic approach of connecting alternatives, improvements and innovations in its system complexity.*
B. *Stakeholders have to understand that course corrections in their effectiveness do depend on often counterproductive system effects that could hinder better solutions even if better knowledge is available. Counterproductive conservative structures can very successfully hinder progress through power and inherent counterforce against change in systems, even if this leads to false solutions or a down pacing of needed progress.*
C. *Ultimate drivers of a system transition such as corresponding urbanization and industrialization should be explored in their systemic interconnectedness as strong solution drivers in an integrated way instead of using reductionist categories of actually systemically interrelated social, economic and ecological spheres. A stronger focus on urban-industrial drivers treats them as nuclei of change through leverage functions into other systemically related transformation fields.*

To perceive problems correctly in their comprehensiveness and to cope with complexity, system thinking is a possible prerequisite. In a system thinking approach the investigated entities and their environment are interpreted from a systemic viewpoint, starting with the analysis of fundamental elements and finally considering more complex related systems (Bertalanffy, 1950; Bertalanffy, 1968). Each entity is seen as a (sub-)system in its relationship to other systems, placed at higher levels of observation. The features of this “system of systems” can be detected in sub-systems and is described as principles of *nested systems hierarchies* or *nested systems organization* (Bossel, 2007). The principal unit of analysis is a system made up of multiple compartments, structures and processes that can be described as functions or ‘services’ within the system (Odum, 1971). Figure 2.1 introduces central termini of the nested systems theory.



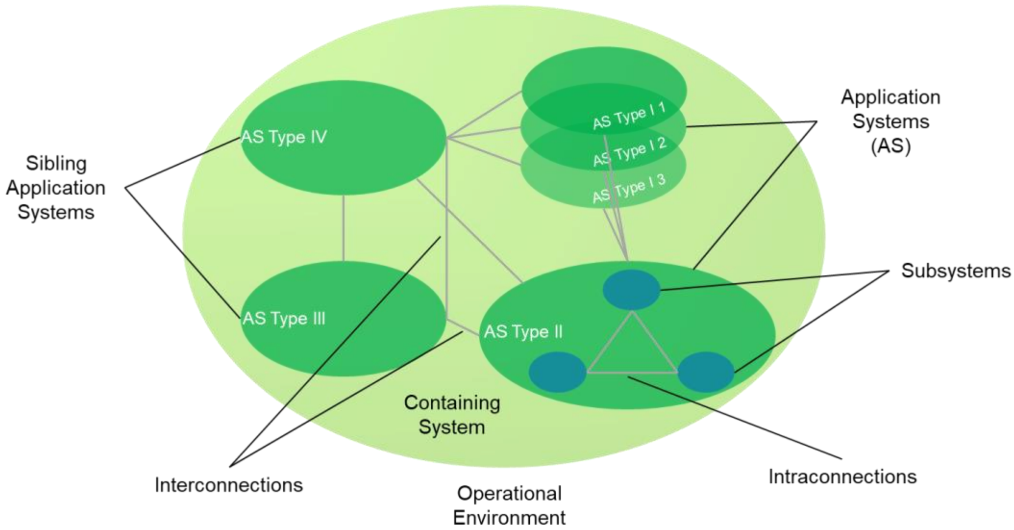


Figure 2.1: Nested Systems Hierarchies (a)/ Nested Systems Organization (b)

Beyond the analytical perspectives on the system status and system organization, concrete alternative *system-oriented management approaches* and setting of new *integrated systemic frames* upon decisions and actions on sustainable development are obligatory (Korhonen and Seager, 2008; Wiek et al., 2012; Miller et al., 2014). To reach this goal, institutions have to effectively balance their demands and need to be enabled to cope with uncertainty as a result of complexity (Fiksel, 2006, 2015). In line with Joseph Fiksel, we can identify central questions in concern of a performance demand profile for future socioeconomic systems, as enumerated below:

a. *How can socioeconomic systems achieve long and short-term economic success AND long-term social stability AND productivity AND long-term ecological integrity under changing conditions of the greater system environment?*

b. *What solutions can science provide to better understand the interlinked behaviours and emerging risks as well as opportunities of complex social, economic and ecological sub-systems contained in bigger system operation orders?*
c. *How can this be applied to design and management of institutional as well as technological, infrastructural and managerial systems to meet societal demands, especially in the cross-sector of (renewable) energy as a conditioning factor for the sustainability performance?*

From a system thinking point of view sustainable development appears now as a way to include the real-life factors (that have been conventionally categorized as social, ecological or economical, but in fact are connected to multi-categorical functions in the observed systems) into frameworks that consider the actual nested organization of the factors in a way to produce long term continuity of the system. Exclusion of factors actually belonging to these multi-categorical functions would in the long run lead to disadvantages in the system performance and with that into regimes of higher instability. Since the observed systems themselves are part and parcel of a dynamic environment, our perception turns towards principles of organization how systems and their sub-systems cope with changes while remaining within a specific frame to allow a continuity of their functions or services. A focus should not be whether specific system factors are included into assessment, planning and management, but rather in which way the comprehensiveness of factors is organized to produce a sustainable – in the meaning of a stable and continuous – interplay and performance.

2.2.5 System Resilience as Point of Reference for Solution Designs

To operationalize the demand profile, we can learn from the complex system behaviour of natural ecosystems emerged through millions of years of (co-)evolutionary processes of the systems, their compartments and nested levels of mutual organization. A central ability and furthermore an organizational principle of natural systems to adapt its functionality and structures dynamically against interference is described as *system resilience*, or simple: *resilience*. Resilience of a system counts on compartments (“agents”) and their interrelations to entirely emerge sustainability, literally as durability or survival of the system in a dynamic surrounding of subtle or sudden change.

This view assumes natural systems as an interesting model for the above-described demands. The observation of natural ecosystems shows that not only transient shocks lead to a destabilization of systems, but also chronic stress, slow and subtly changing conditions, can play an important role (Rapport, 1995). Both are true for factors and processes referred to un-sustainability. The description of system resilience has its scientific origin in the early 1970s

(Holling 1973). The concept has undergone some refinements, but a contemporary definition concentrates on conditions for multiple flexible equilibriums. Resilience commonly refers to *"... the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control its behaviour*" (Gunderson, 2000). In addition to these notions of resilience, further interlinked core aspects are given, including the *extent to which the system is capable of self-organization* (Perrings and Walker, 2004) as well as its *ability to build and increase capacity for learning and adaptation* (Folke et al., 2010). This understanding of resilience is still unwieldy to operationalize for sustainable development. A more applicable detailing of the resilience concept was delivered by Walker et al. (2004). The state of systems is considered in four dimensions:

a. *latitude* – width of the "basin of attraction" in which the system is able to operate,
b. *resistance* – difficulty of changing the system,
c. *precariousness* – how close is the trajectory of the system to a threshold, and
d. *cross-scale relations (panarchy)* – how much are other attributes affected by sub-systems.

In simple terms system resilience can be illustrated with a ball in a basin. An interference or disturbance of the system leads to a more or less powerful displacement and motion of the ball. Normally the ball will return into a stable equilibrium in the middle of the basin after a disturbance. Resilience is determined by the width and depth of the basin, so that the system would lose its original properties when the ball is moved over basin rim, indicating the exceeding of thresholds and the following tipping points of system stability (Figure 2.2). So, both the intensity of stress or disturbance on a system and the lowering or elevation of its thresholds (system properties, displayed as structures, functions or services) has influence on the system resilience.

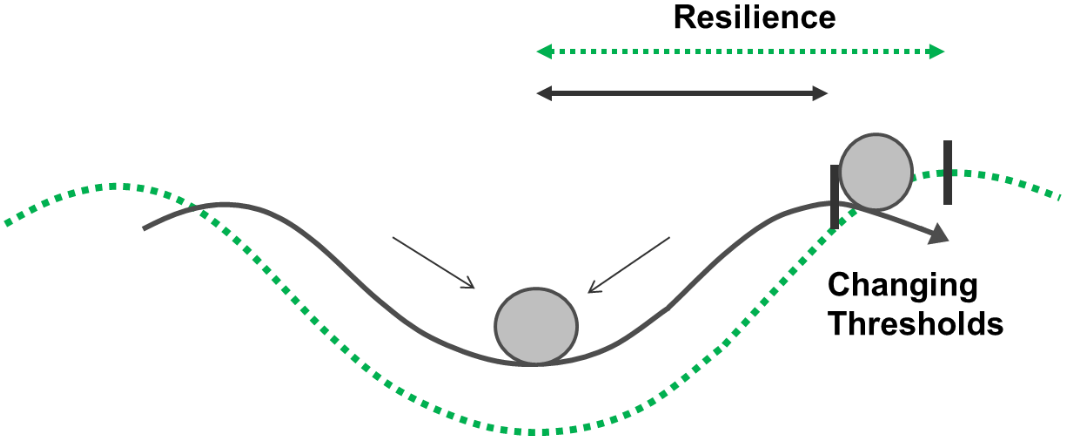


Figure 2.2: Illustration of System Resilience (Source: Stockholm Resilience Centre, modified)

It is striking how much this can be transferred to socioeconomical, socio-technological and industrial systems and their ultimate dependence on an ecological meta-system. Resilience design is driven by the need for flexible adaptation and insight into limited forecasting capacities and non-linear behavior of complex dynamic systems. With help of the above four dimensions of system state, referred to as “capacities”, first qualitative or even quantitative descriptions of resilience can be specified and practicable design options to enforce abilities to learn and to innovate (self-)repair capacities as forms of adaptation can be derived.

Crucial for adaptive capacity is the broadening and diversification of the resource base of desired sustainable systems. The diversity and presence of multiple and also redundant elementary structures, as reserves or buffers, ensure ancillary services, even if conditions change drastically and/or if key elements fail (Folke et al., 2002; Folke et al., 2010; Brown and Williams, 2015). This is the main reason why from a system thinking view, *strategies of pure eco-efficiency do not lead to sustainable improvements* (Korhonen and Seager, 2008; Fiksel, 2015; Korhonen and Snäkin, 2015). Simply lean and energetically optimized resource systems, for example in industrial or urban contexts, cannot meet needed flexibility and adaptability in terms of an “in vivo” fluctuating environment. In the longer term they may be inefficient due to lower long-term persistence in their economic performance and thus bring new risks and additional costs.

The way how agents and interrelationships are organized is decisive for emergence of system resilience against internal and external disruptions. Taking this perspective, resilience can be more interpreted in terms of *conserving functions than cementing structures*. In our context, an ultimate meaning to achieve this would have functional integration of agents belonging to social, economical and ecological dimensions and include their levels of interconnectedness into our strategy. However, a resilience perspective is significantly connected to understanding of dynamics and to plan and manage within social–ecological systems (SES) (Folke, 2006; Walker et al., 2006) as well as for dynamics of ecological-economic systems (Derissen et al., 2011; Chopra and Khanna, 2014). In this context, a focus is on *adaptive management and governance* as a linking momentum between the socioeconomic and the ecological sub-systems in concern of ecosystem goods and services (ESGS) (Costanza et al., 1997; de Groot et al., 2002; de Groot et al., 2010) provided by the ecological system part and the management systems for resource use by institutions/ organizations determined by the socioeconomic part (compare Figure 2.3).

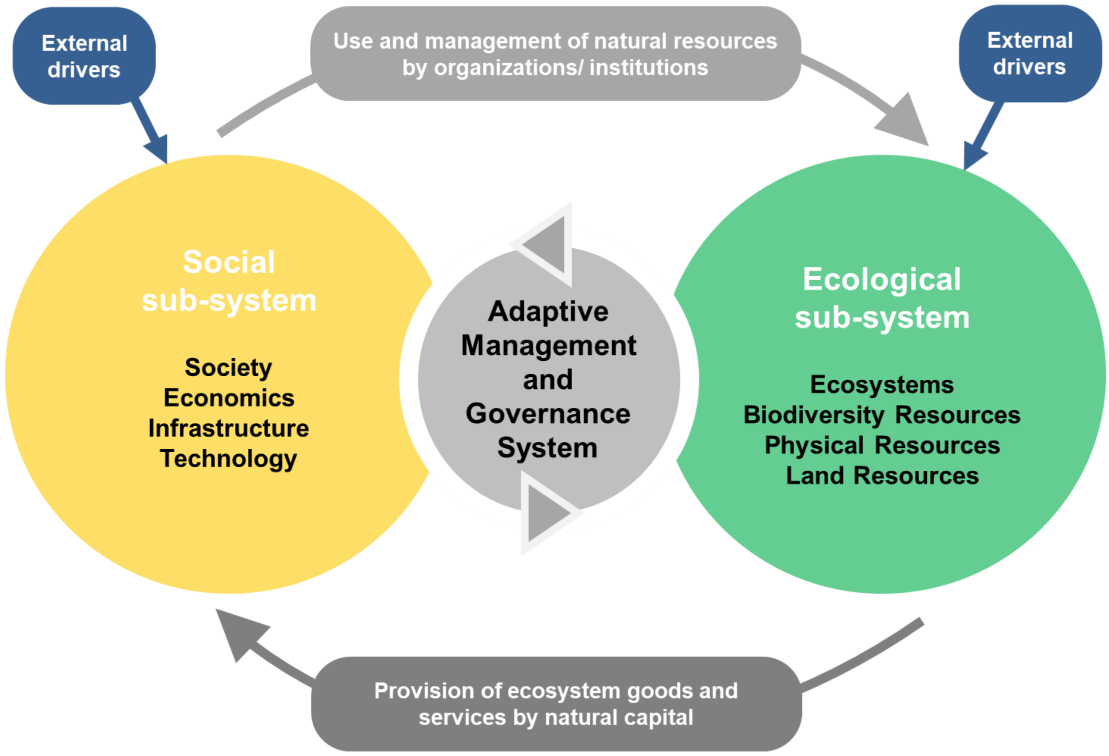


Figure 2.3: Resilience through Adaptive Management and Governance in SES, after Ostrom (2009), modified

To some extent the notion of resilience at more practice-oriented policy interfaces, even in international organizations, often remains disproportionally restricted to efforts enforcing physical infrastructure resilience in light of climate change impacts; see e.g. UNISDR (2012). Although this is an important field, it is essential to note that a truly resilience guided strategy of generally anthropogenic, specifically socioeconomic sub-systems, would address more fundamental skills, essentially related to *social networks* to reconfigure, establish or maintain infrastructures (Hahn et al., 2008; Cote and Nightingale, 2012; Bahadur et al., 2013). It is important to be aware that compensation capabilities in response to uncertainties derive from the behaviour of the stakeholders (individual or as organizational entity) as structural and dynamic properties of the system.

A system needs to be open to learning as a main prerequisite for dynamic knowledge stocks, adaptation policies and intervention strategies, to reorganize structural elements, innovating social and ecological components and – in the end – keep up their key functions as ultimate purposes of the system independent from original infrastructural settings. Therefore, institutions need to be open and flexible in order to allow continuity in working and learning and consequently support an increase in their adaptive capacity. Thomas and Twyman (2005) as well as Bahadur et al. (2013) consider decentralization, equity, justice and social diversity as key issues for effective governance for sustainability. Decentralization can lead to management and decision-making structures, which are closer to specific needs of communities. So, decisions made can be robust, reliable and long-term. Also in case of an upcoming crisis in a decentralized system the breakdown of one authority will probably not lead to a collapse of the entire system.

On the whole, the author states that with regard of SES, resilience is addressed to a spectrum of sub-systems and organizational layers within systems. Consequently specific organizational concreteness for the *social-cultural sub-system (with norms, values, mindsets, etc.)*, *the ecological sub-system (resource base, ecosystem services, carrying capacities and thresholds, etc.)*, *the institutional frames (learning, flexible organizational forms, etc.)*, important *interfaces of the social and the ecological as well as technological assets (maintenance, supply-demand relations, services, etc.), infrastructure (redundancy, reliability, response capacity, etc.)* or *management and engineering (flexibility, modularity, collaborative solutions, user integration, etc.)* can be articulated. This can help to build up better and more structured approaches to implement resilience design strategies in specific work fields of sustainable development (Figure 2.4).

Figure 2.4: Resilience Design in Ecological and Socioeconomic Sub-systems

For the entirety of an observed system and for each sub-system or interface the following four system aspects/ properties play conditioning and cross-oriented roles in resilience design:

- ***a.*** ***System resources*** *and system agent's comprehensiveness and diversity, relating to buffers, alternatives and stocks,*
- ***b.*** ***System structures*** *and boundaries to encompass driving functions for a long-term viability,*
- ***c.*** ***System dynamics*** *defining interactions as balancing, enforcing or attenuating feedbacks, and*
- ***d.*** ***System capabilities*** *as (re-)configurability of the system dynamics on the basis of stakeholders and institutions and their adaptive capacities*

Section 6 will be devoted to a necessary systems integration of (a) resources and (b) structures to ensure basic meta-strategies comprehensive enough for long term viability. This is considered as presuming for active system configurability and the potentials to generate sustainable dynamics and capabilities of and within systems. Section 7 will thereafter outline framework constitutions to portray (c) dynamics and to plan and manage those dynamics to positively influence (d) system capabilities.

2.2.6 Systems Integration: Exploring the Urban-Industrial Nexus

Before taking concrete resilience-based development strategies into account, a crucial step in the definition of the application system is answering the questions:

- *a.* *What is part of the system, and what is not?*
- *b.* *On which nested organizational layers are parts/ agents operating with which consequence for the emerging performance?*
- *c.* *What are driving or critical or determining (sub-)structures and agents?*
- *d.* *And in which boundaries is their interrelationship effectively situated?*

The difficulty where an observed system shows practicable system boundaries depends on the one hand if it is "complete enough" to follow a specific purpose under a given level of complexity, and on the other, to find manageable/planable units and interconnections. Both determine success or failure of efforts for sustainable development. The concrete result of such a selection process may differ in specific contexts on micro- or meso-scales, but more important some fundamental strategic propositions for the macro-scale have to be met in a first instance.

Specifying the operational context of sustainable development, beside many particular (sub-)sectors (agriculture, transport systems, fishery, water management, etc.) literature can be detected purposely on resilience guided sustainable development of *urban systems* as well as of *industrial systems* as two core drivers causing global un-sustainability. For urban systems, Ahern and colleagues (Ahern, 2012; Ahern et al., 2014) promote five strategies to build resilience capacity and a trans-disciplinary collaboration is proposed, concerning *biodiversity, urban ecological networks and connectivity, multi-functionality, redundancy and modularization* as well as *adaptive design* in and of urban systems. In the industrial context others are exemplifying the *efficiency vs. resilience* question on the basis of comprehensive *value chains and material flow networks of and in-between firms considering sourcing, production, distribution and consumption sub-structures of supply chains* (Zhu and Ruth, 2013; Chopra and Khanna, 2014) and derive new policy recommendations rooted in industrial ecology (Deutz and Ioppolo, 2015).

The synthesis of functionally highly interrelated aspects as *urban-industrial nexus* is still missing, although further systems integration of in fact inseparable forces for (un-)sustainability is considered highly necessary (Liu et al., 2015) and obvious for industrial and urban spheres. The reason for this misperception might still be a foreground attention to the physical appearance of (infra-) structures of typically urban- or industrial phenotypes. Apart from conventional sectoral thinking a demand-supply rationale, respectively source-sink relationships, makes the interdependency of the two areas understandable: The overshoot of the planet's ecological capacity can be specified in terms of a drastic resource overconsumption of resources at sinks, already causing acute or predictable scarcity at sources on regional or global scale, and by overstretching carrying capacities of the global system (eco-capacity: the ability to absorb or to assimilate caused disturbances), e.g. by destabilizing the global climate (Rockström et al., 2009; Barnosky et al., 2012; Hoekstra and Wiedmann, 2014; Rockström and Klum, 2015; Steffen et al., 2015). Urban systems are the main drivers of this impact and are systematically connected within a complex nexus of sources and sinks of materials and energy. The drastic disproportional impact of urban systems on the global eco-capacity has been illustrated through the application of ecological footprinting methodology to complex urban agglomerations (Rees and Wackernagel, 1996; Rees, 1997, 2001; Wackernagel et al., 2006). While currently urban areas represent some two percent of the earth surface and inhabit slightly more than 50 percent of the global human population, they consume approximately 70 percent of natural resources and are responsible for roughly 80 percent of the global greenhouse gas emissions (Girardet, 2000; Marchal et al. 2011). Thus, urbanization needs to be considered as a key for understanding and solution of interlinked demand and supply problems in the era of global environmental change. Therefore, it is necessary to make changes in *perceptions of cities including their supply systems and critical dependencies* and shift the planning and management system boundaries beyond the conventional urban form and structure towards *functional sources and sinks pattern in urban-industrial nexus considerations*. Sources would then incorporate not only typical industrial capacities but also those capacities which are sources for the sources in form of ecological resources and/ or ecosystem goods and services ("industrial production as consumption of natural capital") for the background of ecological economics (Costanza et al., 1991; Rees, 2003; Wiedmann et al., 2006). Sources could better be described as *eco-industrial sources* to make clearer that sourcing at the ecological resource and ecosystem goods and services play an important role for the further processing in industrial production on the way towards mainly *urban sinks*.

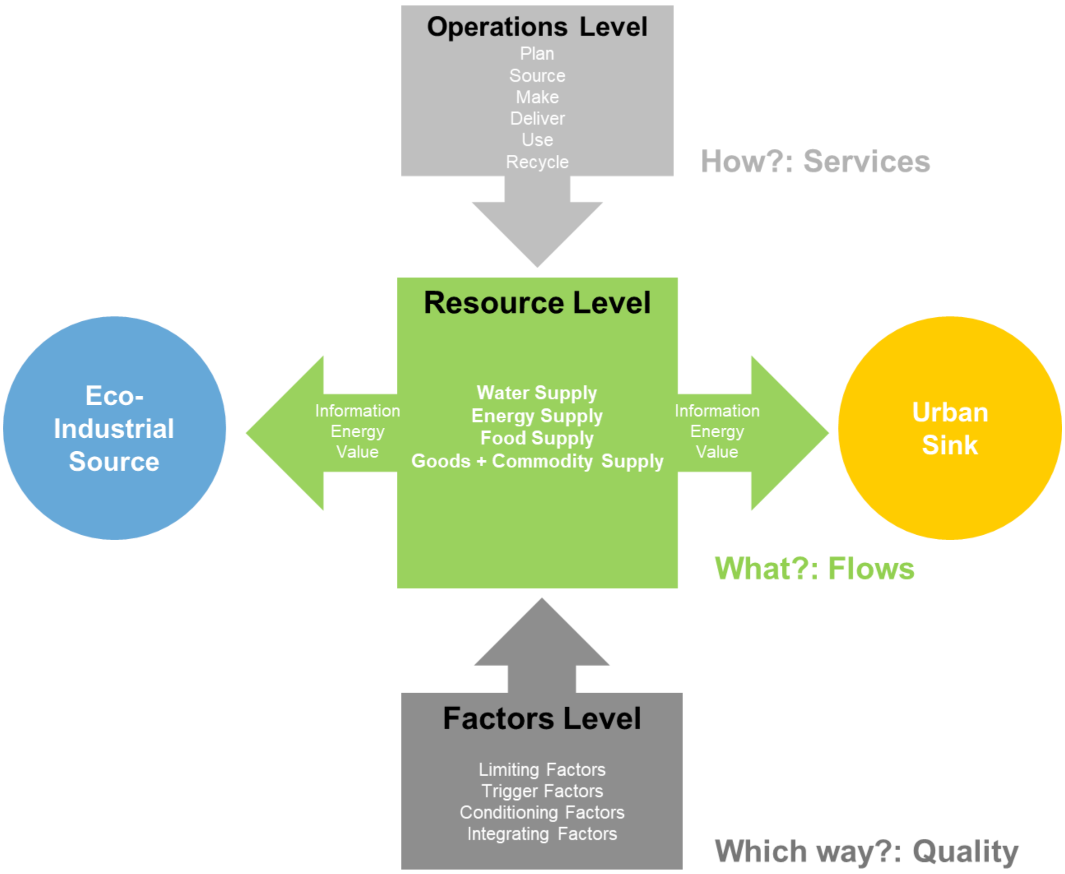


Figure 2.5: Elements of Urban-Industrial Functional Domains of Supply

This shift towards intersectoral approaches across the traditional sector borders is a logical consequence of the earlier introduced system thinking approach. It is necessary to *integrate production, demand and supply systems* from a 'system of systems' perspective. System thinking provides methodological and structured approaches due to its ability to consider subsystem layers as well as the operational environments within the larger system in forms of nested organizations (Bossel, 1987) and supports capturing the dynamic, complex and interdependent nature of the connected (sub-)systems (Sterman, 2000).

The urban-industrial nexus represents a shift from a structural or spatial towards a more functional reception of boundaries to reveal the conceptual inseparability of the two drivers for sustainability. Helpful aspects of such an integrated functional viewpoint are the definition of concrete ***functional domains of supply*** to link up eco-industrial sources with urban consumption sinks within the urban-industrial nexus. Those functional domains could be characterized by concepts of supply chain management (SCM) in terms of *(a) operations and service levels* (plan, source, make, deliver, use, recycle) to perform the supply function and by the dynamics of *(b) material and non-material resource flows* (resources, goods, commodities, energy, information and value) along the structures of a supply chain. Additionally, *(c) supporting typological factors of functional interrelationships* (conditioning, trigger, limiting and integrating factors) describe the quality of the relationship between source and sink to serve sustainability of the respective systems (Krumme, 2006). Figure 2.5 shows principal compartments and relationships consisting of *resource level, operations level and factors level* between the eco-industrial and urban sub-systems.

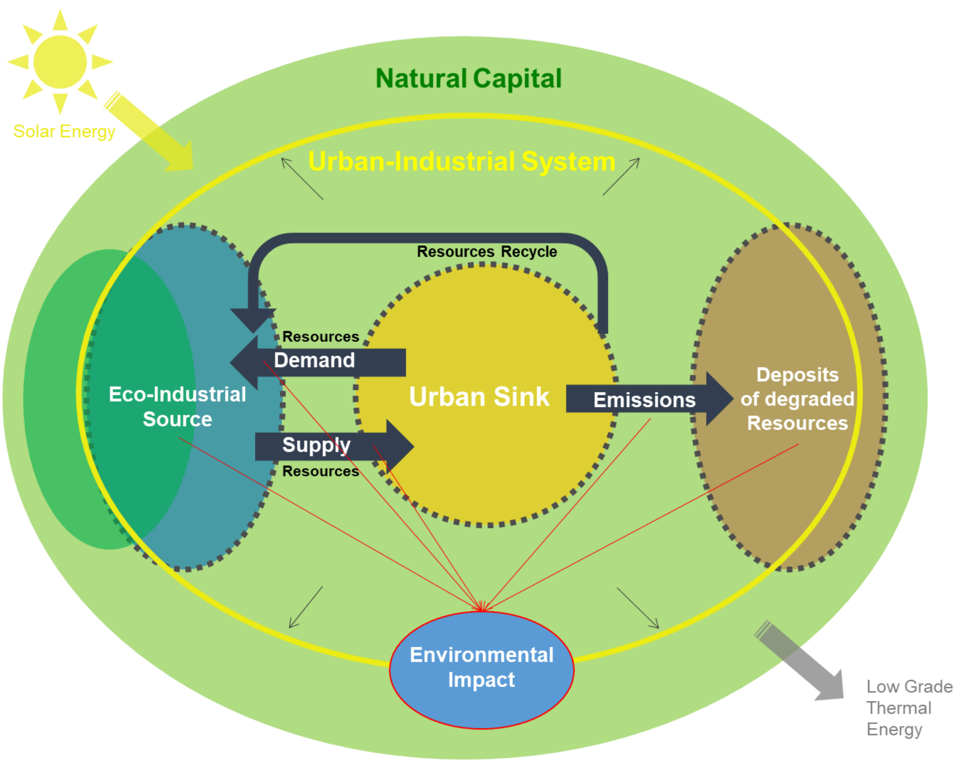


Figure 2.6: Advanced Ecological Economics Urban-Industrial System Metabolism Model

Once the relationship between eco-industrial source and urban sink is qualified by description of functional domains, the relationship can be embedded into a more comprehensive functional metabolism model in an approach of ecological economics and industrial ecology. Figure 2.6 shows a non-spatial *urban-industrial system metabolism model* as a consequence of the functional view of source-sink relations: The urban-industrial system is described as an expanding unit within the finite surrounding system of natural capital. The expansion is driven by both demand and supply between source and sink. The environmental impact is inclusively driven by supply and demand combined with turnover of resources, the effects on the eco-industrial source (in terms of conversion of natural capital into human or industrial capital), all kind of emissions on which the urban sink signs responsible for, and non-recyclable deposits of degraded resources if only a part of resource turnover can be redirected in form of a closed loop towards the eco-industrial source.

Planning and management of an urban-industrial system in a resilient and sustainable manner would consider all system compartments and interrelationships against the background of resilience design. It primarily addresses the multifold factors of the *expansion function* and of the *environmental impact function* in an integrated way to reduce both functions under the thresholds of the carrying capacity of the finite natural system. In parallel an increase of the *closed loop function* between the two sub-systems would be enforced. The establishment of a more integrative system boundary and consideration of interrelated structures as shown in Figure 2.6 and the quality of their relationships demonstrated in Figure 2.5 represent a first ultimate step towards a resilience orientation. Furthermore, it provides several supplementary directions for methodological improvement of the proposed basic functional model.

Such a new perspective directs itself to Jay Forrester's *urban* and *industrial dynamics* (Forrester, 1961, 1969, 1997), basic operations research such as the *Viable System Model* (VSM) by Stafford Beer (1984) and some recently established links of VSM to Sustainability Science (Panagiotakopoulos et al., 2016), *bio-economics* and thermodynamic receptions of *ecological-economic resource systems* (Georgescu-Roegen, 1975, 1993) or even *ecological footprint* methods (Rees and Wackernagel, 1996; Wackernagel et al., 2006). All these provide a meta-perspective of nested system organizations beyond a classical sector view and apart from foreground phenotypic structural perceptions. In terms of first outlines of understanding the language of *system dynamics* methodology, it could be appropriate to approach more complex and dynamic levels of functionalities in the urban-industrial nexus.

After initial steps for systems integration of *resources and structures*, as the first two of four main system aspects of resilience design (section 5) could be demonstrated, the next section adds *dynamics and capabilities* and integrates all four system resilience design aspects together in a final illustrated model contextualized with an advanced resilience framework on the basis of the earlier presented SES (Figure 2.3).

2.2.7 Framework for Resilience Guidance: Social-Ecological-Technological Systems (SETS)

Resilience orientation makes clear that sustainability as a steady state is impracticable. Sustainability refers to *dynamics of interrelated (sub-)systems* to emerge a variety of response forms of systems and their agents in multiple and alternative equilibriums within dynamic environments, evident in the behaviour of natural ecosystems. As natural systems a socioeconomic system, or in the context of this article an urban-industrial system in a more specific focus, depends in its ability to adapt to changing conditions (adaptability) on different *system capabilities* (based on fundamental distinct capacities) that can be actively or passively developed, can flourish or being deteriorated. Therefore, against the backdrop of resilience design, system dynamics and system capabilities stand in a significant affiliation to each other.

Building on the system-theoretical background of system ecology with the goal of resilience, the researcher can interpret technological, economic, social and environmental factors of urban-industrial systems as *interoperable compartments of a dynamic network equilibrium* that considers all system compartments as an “ecosystem” building up system capabilities as characteristic properties. Resilience as a guiding concept allows us encompassing and systematizing the relevant key performance factors for sustainable operations in the networked and nested order of urban-industrial systems.

As mentioned earlier, resilience oriented sustainable development strategies point out on inner control and steering mechanisms of *social-ecological systems* (SES) (see Figure 2.3). Elinor Ostrom convincingly elaborated SES as guiding frameworks (Ostrom, 2007, 2009; McGinnis and Ostrom, 2012) and initiated a new direction of further works on the synthesis of sustainability, resilience and SES (Xu et al., 2014) up into strategic and operational spheres of trans-disciplinarity (Binder et al., 2015). In order to move forward the general perception of sustainable development frameworks, science is recently about to come up with an integration of the technological sphere into SES as *social-ecological-technological systems (SETS),* particularly for sustainable urban development (Krumme, 2016; McPhearson et al., 2016). Technology was seen before as a compartment of the social sub-system of SES. In terms of guiding frameworks for sustainable development of strongly artificially transformed environments, such as infrastructures in urban or industrial systems, the question about the transformative capacity of technology and its contribution to socioeconomic system capabilities arises more strongly. It seems obvious but still poorly reflected that technology plays a determining role in the functional contexts of the urban-industrial nexus and its significance for (un-)sustainability. The question is how the role of technology in modern societies and respectively for sustainable systems driven by the society institutions and organizations can more precisely be described.

It is useful to go back to the original meaning of technology, which comes from the Greek word *tekhnologia* as “systematic treatment” and from *tekhnē* as “art” or “skill”. If we take into account that the human species' use of technology began with the conversion of natural resources into simple tools, it becomes significant how much the human ability to control and adapt to the natural environments is affected and driven by technology. In this context, technology can also describe a more comprehensive frame of methods, processes, materials, machines, tools and techniques and can be considered an ‘enabler’ on the interface of social organizations and their environment to facilitate the capture, distribution and repeatable application of value creating knowledge (DeSanctis and Poole, 1994; Earl, 2001) (Figure 2.7).

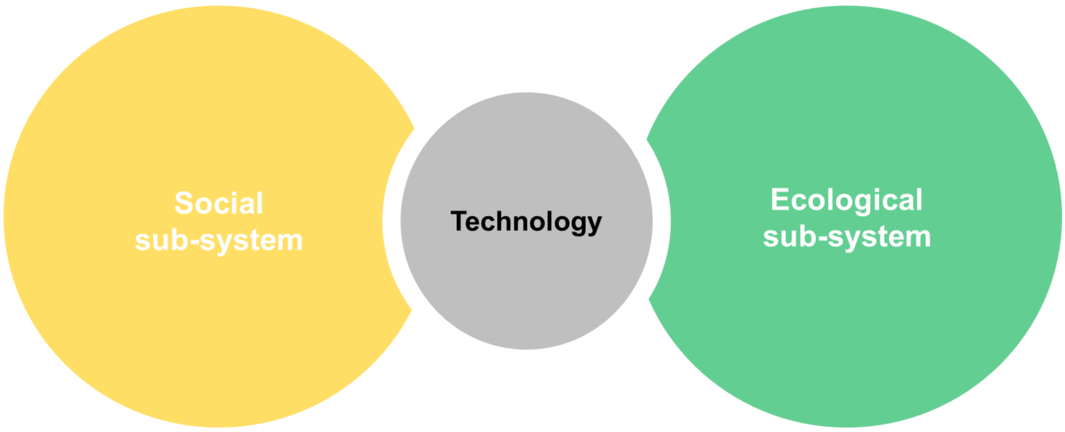


Figure 2.7: Technology in a Sustainability Context

As illustrated below, such a comprehensive understanding of technology makes the depiction of dynamics for sustainable development frameworks more complete and accents further design options to strengthen resilience (Figure 2.8). The presented illustrated model puts the dynamics of SETS on a platform of the four cross-oriented resilience design system aspects. A number of attributes correlated to four resilience design elements exemplifies the affecting of environmental, social and (new) organizational-technological capacities and their determining sub-systems in SETS. The inner arena shows the dynamics of SETS, oriented on visualization by Hahn, Schultz et al. (2008) for fundamental SES, complemented with a new technological sub-system against the background of the above made explanations. Including the new technological dimension, a SETS comprises of ecosystems as natural capital being managed and used by stakeholders and their institutions. This central interplay between humans and natural environment is enabled by a technological sphere in terms of a broad understanding of instruments, processes and methods as explained above. The management and governance systems provide frameworks with which technology is contextualized. The way of management operations is itself influenced by societal norms and values.

The system resilience against external drivers of change of such a SETS imagination depends essentially on carrying capacities of the ecosystem base as well as capacities of institutions and organizations. The way how this bilateral relationship works is enabled by adapted forms of technology and infrastructure on the interface between the social institutions and their management systems as well as the ecological functions of natural capital. Technology, therefore, plays a role as enabler of operational management modes and specific operations being more or less sustainable. A conditioning factor for the described interplay is fulfilled by progress in knowledge and competence capacities that are able to transform institutional as well as management assets of the system and, more subtle, also values and norms (and vice versa).

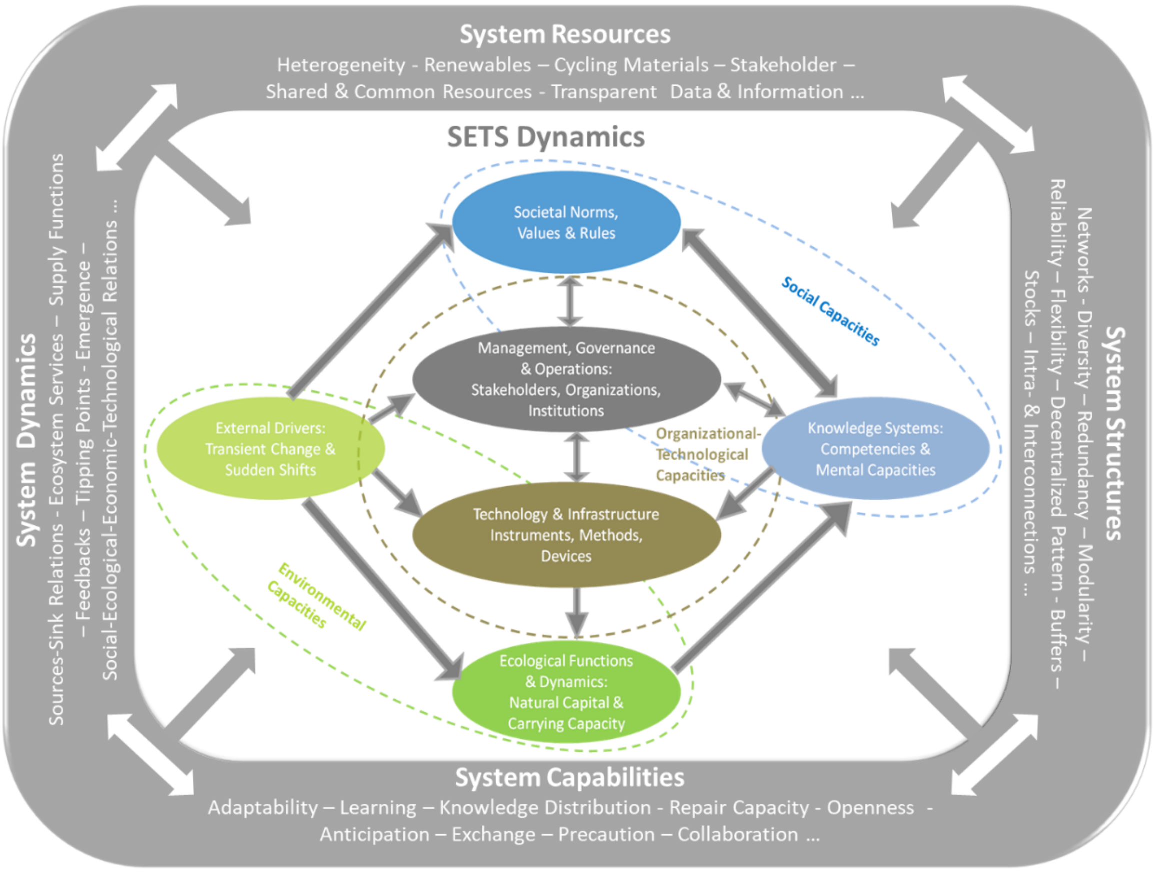


Figure 2.8: Conceptual Model of Resilience Design Dimensions and SETS Dynamics (own conceptualization with reference to Walker et al. (2004) and Hahn et al. (2008))

An exemplification on the earlier mentioned importance of post-fossil energy system conversion may initially reveal resilience driven system design options out of this model:

We can exemplify both external and internal design opportunities from the above explanations. Post-fossil renewable energy networks are driven by a consensus on minimizing negative impacts on the natural capital base and limiting socioeconomic actions below thresholds within ecological carrying capacities (to assimilate impacts and/or to avoid negative feedbacks, transient shifts or sudden shocks to the socioeconomic system). It also integrates ecological services and natural cycles of ecosystem productivity in energy harvesting, while keeping a functional balance between natural productivity and consumption rates. Besides working on infrastructure and spatial pattern (a heterogeneity of green renewable energy sources, infrastructural facilities and energy transport modes, electricity networks and smart grids, energy storage facilities, interactive consumption sub-systems, intelligent energy efficient devices at the consumption side), resilience design may also affect the relationships within the system and influence embeddedness of elements into higher and lower levels of a nested hierarchy organization. This would touch upon concrete hierarchy levels of planning and of operating the networks (levels of complex systems operations management, participatory network designs in decentralized pattern and local, regional (semi-)autarky of closed energy production and supply systems). It would also mean that a sustainable energy transition represents some paramount questions of the institutional and "bottom up" stakeholder frameworks, taking into account that knowledge of sustainability issues and a directed competence and capacity building, empowerment and awareness raising (incorporating all stakeholder groups) would not only increase the quality of results. It would also improve their ability to survive and flourish and also their ability to flexibly modify intermediate results in an iterative manner and to produce continuous improvement and innovation in terms of adaptive management.

2.2.8 Conclusion and Outlook

The article took up the complex and dynamic system nature of the sustainability challenge and transferred problems into a system-based reception of both un-sustainability and sustainability. It has been made clear that truly effective countermeasures necessitate a system thinking approach. Nested systems organization provides not only a structuring of problems in terms of drivers, effects, feedbacks and complex interrelationships. They also ask for principles how systems are able to cope with existential disturbances and stresses through complex and dynamic interplays of system compartments with differentiated feedbacks in multiple equilibriums of the affected system while upholding the essential functions and structures to fulfill the general purpose of the system, defined as resilience. A resilience guided design of socioeconomic sub-systems and their interconnected ecological sub-systems applied in a holistic frame is favoured as a concrete orientation for more deeply understood sustainability strategies. It was furthermore demonstrated that for the purpose of sustainable systems, social networks and their organizations/ institutions play a decisive role for success or failure in our efforts towards sustainability.

Based on four categories of resilience design system properties two central strands of conceptual improvement could be discerned:

- Systems integration based on source-sink and respectively supply-demand rationales with setting advanced inclusive system boundaries towards centrally important urban-industrial systems. The result encompasses and systematizes the relevant key performance factors for a sustainable operations framework of an urban-industrial nexus as an advanced ecological urban-industrial metabolism model and introduces functional domains as new conceptual term into the sustainability discourse.
- Advancement of SES to SETS as guiding framework to concretize a newly contextualized role of technology together with other driving forces within dynamics for sustainable development, especially in heavily transformed artificial environments such as urban-industrial systems. Dynamics of SETS could be brought together on a platform of four resilience design system properties, namely: resources, structures, capabilities and dynamics.

As a future direction for further elaborations the synthesis of the urban-industrial nexus (resources and structures in new integrative boundaries) with SETS as an advanced framework (additionally considering capabilities and dynamics) can formulate new impulses for transition actions in the frame of sustainable development. Such frameworks can help:

a. *Understanding of sustainable or unsustainable systems by providing a completer and more realistic picture on dynamics,*
b. *Guiding and structuring of planning and management for alternative systems or system alternatives,*
c. *Making urban-industrial systems, their governance structures and their transition pathways comparable,*
d. *Supporting sustainable socioeconomic transitions, and*
e. *Determining future needs for research.*

Hence, learning and capacity building play an imperative role for resilience, the co-production of science with the public sector, business and civic organizations are needed to successfully implement new developments. For science stakeholders, this bears two resilience specific meanings: to better understand needs and options for sustainable solutions through transition research and to take part as a promoter of sustainable development based on a specifically academic competence and through exploring new trans-disciplinary methodological settings and experimental innovation designs as transformative research. Combining transition research with transformative research will accentuate a new role of Post-Normal Science without which the desired development will not take place (Wiek et al., 2012; Miller et al., 2014).

A ground for such integrative research and transition settings is contributed by Evans (2011) relating experimental cities with a system approach and resilience design. A combination with a strong system dynamics-based ecosystem approach (Kay et al., 1999; Newman, 1999; Newman and Jennings, 2008) would broaden the experimental city towards the here proposed urban-industrial system boundaries as innovative coordinates for sustainable development.

This should be taken as a strong motivation to further enhance the exchange between sustainability oriented academic disciplines together with stakeholders from business, policy and the civil society in appropriate work interfaces and platforms under a suggested stronger systems integration and with this to substantially contribute to resilience of social, economic and ecological dimensions of the planetary system as a whole.

2.3 Supply Chains and Systems of Sustainability: An Attempt to close the Gap (Krumme, 2019)

The following chapter is a book chapter by the author of this dissertation published in the peer-reviewed *Springer Nature Volume "Innovative Logistics and Sustainable Lifestyles"*, edited by Ani Melkonyan and the author 2019.

The presented content refers to the research project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015, Appendix).

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Abstract

The article presents conceptual theory building based on an extensive literature review of contemporary knowledge stocks, both previous answers of supply chain management (SCM) and logistics regarding the sustainability challenge as well as of Sustainability Science on sustainable systems conceptualization. Grounded in the identified conceptual and knowledge gaps, the work describes building blocks for redesigns of sustainable supply chain management (SSCM).

Finally, an expanded definition of SSCM as well as a metabolism model of sustainable supply systems (SUSY) is proposed.

The valorisation of "strong sustainability"; rooted in nested systems organization, has particular importance by integrating the assets of critical capital, shared responsibility, and distributive equity into sustainable supply chain understanding. A contextualization of sustainable supply chain (management) concepts for a green economy is based on the synopsis of natural critical capital, eco-industrial production, sustainable supply, as well as consumption/product use systems with an emphasis on urban-industrial source-sink relationships.

Keywords:

Sustainable supply chain management · Sustainable logistics · Strong sustainability · Resilience · Nested systems organization theory · Sustainable supply systems · Metabolism model

2.3.1 Background

The relationship between the challenges of sustainable development and the globally fast-growing logistics industry is still in need of clarification. In fact, central aspects of the relationship between the requirements of sustainable development and logistics/ supply chain management (SCM) correspond to a vice versa combination. From a supply chain perspective, it is essential to note that in a drastically changing world, the quality of destructive dynamics (e.g., by the impacts of climate change) is altered toward more substantial threats, and accordingly the risks for supply chains increase. On the other hand, much recognizable potential of supply chain and logistics service innovation for an overall sustainable “green” socioeconomic system and the needed transition pathways is yet not realized. The ecological effect of logistical activities, for example, in terms of growing transport services and the related increase in energy consumption and pollutant emissions, makes a viscous cycle behind this diagnosis obvious. Thus, all efficiency gains of logistics (in terms of financial, energy, or personnel resources), optimized with a focus on the individual processes planned, managed, and controlled, do not provide corresponding efficiency gains of the entire system in terms of sustainability. On the contrary, logistics as an enabling instance of high-performance production and consumption systems (and consistently increasing resource consumption) is an impressive example for a meta rebound effect (Krumme et al., 2015). This rebound effect means that the primary savings are overcompensated by secondary effects, resulting in increased overall consumption (Weizsäcker, 2009). Within the last decades, logistics has shifted from solely providing the classical triple of transport, warehousing, and transshipment services to more or less comprehensive planning, executing, and controlling of value-added services in complex production, distribution, and closed-loop operations within and between networked companies and as backbone of the network economy at all. Drivers have mainly been a continuous SCM orientation as well as increasingly integrated information and communication technology (ICT) based services into the supply chains (Christopher, 2016; Hugos, 2018). As far as some economic entities – e.g., single companies or entire value chains – are confronted with a growing pressure to transform structures and processes as well as their very self-concepts against the background of sustainable development, logistics and the supply chains will undergo further severe changes as well as its corresponding businesses. It is noteworthy that with respect to the modes and networks of the globalized economic system and its production and consumption patterns, root causes of unsustainability are centrally fixed within the mechanisms and organizations of supply chain structures and their operations in logistics (Krumme, 2012). Assuming that, the question arises on how far logistics and supply chains will have to transform and – even more important – what logistics can contribute to a sustainable economy and how supply chains of this economy would be designed. Are there conceptual frameworks of a sustainable economy in which qualified logistics services and supply chains are included? Would logistics be still the "backbone" of such future sustainable systems? Specifications for logistics and supply chains in particular are required for the transformation of economic systems in the context of a sustainable development in general. The sides of a tension field between consistent corporate responses and the challenge of transforming economic framework conditions and policies are directly linked to the sector of logistics. Terms such as "greenhouse gas emissions and climate change" and "energy prices and transport costs" are just two obvious pairs that influence changed conditions for logistics service providers (LSP) and the resulting decisions in the supply chain. Beyond that, much more configurations of overall system sustainability must be seen as coordinates within a common frame of reference. This until now just anticipated framework describes restrictions on logistics in the short, medium, and long term, yet providing interesting opportunities for new developments. The transformation goals, the way to achieve these goals, and good understanding of the mode of transformation as well as the selection of elements to be transformed depend foremost on an entire system perspective (outside in) rather than on focusing on contemporary subsystems of logistics and supply chains (inside out). It is also fundamentally determined by a deep understanding of what sustainability is, the demands formulated by the sustainability challenge on transformation of the economy, and the way of implementation of sustainability dynamics attached to businesses such as logistics. Very basically sustainability "ensures the continuity and prosperity of economic, social and environmental spheres of the global system" (Folke et al., 2002). Apart from this macroscopic goal level, definitions of sustainability and their applicability differ. Moreover, in their current form, they are not useful to guide logistics on this course without further elucidation. For this, a strong scientific basis of the conceptions is essential. Though the expansions of the conceptual works in sustainable supply chain management (SSCM) are important milestones, they are still not capable to explore the deep transformation from the perspective of a future "green" economy. A more comprehensive view and contextualization of supply chains with the theoretical achievements and resulting practical relevancies of Sustainability Science can support further progress. In the following, state of the art with respect to sustainable logistics and SSCM as well as sustainability conceptions within Sustainability Science is evaluated.

Resulting weaknesses in the logistics business as well as on the SSCM conceptions in scientific literature are formulated. To close the gap between transformational concepts in sustainable logistics and SCM, related concepts from the Sustainability Science spectrum are linked to a basic outline of a proposed model. Finally, necessary refinements, needed research, and overall required innovation activities to enrich this groundwork are anticipated.

2.3.2 State of Knowledge: Supply Chains and Systems of Sustainability

2.3.2.1 Logistics, Supply Chains, and Supply Chain Management

Modern logistics and SCM deal in an integrated way with the planning, management, and controlling of goods, information, and energy, personnel, and material flows of the globalized economic and social system. Definitions especially of separating SCM and logistics can appear blurred. In fact, there are corresponding meanings behind the two concepts. Even though a symbiotic relationship exists between them, each represents distinctly different tasks and responsibilities. For the following discussions, logistics is seen as a (service) task within the umbrella of wider and more expanded activities of SCM. Since wider connotations are important from the sustainability perspective, the following discourse ideally is referring to supply chains and SCM, also including logistics. SCM represents a well-established area of knowledge, highly accepted in research and practice (Simchi-Levi et al., 1999; Chopra and Meindl, 2007; Christopher, 2016). The central concept of the “supply chain” describes complex structures and processes of contracting companies/customers as a network of suppliers: manufacturing plants, retailers, and supporting companies involved in various design, procurement, storing, shipping, selling, or servicing processes (Sheffi and Rice, 2005). SCM is the integration of business processes across the supply chain and has grown in importance since the early 1990s, although the approach was already introduced in the early 1980s (see Oliver and Webber, 1982). SCM evolved through several stages of increasing intra- and interorganizational integration, coordination, and cooperation activities of design, planning, execution, control, and monitoring along supply chain structures and flows with the objective to effectively synchronize demand and supply (Cooper et al., 1997). Contemporary SCM can be defined as the management of upstream and downstream relationships with suppliers and customers in order to create enhanced value in the final marketplace at less cost to the supply chain as a whole (Christopher, 2016). According to Simchi-Levi et al. (2008), SCM ultimately aims at the production and distribution of the merchandise in the right quantity, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying modern service-level requirements. Integration of aforementioned factors is an important step toward greater efficiency. Nevertheless, sustainability concerns are not taken into consideration in classical SCM. In this way defined supply chains basically consist of a physical part, i.e., infrastructures, production facilities, distribution facilities, etc., and integrated management, services and information, finance, and energy flows (Figure 2.9). In a more open definition, SCM includes the acquisition of all needed services from the point of origin (sourcing and manufacturing) to the point of consumption and as far as possible back loops toward a (secondary) resource base and (re-)production facility (closed-loop supply chain management, CLSCM). All components from the source through all processing steps, distribution, and trade to the consumer (as a sink) are thus in a system and value creation context. This definition can be seen as first attempt toward integrating the sustainability context into SCM, since the connection with operations within a circular economy is given and the system view is emphasized.

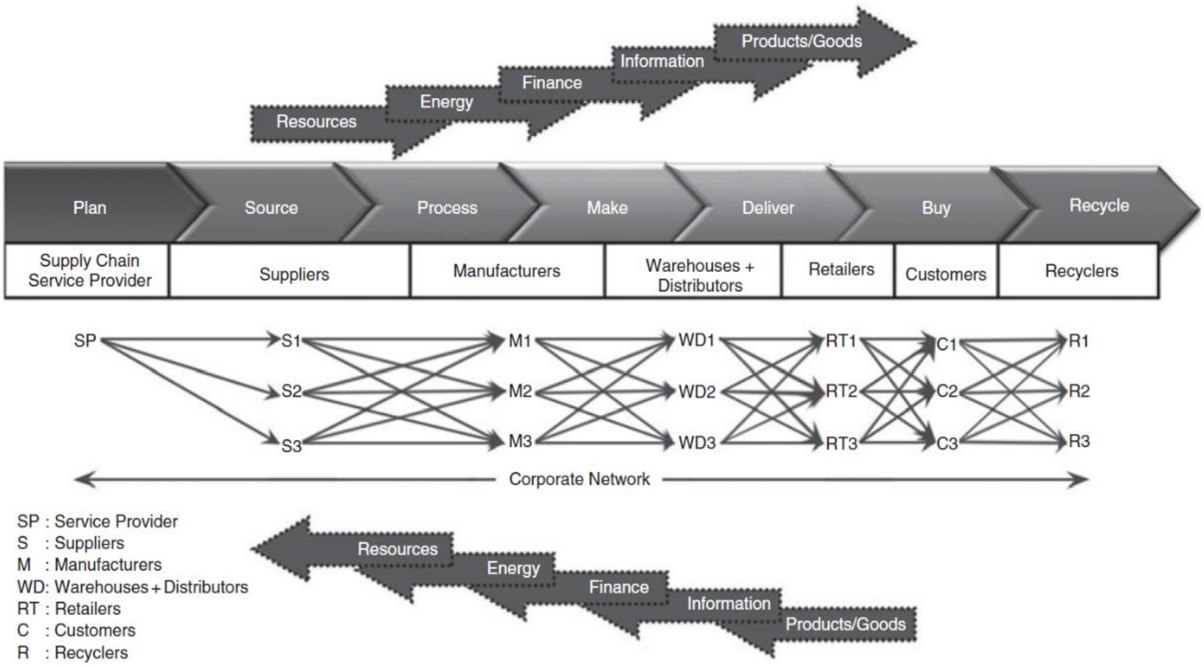

Figure 2.9: Structural elements, operational networks, and flows of a supply chain, including information, energy, and finance

2.3.2.2 Sustainable Supply Chain Management

Sustainable SCM (SSCM) has emerged in the first decade of the new millennium and puts the supply chain into a wider corresponding strategic frame in association with the three dimensions of sustainability: ecology, economy, and society (see Linton et al., 2007; Carter and Rogers, 2008; Seuring and Müller, 2008; Lieb and Lieb, 2010; Crum et al., 2011; Brandenburg and Rebs, 2015). The SSCM expansion provided various conceptual achievements, modelling strategies, and most importantly a more comprehensive SCM paradigm against the backdrop of sustainability. The aim is to qualify supply chain-based businesses for the sustainability challenge in the twenty-first century and support the needed transformation into a green economy. Concerning the ongoing scientific debate on the integration of sustainability-oriented impulses into SCM and logistics, Crum et al. (2011) have published a comprehensive study on the conceptual integration of sustainability references in logistics and SCM. Moreover, they identified trends, potential consensus in findings across studies, and also gaps in order to guide future research and to improve managing sustainable supply chain initiatives. The authors showed two main lines of influence, which, however, are characterized by very disparate temporal appearance and different public visibility: an area of greening economic performances, e.g., regarding the reduction of pollutants or the consumption of non-renewable natural resources since as early as the 1980s, and then only in the late 1990s, taking up the social dimension of sustainability with corporate social responsibility strategies (CSR). Carter and Rogers (2008) provided an integrative framework of the convergence of sustainability perspectives based on conceptual theory-building methods, considering the triple bottom line (Elkington, 1997). They see SSCM as a strategic, transparent integration and achievement of equally social, environmental, and economic enterprise goals in the systematic coordination of key business processes to improve long-term business performance of single enterprises and the supply chain. They also developed research propositions based on resource dependence theory, transaction cost economics, population ecology, and the resource-based view of a firm. Some other studies integrate the sustainability triple bottom line of “people” (social), “planet” (ecological), and “profit” (economic) into central decision-making models of SSCM, such as the aggregate planning model (Türkay et al., 2016). Linton et al. (2007) make clear that SSCM must explicitly include by-products of the supply chain and consider the entire life cycle of products. Seuring and Müller (2008) describe SSCM as the management of material and information flows as well as the cooperation between companies along the supply chain, taking into account goals from all three dimensions of sustainability. These are derived from the demands of stakeholder groups and identified three distinctive features of SSCM:

- SSCM takes into account a wider range of issues and, therefore, refers to extended system boundaries of the supply chain.
- SSCM deals with a more comprehensive set of performance objectives, thereby taking into account the environmental and social dimension of sustainability beside the economic performances.
- SSCM necessitates a much-increased amount for cooperation among partnering companies.

2.3.2.3 Sustainable Systems

In order to design resilient and sustainable systems, Fiksel (2003, 2015) points out that although many companies have adopted sustainability goals, the actual development of sustainable systems remains challenging. Generally, and concerning ultimate goals, sustainable development is about basing progress on a “safe operating space” for humanity, respecting the “planetary boundaries” (Folke and Rockström, 2009; Rockström et al., 2009; Rockström and Klum, 2015; Steffen et al., 2015). Sustainability Science has emerged as a Systems Science since the 1980s as a pulsating field of research and developed until now a core research agenda as well as an increasing ow of results published in some of the leading journals of the academic world (see Kates et al., 2001; Clark and Dickson, 2003; Komiyama and Takeuchi, 2006; Clark, 2007; Kajikawa, 2008; Lang et al., 2012; Kajikawa et al., 2014). Sustainability Science, as described by the website of the Proceedings of the National Academy of Science of the United States (PNAS), is “…an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability…” (Kates, 2011). Research tasks have been evolved through a constructive interplay between a descriptive-analytical and a transformational mode. The first is concerned with analyzing problems in complex and dynamic human-environment systems, whereas the second conducts research on solutions to those problems (Wiek et al., 2012). State-of-the-art sustainability knowledge as the knowledge to achieve sustainable systems has emerged through active discourse in a growing community of sustainability scientists, which has led to Sustainability Science matured as cross-sectoral and transdisciplinary “post-normal” research (Funtowicz and Ravetz, 1995; Funtowicz and Ravetz, 2003; Ravetz, 2006) in contrast to the rather increasingly fragmented “mainstream” academia (Sterman, 2012). The conceptual theory of sustainability itself and its practice orientation have been widely discussed, producing far more sophisticated concepts than the policy-related Brundtland definition or the business-inclined triple bottom line up to scientific discourses about constitutional frameworks and theories (Ayres et al., 2001; Ekins et al., 2003; Neumayer, 2003; Dietz and Neumayer, 2007). It is important to understand that the two popular definitions of Elkington and Brundtland use social, economic, and ecological spheres just as reductionist categories and at last superficial perceptions of a much more complex reality. Today advanced conceptualizations (Kay et al., 1999; Ravetz, 2006; Kajikawa, 2008; Xu et al., 2014; Liu et al., 2015; Steffen et al., 2015; Krumme, 2016) are available, yet not often applied outside the expert communities. Principally the findings of Sustainability Science bear important momentum for concrete developments, strategies, or investments being taken in socioeconomic systems. Based on the achieved results of System Science (Mesarovic et al., 1970; Findeisen et al., 1980), Costanza and Patten (1995) argued fairly early that a nested hierarchy organization of systems must be considered over the ranges of space and time to avoid failures, costs, and further risks. Later research findings of system resilience (Folke, 2006) and social-ecological systems (SES) (Ostrom, 2009) had a big influence on the analysis as well as for the alternative planning and implementation of solutions and finally how to achieve sustainable systems, but mostly outside the business sector. Accordingly, Sustainability Science bases errors or success of systems related to the understanding of nested system hierarchies and system resilience (Hahn et al., 2008; Folke et al., 2010; Steffen et al., 2015). This progress in Sustainability Science has built comprehensive frames upon social, ecological, economic, or technological agents of systems and their levels of organization. State-of-the-art knowledge also points out several but widespread misunderstandings, briefly summarized below.

Critique on the Efficiency Paradigm

It is understood that sustainable development cannot solely be based on higher efficiency in resource consumption but also on a progress in dematerialization, shifts in product and resource life cycles as well as sufficiency-based transitions in societal lifestyles. Simply lean resource systems may be inefficient due to increased instability and vulnerability and lower long-term persistence in their economic performance and thus bring new risks and additional costs (Korhonen and Seager, 2008; Fiksel, 2015; Korhonen and Snäkin, 2015).

The Myth of Sustainability and Substitution of Natural Capital Through Technological Innovation

Many authors of Sustainability Science deny the possibility of a simple decoupling of resource consumption and economic productivity as well as a possible substitution of the assets of the natural capital by technological (human-made) capital. They argue for a comprehensive but differentiated view on a variety of capitals forming a sustainable nested systems organization and under limitation of ultimate critical qualities of natural capital stocks and flows to be preserved (Daly, 2005; Fiksel, 2006; Beddoe et al., 2009; Jackson and Senker, 2011; Costanza et al., 2016).

Bottom-Up and System-Based Forces for Sustainable Development

Beddoe et al. (2009) argue that sustainability transition occurs through an evolutionary process that people can direct and control and seed the iterative redesign of the current socio-ecological regime to achieve sustainability. Finally, it is clear that the socioeconomic agents of a system have to participate as stakeholders in the change of the system itself. All efforts for sustainable development must reach a consensus on the desired characteristics which are ideally consistent with the relationships between socio-ecological subsystems in the hierarchy

(Costanza and Patten, 1995). These efforts should be based on participatory approaches (Kasemir, 2003; Lafferty, 2006; Ghai and Vivian, 2014), adaptive management (Gunderson, 2001; Tompkins and Adger, 2004; Norton, 2005; Walker et al., 2006), and modes of collaboration, as well as joint knowledge production (Hegger et al., 2012; Lang et al., 2012) in a non-technocratic but comprehensive transition process (Elzen et al., 2004; Kemp et al., 2007).

2.3.3 Weaknesses in SSCM Theory and Business Practices

Taking into account briefly summarized achievements of Sustainability Science above in terms of knowledge about desirably sustainable systems and by comparing them to the status of conceptualizations of SSCM and sustainable logistics, the efforts appear centrally restricted. They still relay to a modification of the well-known and already existing SCM system boundaries and strategies by mostly relating already given structures and operations to "external" social or ecological factors. A full system view on the coordinates and organization of alternative, fundamental system redesigns are rather not taken into account. Such a view would have to expand beyond the supply chain and would have to downscale from the claims of alternative economies to supply chains as a subsystem. In the following paragraphs, weaknesses of contemporary SSCM are further differentiated into conceptual and content-strategic weaknesses. The articulated aspects are both relevant to theory building and business practices in SSCM and logistics.

2.3.3.1 Conceptual Weaknesses

Insufficient References in the Understanding of Sustainability

Scientific literature as well as business practice related to sustainability in logistics and SCM mainly consider theoretical concepts and definitions which are not corresponding to the actual state of research and thus reveal a rather inadequate understanding of the terms of sustainability. The prevailing views are mainly shaped by "weak sustainability" models, such as the internationally most influential concept archetype of the "triple bottom line" by Elkington (1997, 2004). The progress in SSCM can be taken as a direct response to the popular discourses of sustainable development in the 1990s that still dominate the common understanding of sustainability needs until today. This discussion is still mainly characterized by the inter-related Brundtland definition (WCED, 1987): "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[10] The popular division of sustainability into the pillars of ecology, economy, and social affairs – as also formulated by Elkington – is originally based on the Brundtland definition, as it can be found in the Agenda 21 as one of the major outcomes of the Rio Earth Summit in 1992 (Kates et al., 2005). The rather broad approach does provide little concrete guidance to companies and other organizations on how to operationalize sustainability as part of their activities. A reason for inconsistencies and shortcomings between logistics practice and the challenge field of sustainability lies actually in this perception of sustainability: Brundtland as well as Elkington leave space for arbitrary addressable approaches that in the end exist side by side. This often results in a very general, quickly consensable, but unconscious understanding of sustainability (Atkinson et al., 1997). Models of weak sustainability assume the equivalence of the three classical dimensions (social, ecological, economic) and try to integrate aspects of these three sectors at action levels without considering functional-hierarchical statements (Atkinson et al., 1997). Thus, on this basis, in business practise further developments have emerged. Strategies and frameworks such as corporate social responsibility (CSR) (Matten and Moon, 2008) or corporate citizenship (CC) (Matten and Crane, 2005) have gained importance for the implementation of sustainability related strategies in companies. Principally they have initially been focussing on the social pillar. However, afterward more holistic reaction by companies in relation to the main discourses of sustainability have been established over the years, which in turn also addresses the other aspects of sustainability (ecology, economy), but again guided by the triple bottom line rationale (Jonker et al., 2011). The fact that all known sustainability initiatives launched in logistics business and SSCM contexts are based on models of weak sustainability reveals a problematic conceptual fundament for further applications in planning and management. Central points of criticism arise, particularly regarding the implementation in the corporate or value and supply chain contexts, and are outlined in the following paragraphs.

Poor Illustration of Complex Reality in Business Decision-Making Structures

The demand for sustainability makes entrepreneurial activity more complex. The question is whether the chosen conceptual approach meets this complexity claim or whether a nontrivial discrepancy arises between the claim, the conceptual disposition, and the arising potential for implementation. As in every weak sustainability model, the triple bottom line model offers only insufficient possibilities for the representation of interconnectedness between the sustainability

[10] In simple terms the Brundtland definition contains two key concepts: The above intergenerational justice deals with a proactive and foresighted attitude with respect to the ecological and social conditions as a long-term and cross-generational task. Besides, intragenerational justice puts the fair distribution of resources, risks, and opportunities among differently privileged groups of the society or regions in the world ("North-South") in the foreground of decision-making.

pillars. In the business reality, the effects of entrepreneurial action are not clearly categorizable on the singularity of sustainability pillars but represent de facto networked consequences for all three dimensions of sustainability, regardless of whether the action was purely economically emphasized or if the other aspects were also included. The reason lays in emerging system dynamics due to complex interconnections and interdependencies. Köylüoglu and Krumme (2015) could show that during experimental concrete extraction of decision criteria for logistics business practise within the three pillars, a mono-dimensional assignment of the criteria is not possible. For example, a “fleet, route, and capacity optimization” directed to ecoefficiency in the ecological pillar of sustainability can easily be assigned to economic relations. “Cooperative transport models” or “corporate innovation management,” which is classically assigned to the economic sector in the most implementation guides, has significant potentials simultaneously within the ecological and the social pillars (e.g., in the sense of innovations in human resource management). Investments in the field of “employee training” (social pillar) promote dynamic feedbacks and can in principle contribute to employee motivation. This also has indirect economic advantages (especially in times of crisis), or it can reduce energy and resource consumption under the focus of environmentally friendly behavioral changes in corporate operations.

Generating Multi-Criteria Goal Conflicts

Functional links between the reductionist dimensions of sustainability are often not synergistic but appear rather conflicting in everyday business. This may be the case, for example, when pricing or legal framework conditions do not reflect eco-friendly behavior (e.g., in the sense of investing in new technologies) to the same extent as business profitability and thus increase the entrepreneurial risks. On such a basis, sustainability is difficult to implement because actions on one single dimension generate multidimensional effects. In general, conflicts can arise among the three pillars of sustainability. Complementarities between the goals and values added can be another issue. Due to the postulated equal treatment and equivalence of the sustainability dimensions in the weak sustainability models, emerging multi-criteria conflicting goals are unavoidable and often misleading for a sustainable corporate development.

Exclusion of Possible Synergies and Long-Term Entrepreneurial Benefits

In a business context, it is crucial to identify synergies between factors or drivers within the networked organization of sustainability where they exist and to assess the value of business decisions for stability in a long term. In this respect, ecological and social motives can certainly support the success of a company. Moreover, beyond short-term effects, they can make economic action more successful considering corporate or supply chain risk management.

Lacks in Sustainability Transformation Strategies

Part of Sustainability Science is the embeddedness of solutions into a transition process (Wiek et al., 2012). Sustainability transition management and the suitable methodological spectrum gain importance in the business sector after having found much attention in the public sector (Loorbach and Wijsman, 2013). Figure 2.10 represents a classical guided transformation in the understanding of Sustainability Science. Some conceptual aspects are fundamentally important:

1. Transformation is an iterative-adaptive process and arises from the spectrum of adaptive management (Gunderson, 2001; Armitage et al., 2010). As in a PDCA ("plan-do-check-adjust") cycle, there is circularity between intermediate results and further refined transformations in connection with learning effects of all system agents.
2. Desired changes and the knowledge of enabling target knowledge factors require the exact knowledge of the problem with regard to factors, subsets, and realistic system boundaries which actually correspond with each other (system knowledge) (Wiek et al., 2006).
3. Knowledge of how transformation can be achieved results from experience, based on system and target knowledge. It involves the application of suitable methods, which above all can involve a broad spectrum of system agents and bring in different perspectives for the transformation, coupled with the ability to harmonize them.

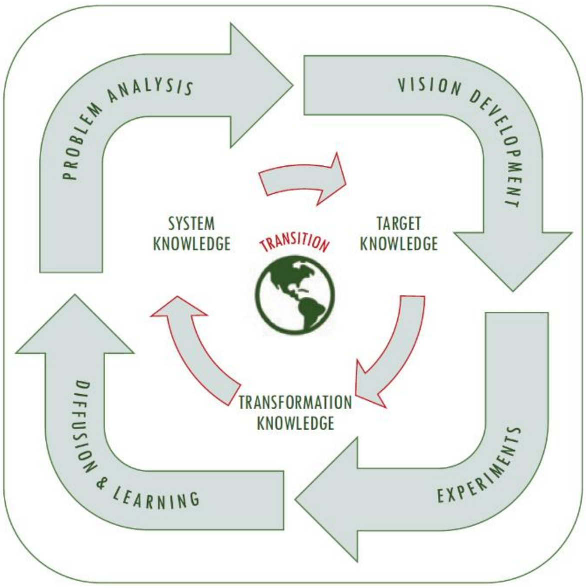

Figure 2.10: A sustainability transition cycle (Source: Wuppertal Institute, modified)

Recalling the previous paragraph, it must be assumed that contemporary approaches of the SSCM and sustainable logistics have only insufficiently defined system boundaries and subsystem interactions in relation to sustainable economic activity. Respectively, only inadequately appropriate transformation goals can be derived from this; thus short-term transformation strategies in supply chains are “pre-programmed.” Especially in the interplay of theory building and its application and the transfer into the ultimately decisive practice of sustainability management, the illustrated transformation process plays an important role. In order to be successful in achieving substantial sustainability benefits, gaps need to be closed. This requires application of suitable understandings of sustainability (analytics) as well as a suitable transdisciplinary and cross-sectoral methodology (Binder et al. 2015). Both have so far been little or not reflected in the context of SSCM.

Misleading Efficiency Guidance

A necessary shift from a dominant efficiency paradigm toward needed resilience guidance is only insufficiently implemented within SCM and SSCM theory and practice.[11] Supply chains have to meet a needed degree of flexibility and adaptability within their structures and processes as well as of the correlated service operations in an in vivo fluctuating business environment. This is essential to achieve the goals of “the right output at the right time and the right location.” Pure efficiency guided optimization in a supply chain must be valued problematic against a resilience background: Even eco-efficient or energetically optimized resource systems of supply chains do not lead to sustainable improvements, since they cannot meet the needed flexibility and adaptability (Korhonen and Seager, 2008; Fiksel, 2015; Korhonen and Snäkin, 2015). To reach a suitable adaptive capacity, the diversification of the resource base, structures, and functions within the supply chain is important. The diversity and presence of multiple and also redundant elementary structures, as reserves, variants or buffers, ensure ancillary services, even if conditions change drastically and/or if key elements fail (Folke et al., 2002, 2010; Brown and Williams, 2015). Efficiency of supply chains must therefore be considered in relation to the emergent system properties and find a meaningful place in the targeted categories of management approaches (Fiksel, 2003; Korhonen and Seager, 2008). In the industrial context, some authors already exemplify the efficiency vs. resilience paradox on the basis of comprehensive value chain and material ow networks of and in between firms considering sourcing, production, supply, and consumption substructures

11 Resilience here is understood as the ability of a system to work under stress and external disturbances or maintain its necessary system services. Resilience will be subject to further elaboration within the context of this chapter.

(Zhu and Ruth, 2013; Chopra and Khanna, 2014) deriving new policy recommendations rooted in Industrial Ecology (Deutz and Ioppolo, 2015).

2.3.3.2 Content-Strategic Weaknesses

Design criteria for sustainable systems beyond "mainstream" contents of triple bottom line-guided approaches such as efficiency management or corporate social responsibility must be found. Some are content specific for this book with regard to the linkages of logistics to consumption pattern and societal lifestyles. These criteria necessitate a general expansion of SSCM theory into the spheres of sustainable consumption and sustainable product life cycles (see Chap. 1). Much inspiration can be provided here by resilience design concepts. Resilience-driven concepts are impressively elaborated in the Sustainability Science communities (Berkes et al., 2000; Gunderson, 2001; Folke et al., 2002, 2010; Fiksel, 2006, 2015; Folke, 2006; Derissen et al., 2011; Evans, 2011; Bahadur et al., 2013; Olsson et al., 2014; Brown and Williams, 2015; Krumme, 2016). A fundamental prerequisite for resilience design is the full recognition of system boundaries connecting the sustainability-relevant linkages between production, supply, and consumption as well as a good understanding of the respective interplays and interdependencies. Specific content weighting in the scientific debate on supply chain resilience (SCRES) is crucial here, which has become considerably more important in the recent years (see Christopher and Peck, 2004; Sheffi and Rice, 2005; Pettit et al., 2010; Jüttner and Maklan, 2011; Hanke and Krumme, 2012; Wieland and Wallenburg, 2013; Tukamuhabwa et al., 2015). However, compared to the main research of Sustainability Science, there are still substantive deficits, which have consequences for supply chain strategy and planning due to knowledge gaps and unrecognized risk potential in SCM. Most research in SCRES still focuses on intrinsic vulnerability factors of supply chains, much less on "external" links to sustainability in general, or research areas which have a high concentration of attention in Sustainability Science such as climate change impacts (compare Tukamuhabwa et al., 2015; Donadoni et al., 2016). The direct link of resilience concepts in SCM/SSCM to climate change risks stays surprisingly underrepresented in scientific literature up to now. Concrete alternative service models do not exist either (Levermann, 2014; Beck and Villarroel Walker, 2013). Just general knowledge lacks, and respective research challenges have been detected, and food systems particularly are recognized as critical bottleneck (Benedikter et al., 2013; Miller et al., 2013; Levermann, 2014; Paloviita, 2015). Water and energy concerns are cross-oriented issues along commodity supply chains and represent dominating factors for their sustainability. Furthermore, supply chains will become more vulnerable against changing environmental regimes and respective disruptive events and chronic stresses (Hanke and Krumme, 2012), significantly related to the three dimensions of the water energy food security nexus (WEF nexus), an area of high attention in the sustainability research landscape (Bazilian et al., 2011; Hoff, 2011; Allan et al., 2015; Rasul and Sharma, 2016; Scott et al., 2015; Smajgl et al., 2016). For the backdrop of global environmental change and the interlinked urbanization dynamics, a needed and long-term resilient availability of water, food, and energy for the growing (urban) sinks pose new challenges for sustainable product life cycles and intertwined modern supply chain businesses (Krumme et al., 2011; Hoekstra, 2014; Hoekstra and Wiedmann, 2014; Krumme, 2016). With respect to the WEF nexus and a SSCM perspective, only few works have been published. According to Ercin et al. (2011), development of highly water-efficient management systems does enclose a more comprehensive product LCA as well as a supply chain perspective. Gerbens-Leenes et al. (2009) published helpful work of assessing water footprints for renewable biomass sourcing and supply. In the future, “water-aware” and “water-sensitive” supply chains of products and services will be standard, monitoring the water use from the source to the sink and also determining “end-to-end” lean water management systems (Boulay et al., 2013). This is principally analogous to the role of energy inputs along supply chains in terms of goods and services, although measurements of energy footprints are less investigated than carbon or water footprinting. Valuable examples are given for the energy footprint of bottled water (Gleick and Cooley, 2009) as for commodity production (Huijbregts et al., 2010). As a cross-oriented aspect the exploitation, efficient use, and addition of new and higher-quality renewable energy sources is essential in its manifold relations to SCM. To raise the atmosphere’s GHG-carrying capacity new sources and supply systems will more strongly be based on a decentralized pattern and differentiated regional supply chain scenarios, particularly with respect to the dominant urban sinks of energy consumption.

2.3.4 Building Blocks of a Sustainable Supply Systems Approach

Entrepreneurial initiatives have so far failed to draw on concrete applicable models of integrated sustainability in the supply chain. Integration work in the form of prioritization and decision-making in the company and along the cooperative structures of supply chains is required (Souren, 2000). This integration work would have to essentially touch on the underlying sustainability models, since they play a constitutional role for derived business innovations. Building on Sustainability Science, central points of criticism with regard to the current state of SSCM described above can be contrasted with some conceptual improvement options. The below listed four options refer to some needed core ameliorations and to a necessary integration work at the level of companies and beyond (i.a. consumer and societal levels). Decision-making must correlate to the entire supply chain and its internal and external sustainability issues as sub-systems within a common system boundary for assessment, planning, management and controlling tasks:

- Application of "strong" sustainability models as a consequence of an increased awareness and knowledge transfer between Sustainability Science and SSCM and to form a new necessary basis for advanced sustainable supply chain concepts.
- Stronger recognition of nested systems organization and system dynamics as attributes of sustainability at the decision-making and supply chain planning levels.
- Enforcing resilience-driven supply chain design as integral compound of SSCM and – vice versa – emphasizing sustainability issues as strongest drivers of SCRES.
- Visualizing of ultimate source-sink relationships as root causes of global unsustainability and development of sustainable "urban-industrial metabolism" approaches based on the above other options.

An integrated supply chain perspective provides holistic views on the entire way of material, energy, value, and information flows from all sources to sinks in the complex net structures of socioeconomic and especially industrial systems and combines effectively macro- (e.g., country), meso- (e.g., urban), and micro- (e.g., firm) levels. The following discussion is intended to provide key impetus without any claim to a complete conceptual model at this time in the absence of further necessary research. However, these initial impulses can avoid misinterpretations of sustainability from a scientific point of view and possibly serve as orientation for further research and testing. Specifically, the basics of understanding sustainability are deliberately elaborated and incorporate conventional "weak" approaches to more clearly explain the advantages and disadvantages of fundamental sustainability models.

2.3.4.1 Integration of "Strong" Sustainability Models into SSCM

As a result of the research of ecological economics (EE), alternatively to weak sustainability, more consistent methods based on so-called strong sustainability (Costanza and Patten, 1995; Costanza et al., 1997; Ekins et al., 2003; Neumayer, 2003; Costanza, 2009; Ekins, 2014; Pelenc and Ballet, 2015) can be proposed for further consideration. The application of strong sustainability models is probably the most striking difference to contemporary SSCM suggested by this chapter. Strong and weak sustainability have been subjects to intensive academic discussions and have led to a quantity of indicators (Daly, 1997; Solow, 1997; Stiglitz, 1997; Neumayer, 2003). In fact weak sustainability and strong sustainability imply different aggregation functions that involve different assumptions of substitutability between relevant factors (Kestemont, 2015). Weak sustainability can be considered as reducing system complexity to a single dimension, whereas strong sustainability takes into account differentiated critical capitals that determine the sustainability or unsustainability of a system. Basically, strong sustainability establishes functional relations between system units in the form of system hierarchical considerations, for example, by understanding assets of the ecological system organization as stocks of a non-substitutable "critical" natural capital. Key principles for strong sustainability are:

1. So-called critical capitals may not fall below certain values of qualities/quantities. Decisive is the application of carrying capacity/limits of use principles of socioeconomically used ecosystems.
2. Responsibilities should be measurable, transparent, and understandable also within complex value chain networks.
3. Equity of (also critical) capitals must be well distributed among producers, traders, and consumers.

To precisely underpin central arguments for an alternative theoretical background of SSCM, a mathematical description is chosen. To explain principles of the neoclassical weak sustainability, Kestemont (2010) considers a set KS of substitutable capitals k_j,

$$KS = \{k_1, k_2, \dots, k_n\}$$

Let $k.$ be the sum of substitutable capitals

$$k. = \sum_{n}^{j=1} k_j \tag{2.1}$$

and let $k.'$ be the growth of total capital

$$k.' = k._t - k._0$$

The generalized condition of weak sustainability is:

$$k.' \geq 0 \tag{2.2}$$

The total capital should not decrease.

This "result" as a general axiom of sustainability is problematic. The total capital approach is doubtful and generates significant errors, because:

- It implies that "unknown" capitals are not taken into account and are implicitly weighted zero. If, for example, new capital is involved due to scientific findings or normative social or entrepreneurial decisions, this inevitably leads to significant shifts in the statements or the quality of sustainability in a (always necessary) sustainability assessment (Kestemont, 2015).[12]

- The choice of the underlying (measuring) units is highly normative and a source of subjective misinterpretation or also external (political) influence.
- Methodological problems of dimensioning and weighting in the transmission to a “sustainability value” exist, as the indicators (such as energy use, ecological footprint, financial volume, or tons of material resources) inhabit inconsistencies for an undifferentiated overall design and some are inconvertible.

Furthermore, if a set W of w_j nonnegative weights of perfectly substitutable capitals is considered:

$$W = \{w_1, w_2, \dots, w_n\}.$$

$$\sum_{n}^{j=1} w_j = 1$$

$$w_j \geq 0 \; for \; j = 1, \dots, n$$

The weighted arithmetic mean of capitals, $A(k)$, is:

$$\bar{k} = A(k) = \sum w_j k_j \qquad (2.1')$$

Let the growth of mean capital be:

$$\overline{k'} = A(k_t) - A(k_0), \quad (t = at\ time\ t,\ 0 = at\ initial\ time)$$

The condition for weak sustainability (2) becomes:

$$\overline{k'} \geq 0 \quad \textit{The mean capital should not decrease.} \qquad (2.2')$$

$$\max \overline{k'} \qquad (2.3)$$

We can conclude, an approach of weak sustainability would maximize unspecifically the average (!) capital value and would therefore simplify important parameters of complex reality in a detrimental way. In contrast, strong sustainability works with natural limits of stressing/using specific capitals, such as natural resources, for example specifically the

[12] Economic history since industrialization, in particular with the establishment of neoclassical economic theories, for example, has not counted natural capital. This mistake is now obvious and illustrates elementary conceptual disadvantages of weak sustainability for portraying the reality, encompassing system properties, and finding of appropriate decisions for planning in economic environments.

functioning of the natural environment in terms of ecosystem goods and services (ESGS) (de Groot et al., 2002, 2010; Daily et al., 2009). In doing so, irreversibility and scientific understandings of preserving functionality, e.g., for natural capital as a set of critical resources, are applied. Other capital concepts can also be principally critical, even in the classical social and economic dimensions. The (critical) capital concept compared to the triple bottom line has a specific systematology to avoid multiple assignments of capitals in decision-making.[13] Consequently, sustainability can be expressed as the presence or specific performances of critical capitals. Strong sustainability means that critical capitals (such as assets of natural capital) are not substitutable, e.g., through technology assets.

Consider a set KR of critical capital k (not substitutable and non-zero):

$$KR = \{k_1, k_2, \dots, k_n\}$$

Let k' be the growth of each critical capital:

$$k'_r = k_{rt} - k_{r0}$$

$$k_{r0} = capital\ r\ at\ initial\ time$$

$$k_{rt} = capital\ r\ at\ time\ t$$

The generalized condition of sustainability is (Kestemont 2010):

$$\forall k_r \in KR, k'_r \geq 0 \tag{2.4}$$

Any critical capital must behave stably or increase; decrease of a single critical capital leads to unsustainability.

This result corresponds to a great extent to the behavior of natural ecosystems and is thus well founded by observation in complex natural systems. A (normative) weighting or selection methodology is unnecessary. Literature of Sustainability Science is full of application potential for specific factors, and the other way around, these factors are essential for the overall sustainability assessment procedure, particularly with respect to the natural environment (such as fish stocks, renewable/non-renewable energy sources, minerals, ecosystem footprints of cities, etc.) (see Folke et al., 1994; Rees and Wackernagel, 1996; Costanza et al., 1997; Martinet and Rotillon, 2007; Rockström et al., 2009; Kestemont, 2010, 2015). A further specification goes beyond the scope and the intention of the book to motivate a principal

[13] The limits may be directly detectable, such as in the case of depletion of a nonrenewable energy source, or combined when multiple sources and products are considered.

"turnaround" in the context of sustainability of socioeconomic systems, particularly (integrated) production, supply, and consumption systems through SSCM, and cannot be at this point subject to more extensive elaborations. To conclude about the integration of strong sustainability into SSCM we can recognise aspects that bring those theoretical foundations naturally together with the initially mentioned essence of SCM. As mentioned above, the concept of strong sustainability includes the conditions of responsibility and equity beside critical capitals. Here particularly interesting conceptual linkages toward SCM exist. In strong sustainability, production, supply, and consumption systems are linked by a shared responsibility along a life cycle of products, including its associated services. Concepts of SSCM should in this light include the fiduciary service of the shared responsibility to enable strong sustainability. Consequently, equity, in particular a minimal distribution of (critical) capital at all stages of source-sink relationships and respective supply chain partners, is vitally important. With a supply chain perspective, (critical) capital as terms of stock is not sufficient. Supply chains are capable of symbolizing literally a shared responsibility of value chain partners and further stakeholders as well as the translations of strong sustainability into the other component of capital, which represents the flows. Flows within and due to supply chains make the handling of the concept of strong sustainability more complex, since causes and effects of environmental impacts are not always situated at the same place and time, yet they are more promising for further elaboration. Beside ecological effects, this would also include social impacts caused by the untransparent complexity of supply chains related to, for example, conditions of production in a developing country and a functionally linked level of comfort in an industrialized country. The supply chain actually connects complex sustainability-related cause-effect relationships through often globalized network structures. Factors in production are therefore always correlated to feedbacks in the consumption function, and the supply chain and the associated services are more than just a transmission of products but an enabler of consumption and production. Modern supply chain services are not just connecting but qualitatively influencing functions of supply and demand, as well as their dynamic interplay. An important operationalization for strong sustainability considering the above-named aspects lays in the internalization of "sustainability burden" into price building of products but also supply chain services as a signal for the consumer. Vice versa the consumer must be enabled to oversee the mechanisms and conditions that lead to a "truth of costs" concerning the full product life cycle. It necessitates activating SSCM for the informational logistics of sustainability values and data along the chain up to the consumer (supply chain transparency). On the other hand, active impulses of the consumer in choosing specific mechanisms and conditions along the supply chain should be set in order to support sustainability. Authors in Sustainability Science have not sufficiently considered this synergy up to now. It would remarkably demonstrate principal progress of measuring sustainability with strong sustainability approaches to reach a sustainable green economy yet remaining an unexplored area of research.

2.3.4.2 Strengthening Systems Thinking for Sustainable Supply Chains

Sustainability is a systems concept, and system agents interact all across the known three sustainability dimensions. Systemic emergence through dynamics and complexity of a variety of system agents must be reflected in the understanding of sustainability and resulting development strategies (de Vries, 2013). Application concepts in the economy inevitably depict systemic and nonlinear relationships in decision-making structures in order to avoid errors with short-term effects, secure investments in the long term, and ultimately make stability efforts (also in terms of expansion) sustainable. System thinking and nested systems organization theory (see Mesarovic et al., 1970; Findeisen et al., 1980; Forrester, 1994; Bossel, 2003, 2007; Meadows and Wright, 2008), and their application in Sustainability Science (Fiksel, 2006; Hjorth and Bagheri, 2006; Wiek et al., 2011; Abdelkafi and Täuscher, 2016), can provide good progress also for SSCM expansions and refinements. Supply chains are dynamic systems having a complex network structure. For a successful sustainability management of supply chains, the question of the “de facto” effective network structures and the system boundaries for planning and management is of utmost importance. For sustainability purposes, it is essential to identify the relationships between external and internal elements for the quality and accuracy of a forthcoming sustainability management or transition process. Objectively seen, supply chains exchange energy, information, and material matter with the environment as open systems beside the actual goods handled and supplied but functionally interdependently linked so-called “co-flows” and will even be controlled by this to a considerable extent. The surrounding system (the regional, national, or international economic system but also complex social and ecological interrelationships) can be decisive in the sense of profit and loss for the enclosed business system, if the interactions are correspondingly strong. Economic systems in general and supply chains specifically are characterized by a higher proportion of merely qualitatively comprehensive interactions. This is mainly due to the subjectivity and heterogeneity of socioeconomic stakeholders as “conscious” elements and contributes to the fact that the self-transformation potential, including a number of relevant dynamic capacities, are encouragingly strong. A crucial first step in an advanced SSCM process is the definition of the system boundaries: what is part of the actual system to be transformed/improved and what can be excluded. Even though the answer can be extremely difficult, qualitative system dynamics (SD) represented in causal loop diagrams (CLD) can help and deliver insightful results. Even quantifiable results can be achieved with SD, although it is generally difficult to find quantifiable indicators for system boundaries.[14] System boundaries in the context of the SSCM are defined in two ways. On the one hand, it is important to make decisions about the horizontal structure in terms of the management scope. This concerns the inner core of this book and means the functional connections of the classical supply chain structure with upstream production and sourcing structures as well as downstream with consumption, product use, and possible reintegration into product life cycles. The determination of the system boundaries in a vertical manner concerns external elements, which are not directly related to the value chain, and issues of the natural or social/economic environment or repercussions of the supply chain with these elements and issues.

A second step is to assess the inner composition and organization of the included system elements. Each entity is seen as a (sub-)system in its relationship to other systems, placed at higher levels of observation. The features of this "system of systems" can be detected in subsystems and are described as principles of a nested systems organization to be used for sustainability-related purposes (Bossel, 2007). The finding of system states of sustainability ("sustainable systems") appears now as a way to include the "real-life" factors (that had been conventionally categorized as social, ecological, or economical) into frameworks that consider the actual nested organization of the factors and the connectedness in multi-categorial functions in a way to produce long-term continuity of the system. False decisions or exclusion of vital factors would in the long-term lead into system regimes of higher instability, which can already be observed through the global sustainability crisis. Here, too, methods of system dynamics are helpful for determining interrelationships, identifying central functional areas, identifying functional principles, or applying archetypes of known system behavior to functional networks (Sohofi et al., 2016). Since the observed systems themselves are part and parcel of dynamic environments, the focus is put on the organizational principles, such as coping the systems and their subsystems with changes while remaining within a specific frame allowing a continuity of their functions or services (resilience). The description of system resilience has its scientific origin in the early 1970s (Holling, 1973). The concept has undergone some refinements, but present-day definitions concentrate on conditions for multiple flexible system equilibriums to absorb disturbances before the system changes its structure by changing the variables and processes that control its behavior (Gunderson, 2000). According to Pettit et al. (2010), who described how companies deal with uncertainty in supply chains, resilience is an

[14] As a quantitative system analysis usually involves a complete description of the relevant system elements and their interactions, one possible way could therefore be to describe the system boundaries with the help of a measure (e.g., number of items, the total strength of the interactions). The system boundaries could then be defined by setting a target value for this measure, which is reached depending on the choice of system boundaries or not. The implementation would require, however, that we previously know the actual and total environmental impact.

evolving concept that offers advantages against the background of traditional supply chain risk management. Thus, a further focus of system analysis should not stop by whether specific system factors are included into assessment, planning, and management, but rather ask in which way the comprehensiveness of factors is organized to produce a sustainable (stable and continuous) interplay and performance. The way how agents and interrelationships are organized is decisive for emergence of system resilience against internal and external disruptions or chronic stress. This leads to issues of long-term system behaviors and options to keep up services under change, which are subject to some statements in the next paragraph.

2.3.4.3 Linking SSCM with SCRES Design

System resilience can be perceived as a point of reference for solution designs in sustainable development (Krumme, 2016). SCRES particularly shows some conceptual differences compared to supply chain risk management (SCRM) and appears thus suitable for integration into a context of sustainability transition management. From a strategic risk management standpoint, qualifying supply chains for the sustainability challenge has another aspect: The intensity of the world’s global environmental change (particularly the effects of climate change) and the interconnected rise of social and economic volatility are destabilizing supply chains in a range of ways. Since business decision-making is often based on historical data and already made experiences, it could be shown that the greatest weakness of risk management is its inability to adequately characterize low-probability, high-consequence events (Kunreuther, 2006). Following Korhonen and Seager (2008), a supply chain risk-based management strategy is insufficient to achieve long-term sustainability, because particularly environmental risks do exceed our understanding and limited forecasting capacities. Single drastic events can have vast influences and lead to enormous financial and non-financial damages for companies and hence the overall society in terms of supply bottlenecks and deadlocks. Assuming that the diverse effects of climate change and the interrelated other ecological and socioeconomic instabilities will modify quality, intensity, frequency, and the overall predictability of disruptions of supply networks, resilience is significantly relevant for SCM. Additionally, with respect to the sustainability of supply systems, event-driven precautionary and preventive systems may not be sufficient. The observation of ecological or also social change processes (such as climate change or emerging societal trends accordingly) shows, however, that often not only sudden events lead to a destabilization of systems but also slow and subtly changing conditions. It is striking how much resilience design can be transferred to socioeconomic, socio-technological, and industrial systems and their ultimate dependence on an ecological meta-system. In addition to the above notions of resilience, further interlinked core aspects are given, such as the extent to which the system is capable of self-organization and flexible adaptation (Perrings and Walker, 2004) through its ability to build and increase capacity for learning and adaptation (Folke et al., 2010). In particular, this corresponds with the aforementioned paradigm of Sustainability Science to system-based forces for participatory, collaborative designs for system change (Beddoe et al., 2009). For the entirety of an observed system and for each subsystem or interface, the following four system properties play conditioning roles in resilience design (Krumme, 2016):

1. System resource and system agent comprehensiveness and diversity, relating to buffers, alternatives, and stocks
2. System structures and boundaries to encompass driving functions for a long-term viability
3. System dynamics defining interactions as balancing, enforcing, or attenuating feedbacks
4. System capabilities as (re-)configurability of the system dynamics on the basis of stakeholders and institutions and their adaptive capacities

Crucial for adaptive capacity is the broadening and diversification of the resource base of desired sustainable systems. The diversity and presence of multiple and also redundant elementary structures, as reserves or buffers, ensure ancillary services, even if conditions change drastically and/or if key elements fail (Folke et al., 2002, 2010; Brown and Williams, 2015). In the context of SSCM and SCRES, a focus is on adaptive management and resource use governance as a linking momentum between socioeconomic and eco-logical subsystem relationships, demonstrated on the example of the economic use of ecosystem functions as ecosystem services by some authors (Costanza et al., 1997; de Groot et al., 2002, 2010). In case of SSCM (e.g., extraction and further processing, distributing, and retailing of goods, for example, food products), the socioeconomic part stands for the supply chain and resource use by cooperating companies. Another important design feature for resilience is decentralization of supply systems. Decentralized supply pattern has direct links to regionalization of supply chains, e.g., local food. Regionalization would lead to macro-scale decentralized supply chain structures and can introduce management and decision-making structures, which are closer to specific needs of consumer communities. To foster sustainability this is particularly relevant in a worldwide dominant urbanization context, if some other implications are considered which are subject to the following paragraph.

2.3.4.4 Respecting Ultimate Source-Sink Relationships of Urban Industrial Supply Networks

Cities control the worldwide relations between sources and sinks. Supply chain businesses integrate strongly urbanized pattern and contextualize the supply chain as a mediator between the (consumptive) city and its markets and retailing system as patches within the dispersed worldwide pattern of production. In this connection supply chains are in manifold directions, yet being directly linked to global unsustainability. The overshoot of the planet's ecological capacity can be specified in terms of a drastic resource overconsumption at the sources (to produce or regenerate resources), already causing acute or predictable scarcity or deadlocks at regional or global scale, and by overstretching the capacities at the sinks, e.g., by destabilizing the global climate (Rockström et al., 2009; Barnosky et al., 2012; Hoekstra and Wiedmann, 2014; Rockström and Klum, 2015; Steffen et al., 2015). With the increase of population and global wealth production concentrated particularly in urban areas and directing most world resource stocks to cities, the cities are the utmost cause of the global environmental degradation (Alberti, 1996, 2010; Rees and Wackernagel, 1996; Wackernagel et al., 2006; Murphy, 2013; Vojnovic, 2014). Cities enable corporate developments for transnational activities through infrastructure and expertise and by representing the major communication and transportation hubs. They are hotspots of incoming or outgoing investment activities, resulting in innovation in business and society that in the end controls developments of a "global village" (Harris, 1994; Derudder, 2009; Brown et al., 2010; Sassen, 2010; Taylor and Csomós, 2012). They are systematically interlinked within an industrial connex of material and energy flows. Several authors highlight the dependency of future urban systems from those functionalities and industrial life support systems capable to preserve water, energy, and food supply (Sassen, 2009; Krumme et al., 2011; Beck and Villarroel Walker, 2013; Villarroel Walker et al., 2014; Biggs et al., 2015; Krumme, 2016; Smajgl et al., 2016). As much as at the current status cities are a major force of unsustainability, it gets obvious that the cities are key for sustainability (Rees and Wackernagel, 1996; Bugliarello, 2006) and thus bear up to now less explored momentum for SSCM strategies. In a consequence, alternatives to the globalized current urban-industrial "world city networks" could be contradicted by a renaissance of higher levels of a regional self- or semi-sufficiency of taking up alternative organizations of nested hierarchies as indicated but not fully elaborated by some scholars (Baccini, 1996; Roseland, 1997; Newman, 1999, 2006; Andersson, 2006; Newman and Jennings, 2008). Such alternative constellations for urban systems would not principally withdraw the globalization of cities in their networks but would postulate new orientations especially for the critical material and energy flows by respecting critical ecological capacities as well as opportunities within newly balanced multi-scale nested hierarchies of urban systems through innovative urban-industrial supply chains. One central issue is how the urban metabolism of cities considering the in- and outflows in the context of supply systems can be rearranged for cities (Rees, 1997; Newman, 1999; Ravetz, 2000; Pincetl et al., 2012; Chrysoulakis et al., 2013; Huang et al., 2015; Kalmykova et al., 2015). Urban regionalization strategies could lead to more dense but also stronger decentralized production and consumption pattern, correlated ideally with increased regional supply capacities and alternative pattern for closed loops in the respective supply chain systems.[15]

2.3.5 Sustainable Supply Systems (SUSY): Advanced Conceptualizations of SSCM

On the basis of the interpretation of the beforehand elaborated building blocks, six guiding principles can be identified to elaborate (1) an advanced definition of SSCM as well as (2) a first outline of a conceptual model including illustration. Both are centred on the principle understanding of “sustainable supply systems” (SUSY). SUSY represents nested parts of a green economy, itself being dependent to non-substitutable functions of natural capital. The guiding principles are the following:

1. Respect limitations of socioeconomic use of (natural and socioeconomic) system environments by integration of the concepts of critical capital, shared responsibility, and distributive equity as guidelines for strong sustainability-based decision-making in SSCM.
2. Base planning and management of supply chains on the in vivo nested systems organization of the chain and its ecological and socioeconomic environment resulting into complex and dynamic system behaviours.
3. Define comprehensive system boundaries: Assets of critical (natural) capital should be equally considered along the full scope of integrated production, supply, and consumption systems for SSCM.
4. Interpret integrated production, supply, and consumption systems as urban-industrial source-sink relationships to effectively serve a green economy.
5. Integrate SSCM with concepts of supply chain resilience (SCRES) design, particularly with respect to supply chain “external” sustainability-related factors.
6. Consider SSCM as continuous improvement cycle of a stakeholder-driven sustainability transition within the green economy context.

[15] Enforced independence in supply if it could be implemented in radical forms, which is for cities beyond a critical size in reality hardly realistic.

2.3.5.1 Proposal for an Advanced Definition of SSCM

Referring to the above conceptual building blocks and on the earlier “classical” SCM definitions such as by Simchi-Levi et al. (2008), an expansion of SSCM can be proposed at this point:

Sustainable supply chain management (SSCM) is the development, design, and coordination of cross-company and affected external material, information, energy, and financial flows throughout the entire value chain and its operational environment. Services ultimately aim at the production and distribution of the merchandise in the right quantity, to the right locations, and at the right time, in order to minimize system-wide costs, including externalities in terms of water, energy, waste, and further interlinked natural resources, while satisfying certain service-level requirements addressed to and by the customer but balanced with overall societal needs.

With regard to this definition, we consider modern logistics a responsible instance for the design, coordination, management, and control of sustainable operational networked systems. The more companies work together in the supply chain, the more comprehensive and successful sustainability implementation can be in the interests of all stakeholders. The inclusion of externalities and balances with overall societal needs is centrally addressed by the conceptual assets of critical capital, shared responsibility, and distributive equity. This results in business and service opportunities for LSP in the planning and operationalization as well as the quality management of the entire sustainable supply chain. A sustainable operational system integrates the economic dimensions with the environmental and social needs in a functional order of a nested organization to increase resilience. Systems integration of production, supply, and consumption/use within boundaries of urban and industrial source-sink relations plays a significant role for sustainable “green economy” strategies.

2.3.5.2 Proposal of a Model for Integrated Sustainable Supply Systems (SUSY)

Unifying the above conceptual blocks can successfully be done as in the form of a metabolism model. Metabolism models show a high suitability to illustrate flows in source-sink relationships and thus indicate "common languages" with SCM. Krumme (2016) presented already an ecological economic-based model on urban-industrial supply and demand systems orientated on the functional view of source-sink relations, but a further specification as with supply chain elements has not been considered (Figure 2.11). As integrated by Krumme (2016), the metabolism model is rooted in the understanding of the "full-world" economy models of ecological economics (Costanza et al., 2014). In the opposite to the neoclassical economic theory, natural capital is not considered a resource of value-creating economic systems but as a limited system environment in which the structures, processes, and functionalities of the economy are embedded, determined to a large extent by "laws" of Natural Sciences, particularly Physics and Ecology (Daly, 2005; Costanza et al., 2014). The economic subsystem puts pressure on the functioning of the surrounding system through economic activity and economic growth. Thus, industrial production, supply, and consumption systems can be interpreted as expenditure of natural capital. Krumme (2016) specifies this general model with subsystems of source-sink relationships and points out a resulting principal metabolism (Figure 2.11). Beside more precise views on the typology of the sinks as "urban", a source view then incorporates not only typical industrial capacities but also those capacities which are "sources

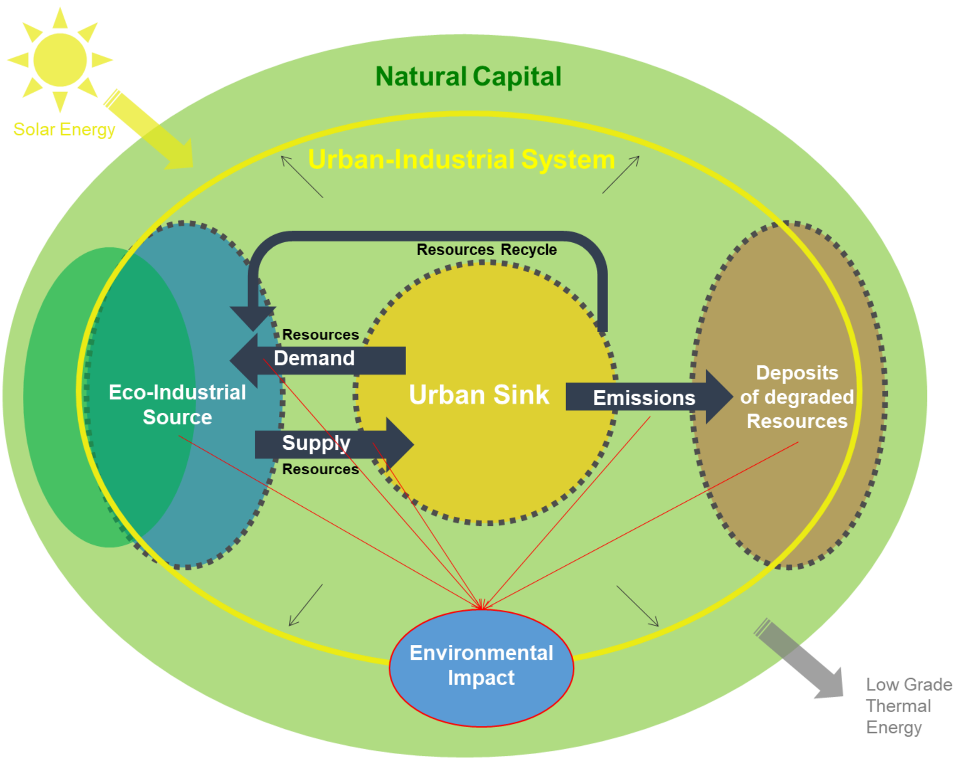

Figure 2.11: Advanced Urban-Industrial Metabolism Model (Krumme, 2016)

of the sources" in the form of ecological resources and/or ecosystem goods and services (ESGS) against the background of ecological economic theory (Costanza et al., 1992; Rees, 2003; Wiedmann et al., 2006). Thus, sources could more adequately be described as eco-industrial sources. The expansion of the (urban-industrial) economic subsystem is driven by both demand and supply between source and sink. The environmental impact is inclusively driven by supply and demand combined with turnover of resources, the effects on the eco-industrial source (in terms of conversion of natural capital into human or industrial capital), all kind of emissions of the urban sink, and nonrecyclable deposits of degraded resources (if only a part of resource turnover can be redirected in the form of a closed loop back toward the eco-industrial source). The urban-industrial metabolism model represents a shift from a structural or spatial toward a more functional reception of system boundaries to stress the conceptual inseparability of the two drivers of urban and industrial dynamics for sustainability or, more precisely, the transition toward a sustainable socioeconomic system. Helpful aspects of such an integrated functional viewpoint are the definition of concrete functional domains of supply to link up eco-industrial sources with urban consumption sinks within the urban-industrial nexus. On such a basis, those functional domains of supply could also be characterized by concepts of supply chain management (SCM). Once the relationship between eco-industrial source and urban sink is qualified by the description of SCM, the relationship can be embedded into a more comprehensive functional metabolism model which is here named SUSY: sustainable supply systems metabolism model. Needed is specification of the concretely tangible occurrence of interrelated (sub-) structures of a supply chain. A SSCM perspective would further refine the already described principal stocks, flows, and functions and conceptually link up SSCM with ecological economics as well as with the main drivers of (un)sustainability (Figure 2.12).

The SSCM scope of Figure 2.12 can be characterized as the operation levels of supply between the eco-industrial source and the urban sink. Therefore, resource flows (material and nonmaterial) and value creation are characterized for the supply chain and correlated with service and operation levels. Terms are then (a) operations and service levels (e.g., plan, source, make, deliver, use, recycle) to perform the supply function and (b) material and nonmaterial resource flows along the stages of the supply chain (resources/material (including products, resources, and material co-flows), energy, information, and value).

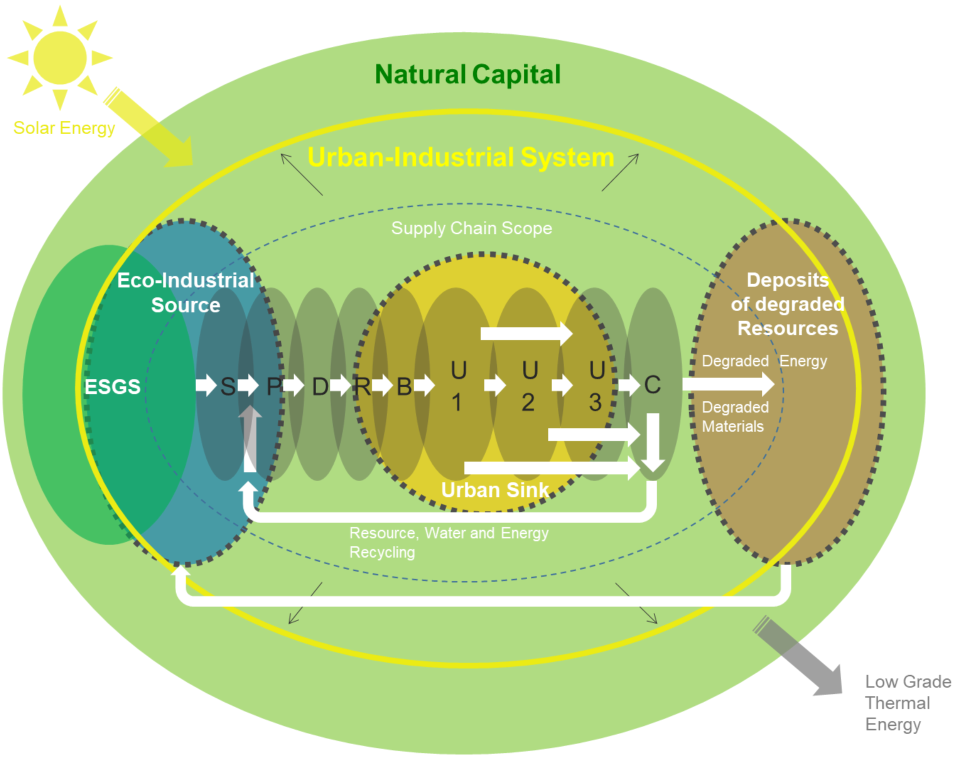

Figure 2.12: Sustainable Supply Systems based on the Urban-Industrial Metabolism

Operations and service levels of SSCM decide on the way how managing of flows in the chosen environment is implemented in a sustainable way. Principles of strong sustainability, particularly with respect to critical capitals, would then be implemented at all stages of the supply chain: S (sourcing of materials), P (production and manufacturing), D (distribution, storage, transshipments), R (retailing), and B (buying). Direct further effects on system sustainability are addressed by nonclassical elements of SCM in the after-sales area. These are in direct relation with forms of consumption and lifestyles and have a decisive effect on higher or lower rates of resource consumption and environmental impact through a redesigning of product life cycles. Within the urban system, at least three different forms of consumption are taken into account in the SUSY model: U1 (primary consumption), U2 (further circulation of used products in the sense of a sharing economy), and U3 (product modification or modularization including upcycling into other forms of use in the sense of extended circular economy). C describes the conventional recycling of materials (basic circular economy) after all these stages have already been completed. Closed loops in correspondence to the eco-industrial source (e.g., via remanufacturing or refurbishment) have to be established at all segments in the after-sales area. This also applies to deposits that are initially no longer usable, whose integration into the closed loop has to be intensified, or their emission must be avoided by upstream structures of the supply chain. The full supply chain is contextualized with the ultimate importance of ecosystem goods and services (ESGS) as a direct form of how critical natural capital becomes "valuable" in the economic system. Planning and management of an urban-industrial system in a resilient and sustainable manner would consider all system compartments and interrelationships against the background of resilience design. It primarily addresses the multifold factors of the expansion function and of the environmental impact function in an integrated way to reduce both functions under the thresholds of the carrying capacity of the finite natural system. In parallel to an increase of the closed-loop function between the three subsystems of the eco-industrial source, the urban sink and deposits of degraded material and energy would be enforced.

2.3.6 Conclusions

It has been shown that against the background of sustainable development, new paradigms and patterns of planning, design, and action in SCM and logistics are needed. In this area, new concepts may have a potentially decisive positive impact on the establishment of a sustainable socioeconomic future. So far, conceptual advances in SSCM as an extension of SCM's conventional achievements already demonstrate some integration of mainstream sustainability concepts. However, due to the deficient nature of the underlying sustainability models used and the lack of knowledge transfer, this basis can be substantially criticized from the state of established Sustainability Science. Sustainability Science can provide valuable knowledge about the sustainability of systems to be planned, developed, and operated. Much progress is based on a Systems Science approach with various specializations, concepts based on nested systems organizations, and resilience in and of social-ecological systems (SES). Nested systems organization not only provides structuring of drivers, effects, feedback, and complex issues. It also provides principles for how systems can cope with existential perturbations and exposures by specific (and flexible) system compositions and resulting behaviors. This available theoretical knowledge about the ability of systems to be sustainable has already been transferred to decision support sustainability models, strongly influenced by the agenda of ecological economics, and can be used as "strong sustainability" for the transition to a green sustainable economy. Core sub-concepts such as "critical capital", "shared responsibility", and "distributive equity" in value creation systems and product life cycle settings are suitable for being transformed into a targeted enrichment of SSCM. Based on the identified building blocks, an advanced definition of SSCM is given. It is vital to understand that the translation of new concepts of SSCM into practice and the testing of conceptual advancements within the normative context of a green economy, or wider, a more sustainable socioeconomic system, are a stakeholder-driven iterative process. The success of a necessary transformation depends on the adequate understanding of the (sub-)systems involved and a complete vision of what can be achieved on this basis of system knowledge and how. The proposed conceptual model of sustainable supply systems (SUSY) builds on horizontal integration of natural capital, production, supply chains, and consumption patterns under identification of ultimate source-sink relationships of dominant sustainability/ unsustainability potentials (urban-industrial system). A metabolism approach was chosen to illustrate the conceptual blocks in a consistent scheme. In the tradition of ecological economics, the scheme fundamentally situates the socioeconomic system and all its subsystems (including supply chain structures) as “pressure” within the limiting framework of the ecological resource and ecosystem base. Crucial to the success of the practical implementation of SUSY in the respective socioeconomic settings is an integrated view of (critical) natural capital, eco-industrial production, and sustainable product life cycles. The latter depends on the further development of SSCM service portfolios based on the strong sustainability assets of critical capitals, shared responsibility, and distributive equity. This would include the continued innovation of closed-loop control, as well as lifestyles that fundamentally change product service systems to allow at least some alternative ways of permuting supply chains within new life cycles.

2.3.7 Outlook

Based on the findings of the presented work and the proposed extensions of SSCM, there is a considerable need for research that would make comprehensive application possible in practice. The most important point here is the actual transferability of strong sustainability-guided supply chain concepts, for example, to come to the pilot-proof application of long-term viable innovative solutions within individual (logistics) companies but also with respect to exemplary supply chains or including selected interrelationships with the economic system as a whole. Specific but interrelated research perspectives concern individual fragments of a holistic strategy:

1. *Supply chain transparency* is a fundamental condition of information logistics to facilitate the targeted transformation processes of supply chain. Decentralized data and information systems, such as block chain, can provide interesting approaches here, especially in terms of the “democratization” of economic data and the broader diffusion of innovation processes.
2. *Supply chain integrity* will be a key performance indicator area of modern supply chain management. It will reflect on the preferences of a growing number of responsible consumers. This is based on transparency but also on a further intermediate step: the truth of the costs, meant as the internalization of critical capital into the price formation

mechanisms of the products, including the associated services in and of the supply chain.

3. Ultimately, a comprehensive *supply chain governance* needs to expand scopes and tools of SSCM. This would include shared responsibility with a focus on the internalization of critical capital or distributive equity.

Subsequent to the questions of conceptual extensions of SSCM as the facilitator of central transformations of the green economy and the aforementioned transition areas between strategic management and operational management, open questions concern the finding of complex algorithms as a basis for the programming of suitable information and software technology. On this basis, digitization can be essential for transformation into the green economy. However, specific links of digital SCM and SSCM must be identified and articulated in integrated concepts. Actually, the logistics industry already shows fundamental levers at this point due to the strong orientation of the SCM and much progress in IT implementation, which make systemically oriented approaches seem applicable. SCM orientation could also help in the establishment and application of appropriate criteria, indication, and accounting procedures of strong sustainability in the practice. This results in comprehensive fields of action for cross-sectoral research collaborations between scientific, economic, and social actors using common suitable methodological transdisciplinary toolkits. At this point, the first promising trials of strong sustainability are helpful in strengthening transfers to other areas of innovation. For example, Roseland and Fontaine (2017) and Bird (2015) have developed a methodology for applying and measuring strong sustainability in community development (Community Capital Tool, CCT). Interesting features emphasize a taxonomy of system states: the tool breaks down all capital into smaller stocks, defines requirements that are measured by indicators, and considers thresholds. Here a complementary aspect may be the application of target modelling languages. Building on definitions of strong sustainability models, catalogues of criteria of strong sustainability could be converted into an integrated target model, specifying objectives. This target model, which would include target criteria and prioritizations, could be extended to other aspects such as key figures, responsible organizational units, and exemplary reference processes. Target criteria provide measurability and comparability of supply chain services. A continuous improvement process could thus be effectively supported. Overall, clear dependencies on successful transformation processes of supply chains exist with regard to superordinate societal and legal framework conditions. Here, too, the necessary complementary regulations have not yet been found in the sense of a holistic, strong understanding of sustainability. A “truth of costs” can only be achieved at this point, since new price formation initiatives need legislation-compliant frameworks. Once set, however, they should be able to boost sustainability transformations extremely. Building on these necessary framework conditions, new business models can emerge in a future green economy. Many of them will involve recourses to logistics skills. If the network structures of the extended supply chain “learn” to operationalize sustainability, very innovative business models for logistics emerge based on the elements of strong sustainability strategies. The service model of the Sixth Party Logistics Service Providers/Lead Sustainability Service Providers (6PL) could be a crucial milestone to the success of structures and services in the future economy.

2.4 Urban-Industrial Supply Systems: From Global Challenges to Strong Urban Sustainability (Krumme, 2020)

The following chapter is a book chapter by the author of this dissertation published in the peer-reviewed *Cambridge University Press Volume "Sustainability Assessment of Urban Systems"*, edited by Claudia R. Binder, Romano Wyss and Emanuele Massaro 2020 (all École Polytechnique Fédérale de Lausanne, EPFL). Any reference to this chapter should be cited as:

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Abstract

Global un-sustainability is shaped by a form of urbanisation that has created urban systems with disproportionate natural-resource consumption. This results in severe damage to the global ecosphere. The causal mechanisms of this relationship can be related to Castells' idea of the 'dominance of the space of flows' or expressed in terms of World City Networks.

Critical to sustainable transformation are material-resource and energy-network flows, understood as telecoupling between urban sinks and planetary sources. So far, there is no interpretation of this nested global urban-industrial network and its correlated impacts that builds links to a sustainability transformation strategy.

Concepts such as global commodity chains (GCC) offer valuable impetus, as they address research on material and product flows in globalised urban-industrial finance, information, and service networks.

However, to achieve levels of sustainability transformation, a perspective that goes beyond an analytical and descriptive lens is necessary regarding the design of sustainable supply chains. Moreover, qualitative extensions of Sustainable Supply Chain Management (SSCM) in the understanding of ecological economics provide possibilities for solutions.

In order to pave the way for this further, this article provides an outline of a multi-domain framework for sustainable urban-industrial supply systems based on strong sustainability and nested systems organisation theory.

Keywords

Global and Urban Sustainability, Telecoupling, Space of Flows, Supply Chain Management, Sustainable Urban-Industrial Supply Systems, Multi-Domain Framework

2.4.1 The Urban System and Global (Un)Sustainability

In the twenty-first century, global urbanization has taken human progress into unknown, but most of all simultaneously risky and challenging, territories. Urbanization is not just an infrastructural process that changes patterns in the agglomeration of materials and people worldwide; it also represents increasingly ubiquitous urbanized network economies, societies, and lifestyles (Castells, 2002; Hashemianet al., 2017; Sassen, 2002; Taylor and Derudder, 2015). In this way, urbanization shapes the land use and structural appearance of super-artificial city systems and transforms natural ecosystems, interwoven with network flows of material resources, people, energy, and data in the changed source-sink relationships of globalized urban systems (Bai, 2007; Grimm et al., 2008; Rees, 1992).

The aim of this chapter is to develop a better understanding of the interrelationship between global sustainability and urban sustainability by (1) putting urban sustainability first in relation to globalised urban network organisation. The predominant interpretive approach of considering global urban systems against the backdrop of material, energy, financial, and information flows is used (2) to emphasise a focus on networked urban supply systems. To bring about a needed transformation, new concepts are developed, grounded in supply chain management (SCM) and extended by incorporating ideas of strong sustainability (Ekins et al., 2003; Neumayer, 2003; Pelenc and Ballet, 2015).

2.4.1.1 The Duality of Urban Power and the Root Causes of Global Un-Sustainability

Urbanisation is linked with existential global processes of change in two central interrelated ways, which have significantly shaped both the planet and human society, as parts of a global social-ecological system, in the recent past, continue to do so in the present, and will persist into the future as two sides of the same coin:

1. *Cities are nuclei of global societal and demographic developments and of the globalised network economy as both business powerhouses and markets* (Friedmann, 1986; Sassen, 1991; Taylor, 1995; Sassen, 2015).

The dominant global position of modern cities is in a way summarised by the term ‘global cities’ (Sassen, 1991). The hereby indicated shift in the global economy and in global society towards a number of urban power hotspots in complex urban networks has opened a scientific discussion about how to generally analyse and describe the role of the world’s urban centres in the patterns and trends of globalisation (King, 2009).

Cities are key for the ‘*widening, deepening and speeding up of worldwide interconnectedness in all aspects of social life’* (Held et al., 2000). They enable corporate developments for transnational activities through infrastructure and expertise and by representing the major communication and supply network nodes. Thus, they are global hubs of incoming or outgoing activities and resulting innovation in business and society that control the overall developments of a ‘global village’ (Sassen, 2010; Taylor and Csomós, 2012). Dominance structures, functional hierarchies and nested organisational frames within emerging sets of cities and of connections between cities are underpinning this global impact and are determining a globalised pattern of economic relationships, social interdependencies as well as a still emerging cultural development of global urbanism. These contexts have been subjects to what has been described as *‘World City Networks’* (WCN) (Taylor, 1997, 2004; Taylor and Derudder, 2015).

The context of cities in networks of exchange described here has long been the subject of Urban Theory. Weber (1921) already saw the exchange of goods as a distinguishing feature of cities over other forms of settlement. Ullmann (1953) considered the connections between settlement areas to be just as important as the characteristics of the areas themselves. In times when society and economics are part of globalised networks, Ullman's argument has rather yielded to the ‘*Dominance of the Space of Places by the Space of Flows*’ (Castells, 2002) and has further fuelled the interplay between places and flows. Amin and Thrift (2002) finally replace the idea of the city as a territorial economic power spot with a definition of cities as places that are of and within spatially extended socioeconomic relations.

2. *Urbanisation and the emerging global urban system is closely linked to the fundamental drivers of the unsustainable forces threatening the planet’s ecological capacity and integrity* (Rees, 1992; Keivani, 2010; Ahern, 2011; Seto et al., 2014, 2017).

With the increase of population, wealth production, and primary energy and material consumption concentrated in urban systems and directing most world resource stocks to urban areas, cities are the largest cause of global ecological impacts (Wackernagel et al., 2006; Bai, 2007; Cajot et al., 2015). While currently representing about 3 percent of the earth’s surface, urban areas are home to slightly more than 50 percent of the earth’s population but consume approximately 75 percent of natural resources and almost 80 percent of the global greenhouse gas (GHG) emissions come from urban emitters (Girardet, 2000; Marchal et al., 2011; Seto et al., 2014; Worldwatch Institute, 2016). The global overshoot is already causing acute or predictable scarcity of resources at regional or global scale, and is overstretching ecological capacities, e.g., by destabilising the global climate (Hoekstra and Wiedmann, 2014; Steffen et al., 2015). The impact of cities, measured as urban ecological footprints (Rees, 1992; Rees and Wackernagel, 1996; Wackernagel et al., 2006), is not just a result of cities' status as consumptive territories or 'places', but an outcome of a 'machinery' of worldwide economic value-creation patterns driven by cities in terms of modern product lifecycles/energy-supply systems and their correlated material flows and services (from resource extraction, design and production, and supply chains, to consumption and use).

Despite the progress made so far in technology for resource efficiency and substitution of harmful materials, the absolute global amount of resource consumption is still increasing; a decoupling from economic growth is not in sight and material efficiency has recently declined due to shifts in international economic production patterns (Wiedmann et al., 2015; Schandl et al., 2018).

The effects of climate change on production and supply capacities, and further increases in demand due to urbanisation, will only increase this problem nexus, since the proportion of urban dwellers in the world population is expected to be around 70 percent in 2050 (United Nations, 2017).

2.4.1.2 The Urban Turnaround: Towards Sustainable Urban Systems

As much as cities are currently a major force for un-sustainability, it is obvious that cities could equally be key to sustainability (Bugliarello, 2006; Rees and Wackernagel, 2008). Concepts to achieve urban sustainability have to be capable of reversing the contradictory relationship between urbanisation and global sustainability, going beyond concepts of mitigation and adaptation, which, in the narrower focus on fighting climate change, have only been considered as a crucial but not sufficient aspect of sustainable urban development.

True sustainable urban development should be capable of integrating various fields of development at higher levels of understanding and with a view to identifying and executing comprehensive solutions. Thus, central to urban sustainability is a view of the city/cities as nested systems by exploring the root causes, feedbacks, and emergence of urban as well as global un-sustainability in their connectedness and in a comprehensive way.

There are still knowledge gaps and a necessity for new research priorities that need to be tackled before it is possible to view cities in this way (Seto et al., 2017). The need for more comprehensive concepts of the city has been articulated from different disciplinary perspectives. From the viewpoint of urban sociology and urban social theory, the demand for conceptually embedding cities in the context of ecosystems, as social systems and beyond their physical presence, has been reinforced by Harvey (1996). From a background of Environmental Geography and environmental studies, Seto et al. (2013) argue that a functioning planetary ecosystem needs a focus on urban systems; conversely, urban sustainability cannot succeed without a deep understanding of the ecological foundations of urban developments.

The resulting system to be transformed is complex because it involves multiple scales, dimensions, and transformation domains. On the one hand, the direct spatial scale of the city is affected. At this point, we know quite a lot about the emergence of so-called un-biological scaling behaviour of cities and metropolitan regions due to internal network effects, which may partly explain, among other things, the disproportionate resource consumption of cities in relation to urban growth curves (Bettencourt and West, 2010). On the other hand, in socioeconomic terms, there are obvious network connections and interdependencies with respect to the bioregional hinterland in order to grasp system relationships of production and consumption in a more sustainable way (Jacobs, 1984; Newman, 1999, 2006; Newman and Jennings, 2008; Torreggiani et al., 2012; Zasada, 2013). This includes new relationships between local and regional/urban and rural producers, traders, and consumers on different regional scales.

To invert the un-biological scaling behaviour of cities and metropolitan regions, Sassen and Dotan (2011) promote a mutual coping of the multiscale ecological interconnectedness of cities with the biosphere. To establish sustainable cycles between cities and the biosphere, ‘third nature’ capacities (mergences of boosted interplays between city and natural ecosystem functions), supported by ground-breaking technological and social innovations, will enable a productive interplay and a shift in the mode of consumption and production. This theoretical approach connects the urban socioeconomic system to ideas that are widely accepted in ecological economics (EE) (Costanza et al., 1992, Costanza and Patten, 1995) and puts technological innovation into dynamic relationships to social-ecological systems (SES) (Ostrom, 2009), as in the recent conceptualisations of social-ecological-technological systems (SETS) fur urban sustainability (Krumme, 2016; McPhearson et al., 2016; Grimm et al., 2017).

However, still the majority of existing approaches either remain city-centred or relate the city to the direct functional spatial environment, e.g., of the region. Multiple levels of globalised functional interaction, as demonstrated by WCN research, are largely not included. Given the level of global interconnectedness of production, supply, and consumption patterns with respect to urbanisation, it seems that planetary teleconnections and resulting macroscale dynamics of cities are still under-recognised in the implementation of urban stewardship frameworks for planetary resources and ecosystemic relationships (Seitzinger et al., 2012; Seto et al., 2012; Liu et al., 2013). As Seto et al. (2017) point out: '(…) *given the magnitude of current urban transitions and the global reach of their production-consumption systems, there is a need to generate robust scientific knowledge on cross-scale interactions, tipping points, thresholds, and limits that are set off by urbanisation to orient urban development towards more sustainable trajectories*.' Moser and Hart (2015) conceptualize eight categories of socioeconomic teleconnections in relation to global climate change without, however, emphasizing the magnitude of the global urban system. Liu et al. (2013) refer to teleconnections rather as physical interactions of natural (and already modified) systems and by definition separate globalization as the interaction of socioeconomic systems. Finally, they understand 'telecoupling' as a framework that combines the dynamics of both, as SES of not primarily territorial, but globally functional networked interactions via flows, agents, causes and effects.

To take up again the basic idea of this chapter – Castells's notion of the dominance of flows over places –, it is this globalised 'space of flows', that determines the global urban ecological footprint through the nature of urban demand, supply needs, and practices, which has to be changed drastically (Wackernagel et al., 2006; Grimm et al., 2008; McHale et al., 2015; Moore, 2015). The required system integration for multilayered sustainability strategies (Liu et al., 2015) would rely on the power of cities to operationalise ecosystems, their services, (industrial) production, supply, consumption, and lifestyles both integratively and sustainably. Such an approach would affect both of the strategic integration levels identified by Liu et al. (2015): the interaction of (a) human-nature-nexuses and the integration of (b) telecoupling, understood as teleconnected socioeconomic and environmental interactions.

Figure 2.13 below demonstrates scales of urban sustainability concepts from city-centred, via bioregional up to telecoupling-based (global) strategies.

However, the operationalisable system knowledge for this is missing in Sustainability Science and sustainability practice (Seto et al., 2017). Nevertheless, there are well elaborated, but still theoretically and practicably disintegrated, approaches that can merge in a synergistic way to give alternative solutions. Those building blocks of a new concept are the subject of the next paragraph.

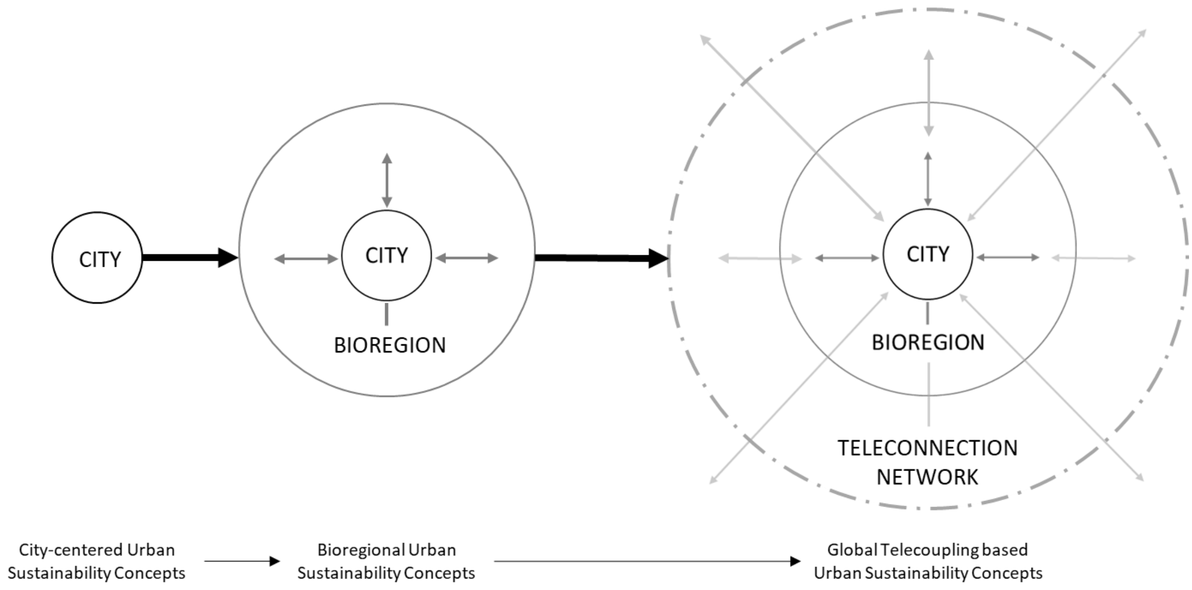

Figure 2.13: Scales of Urban Sustainability: City-centred, Bioregional, Telecouplings

2.4.2 Sustainable Urban-Industrial Supply Systems

2.4.2.1 Conceptual Foundations: Challenges and Building Blocks

Based on the paradigm shift described by Castells (2002) as the 'space of flows' and the causal relationship between these flows and the exceeding of the thresholds of planetary boundaries, WCN-compatible concepts are available, although they are primarily descriptive-analytically oriented and lack a stronger transformative sustainability-oriented component. It can hardly be doubted that the findings regarding the nested systems organisation of global urban systems are not only relevant to the understanding of global un-sustainability (as explained above), but also provide several starting points for an inverted transformative theory. The aim must be to find the 'safe operating space' for cities based on the planetary boundaries framework (Steffen et al., 2015) and to promote perspectives for sustainable development by means of modified qualities, quantities, and constellations of supply and demand in the global urban system.

As Friedmann (1986) postulates in his world city hypothesis *'the form and extent of a city's integration with the world economy and the functions assigned to the city in the new spatial division of labour will be decisive for any structural changes occurring within it'*. Following this, alternative constellations in the hierarchical functional order of urban systems would not have to reverse the globalisation of cities in their networks, but would promote new orientations, especially for critical resource, information and energy flows, that respect ecological capacities, as well as find opportunities within newly balanced multi-scale nested hierarchies of urban systems.

Although also not sustainability-oriented, an interesting concept that could be used originates from Economic Geography: the global commodity chain (GCC) framework (Gereffi and Korzeniewicz, 1994) is used to understand interrelated functions, operations, and transactions that produce, distribute, and globally consume commodities. Like WCN, GCC emerged as a 'global network alternative' to city-centred or national small-scale analysis in urban and Economic Geography (Derudder and Witlox, 2010). In terms of a 'world-system analysis', GCC analysis (as well as its derivatives, Global Value Chains (GVC) and Global Production Networks (GPN)) relates economic urban network centres to their role as financial, information, and trade nodes. It becomes clear that the upward trend of cities worldwide is a downstream result of urban functions in these networks (Derudder and Witlox, 2010; Hesse, 2010). This, however, only indirectly addresses domains of urban policy. Rather, the decisive domains of design and action lie with companies or the emergence of their interactions in value chains (Yeung, 1994).

To ascertain the root causes of global un-sustainability we fundamentally identify that the urban pressures on the planet, discussed above, are strongly associated with industrial – corporate-driven – value creation as a functional urban-industrial amalgamation (Liu et al., 2015; McHale et al., 2015; Krumme, 2016). Globalised industrial value and supply chains are caused by a largely urban demand system, which requires structures and services for bridging global teleconnections and actually built up the 'nervous system' of the urbanisation progress.

While the GCC framework provides models for describing and understanding the space of flows and the specific dominance effects of globalisation and urbanisation, it still does not adequately exploit the role of modern operations-design services in their value-added relationships (Coe et al., 2008). The role of modern supply chain management (SCM) and logistics services in particular have been underrepresented as a conditional performance factor (Hesse and Rodrigue, 2006).

2.4.2.2 Taking a Supply Chain View on Urban Sustainability

In addition to the need for innovation in order to develop the functional capacities for the interaction between cities and the nested organisations of the biosphere, developed by Sassen and Dotan (2011), further approaches are needed. Sassen and Dotan contextualise shifted cycles of production and consumption, among other things, in ecological economics. This combinatorial strategy is helpful but needs to be extended with other essential elements. These elements refer in particular to the fact that in the modern economic system, the interaction of production and consumption alone is not sufficient to fully explain the resulting demand for resources (Melkonyan and Krumme, 2019).

Rather, the emergent system effect is co-generated by the nature of the structures and services of the intermediate 'translating' supply chain system (O'Rourke, 2014; Krumme, 2019). A good example of this is the digitalised interaction of buying and trading and of such marked product lifecycles. The growth of E-commerce, with all its implications and partly unsustainable new consumption trends, is made possible only through the power of (digital) supply chain structures and services (flexible 'on demand' services, fast home delivery, supply chain tracing, returns, etc.).

The connections between and operationalisations of urban-industrial value-added functions, on different scale levels, are therefore represented by industrial supply chains, which represent a variety of services connected with a flow of goods that connect industrial sources with mostly urban demand and consumption systems. It does not matter if industrial sources and production sectors are urban or rural. They are planned and operationalised not by cities but by companies worldwide in order to operate and develop supply systems based on mainly urban demand systems. This generates 'on the ground' feedbacks in the sense of global un-sustainability, as the operationalised levels of value creation, transportation, storage, transshipment, information flow, and energy flow are linked to enormous emissions and resource consumption. The supply chain is a major trigger for the energy consumption and ecological footprints (water, carbon) that accompany the product (Hoekstra and Wiedmann, 2014; Hoekstra, 2015). Product life cycles are thus underpinned by services and structures that to a large extent become anchored in spatial forms in cities and metropolitan areas.

Alternative circulations of products, energy, materials, information, and cash flows can only be realised through the services and structures of supply chains (O'Rourke, 2014; Krumme, 2019). Given the global space of flows and the role of urbanisation in overstating and controlling production and consumption patterns, alternatives constellations must be integrated into supply services and structures (i.e., supply chains) and be considered in reference to urban-industrial source-sink relationships.

However, on the demand side, especially for cities, this requires sustainable reversal in the commercial and consumer systems, deeply rooted in the sphere of lifestyle transformations (Melkonyan and Krumme, 2019). Changing lifestyles necessitates a significant qualitative behavioural shift and places the collective societal interest alongside individual needs (Jackson, 2005; Lorek and Spangenberg, 2014; Moore, 2015). Extensive recent research shows a strong interaction between lifestyles and supply chain (including logistics) services with respect to unsustainable effect and also potential sustainability gains (Melkonyan and

Krumme, 2019). Further conceptual progress makes it necessary to take a closer look at sustainable supply chain strategies.

2.4.2.3 Sustainable Supply Chains Revisited

Supply chains connect sources and sinks. When it comes to the role of urban systems in the global displacement of source-sink structures, as discussed above, a supply chain strategy must provide the necessary coordinates for sustainable urban-industrial supply systems.

Generally, the concept of the supply chain describes complex structures and processes of contracting companies/customers as a network of suppliers: manufacturing plants, retailers, supporting companies involved in various design, procurement, storing, shipping, selling, or servicing processes (Sheffi and Rice, 2005). Defined in this way, supply chains basically consist of physical elements – i.e., infrastructures, production facilities, distribution facilities, etc. – and integrated management, services, and flows of information, finance, and energy (Figure 2.14). Very generally, supply chain management (SCM) describes integrated, coordinated, and cooperative activities of design, planning, execution, control, and monitoring along supply chain structures and flows with the objective of effectively synchronising demand and supply (Cooper et al., 1997).

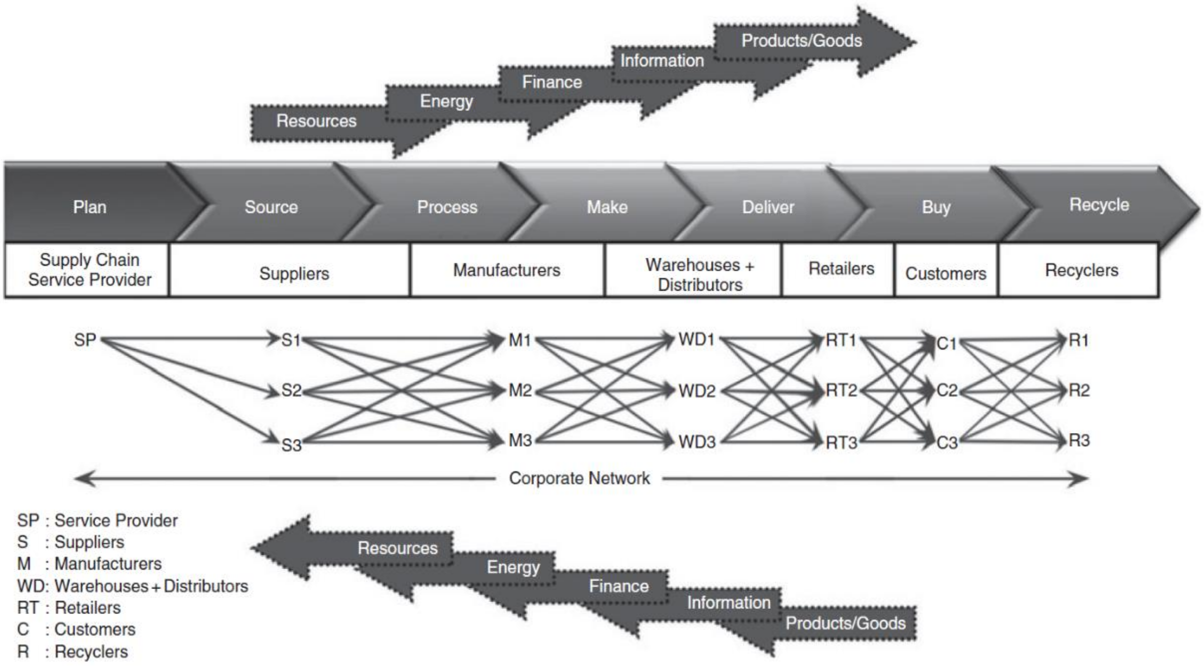

Figure 2.14: Structural elements, operational networks, and flows of a supply chain, including information, energy, and finance (Source: Krumme, 2019)

In the context of this chapter, supply chain businesses integrate strongly urbanised global patterns and contextualise the supply chain as a mediator between the (consumptive) city and its markets and retailing system as terrains within the dispersed worldwide pattern of production and product-service distribution.

Principally, there are manifold potential starting points for sustainability in SCM. By definition, modern SCM integrates flows of goods, information, energy, personnel, and financial value into economic and social systems. With respect to the challenge of sustainability, the paradigms of SCM have been expanded to develop sustainable SCM (SSCM) (Carter and Rogers, 2008; Seuring and Müller, 2008). Central performance indicators to be addressed by effective SSCM are those that display and modify ‘co-flows’ of resources (e.g., water, energy, carbon, or further ecosystem-dependent assets) that support sustainable economic value creation (Linton et al., 2007; Krumme 2019). Notwithstanding, the ‘proactive’ role of transformative supply chains in bringing about changes in the overall socioeconomic system – for example, based on concepts from GCCs – has so far been under-examined (Krumme & Melkonyan, 2019).

In this respect, Krumme (2019) as analysed some shortcomings of state-of-the-art SSCM, which are believed to be primarily due to SSCM being founded on ‘weak sustainability’. He proposes strategical improvements based on strong sustainability, particularly the integration of *principles of nested systems organisation* as well as conceptual bonds from ecological economics: (1) the assessment of *critical capital*, (2) the *distributive equity* of capitals within and along the entire supply chain, and (3) the *shared responsibility* of supply chain stakeholders. He also advocates an advanced definition of SSCM that takes account of externalised environmental and social costs in order to balance the service-level requirements of individual customers with societal interests. This results in advanced business and service archetypes at different levels of supply chain planning, management, and controlling as *‘Lead Sustainability Service Providers’* (Gruchmann et al., 2018; Krumme and Melkonyan, 2019).

The above explanation is relevant in the context of this chapter, since in this way, SSCM would represent the missing link between the network nodes of GCC and the needed transformative sustainability orientation. Since a reduction of the urban ecological footprint depends ultimately on the altered qualities, quantities, and constellations of resource consumption in the form of imported material and energy, and on the quality and quantity of correlated outflows (including all waste deposits), SSCM is needed to implement modified compositions as well as changed spatial and temporal patterns of product-service lifecycles and respective material-resource and energy flows. Moreover, SSCM is capable of communicating between strategical levels of governance in value-creating networks to downscale operations and decision-making. It can be shown that any form of sustainable change in modes of production – e.g., the modularisation of products and product components – in the fundamental structural and temporal extension of product lifecycles, and in effective circularity depends on their implementation by supply chain services (Krumme and Melkonyan, 2019).

2.4.2.4 Taking an Ecological Economics View of Urban-Industrial Supply

Against the understanding of worldwide dispersed network flows of resources, energy, and data, certain capacities would have to be incorporated conceptually, namely those that are not typical industrial capacities but also act as 'sources for the sources' in the form of ecosystem goods and services (ESGS). According to ecological economics (EE), industrial production would be seen as the consumption of natural capital (Costanza et al., 1992; Wiedmann et al., 2006).

The importance of EE for urban sustainability, as a counterpoint to neoclassical socioeconomic theories, has already been indicated by Sassen (2009, 2010a, 2010b). EE is based on the essential idea that the evolution and survival of complex systems is critically connected to nested systems hierarchies (Costanza et al., 1993). Following this, Costanza and Patten (1995) argue that a nested hierarchical organisation of systems must be considered in sustainable development in order to avoid failures, costs, and further risks.

EE recognises the overall design of desirable sustainable systems as a nested organisation of distinct capitals, understood as stocks and flows (natural, human, social, financial, technological/manufactured capital), where natural capital plays an ultimate role as the conditioning and limiting factor for other capital forms. As the basis of the central paradigm of 'strong sustainability', natural capital is therefore classified as 'critical capital' for sustainable development and not substitutable through other capital forms (e.g., technology) (Daly, 1997). This contrasts sharply with the 'weak sustainability' models, which are much more popular and in principle assume equivalence (and hence substitutability) between less differentiated categories of sustainability (as social, ecological, and economic).

However, aspects of strong sustainability offer high conceptual compatibility with the terms of SSCM (Krumme, 2019). Beside the notion of critical capitals, this is based on the sub-concepts of the *shared* and (to all) *transparent responsibility* in and along value chains and of the *distributive equity* of capitals among the value chain's share- and stakeholders (Kestemont, 2015; Krumme, 2019).

2.4.3 Strong Sustainability Frameworks of Urban-Industrial Supply

2.4.3.1 Metabolism Models and Sustainable Urban-Industrial Supply

Principally, source-sink-relations of demand and supply have been central to the urban metabolism (UM) of the 'Ecology of Cities' (Pickett et al., 1997) since the 1970s. UM describes holistic budgets that can help visualise the flow of material resources and energy and rearrange in- and outflows and circulations (Newman, 1999; Chrysoulakis et al., 2013; Kalmykova et al., 2015; Thomson and Newman, 2018). UM can serve as a modelling tool to make cities more resource- and energy-efficient, to provide indicators for alternative urban design, to introduce information and control levels, and to strengthen the physical and technological aspects of the city as a circular resource system (Thomson and Newman, 2018). Although metabolic references of the UM may be fundamental to sustainable cities, the limits of the concept have so far lain in its fundamentally spatial foundation. The UM is essentially unable to integrate teleconnections and globalised supply chains into the global sustainability impact of the urban demand system.

In terms of visualisation, control, and modification, as well as a consistent idea of establishing dynamic flow, UM shows many intersections with the concept of the supply chain. One could say that UM is a clear concept that, initially, seems very clear within named system boundaries, while the supply chain is primarily defined functionally against the background of planning, management, and controlling tasks. Of course, every supply chain is reflected spatially. Within this section of the chapter, a conceptual fusion of both approaches is shown.

The 'Urban-industrial Nexus' (Krumme, 2016) represents a conceptual shift from a structural/ spatial approach towards a functional redrawing of system boundaries to reveal the inseparability of the 'urban' and the 'industrial' spheres as the two planetary drivers for (un)sustainability. Krumme (2016) presented an EE-based metabolism model of 'urban-industrial supply and demand systems' (Figure 2.15). A recent refinement integrates supply chain thinking and illustrates sustainability gains through transformative SSCM (Figure 2.16) (Krumme, 2019).

In accordance to the 'full world' economy models of EE (Daly, 1973; Daly, 2005), the general concept (Figure 2.15 below) considers natural capital as a limited system environment in which the structures, processes, and functionalities of the economy are embedded, determined to a large extent by 'laws' of Physics (hermodynamics) and Ecology in particular. The economic system, expressed here in terms of the urban-industrial nexus, is seen as a sub-system as part of a nested organisation within planetary boundaries (critical natural capital), but puts pressure on the functioning of the surrounding system through economic activity resulting in economic growth. Thus, the ties between industrial production, supply, and (urban) consumption systems can be interpreted as the expenditure of natural capital. Beside the typology of the sinks as ‘urban’, a source-based view then incorporates those capacities which are the ‘sources of the sources’, linked as *eco-industrial sources*. The expansion of the urban-industrial, economic sub-system is driven by demand and supply between source and sink. The environmental impact is determined by supply and demand, combined with the turnover of resources, the effects on the eco-industrial source (in terms of conversion of natural capital into human or industrial capital), and all kind of wastes/emissions from the urban sink, including non-recyclable deposits of degraded resources.

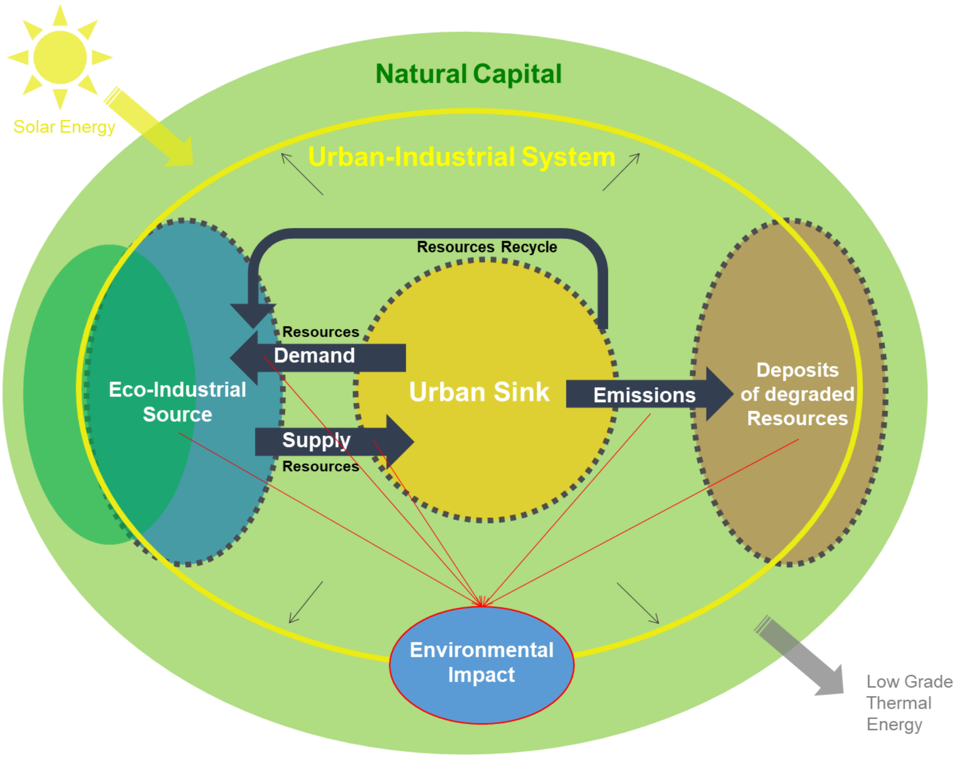

Figure 2.15: Advanced Urban-Industrial Metabolism Model (Source: Krumme, 2016)

On this basis, future sustainability functions can be captured by SSCM (Figure 2.16 below). Once the relationship between the eco-industrial source and the urban sink is further qualified by a supply chain, the relationship can be embedded into a more comprehensive *Sustainable Supply Systems Model (SUSY) (Figure 2.16)*. A supply chain perspective is linked conceptually to the EE and UM framework and the main drivers of (un)sustainability. The scope of the supply chain is contextualised with the ultimate meaning of ecosystem goods and services as a direct form of how critical natural capital becomes ‘valuable’ in the economic system.

Principles of strong sustainability, particularly with respect to critical capital, shared responsibility, and distributive equity, are implemented at all stages of the supply chain: *S* (sourcing of materials), *P* (production and manufacturing), *D* (distribution, storage, transshipments), *R* (retailing), and *B* (buying). Direct further effects on sustainability are addressed by non-classical elements of SSCM in the (urban) after-sales area. This is related to sustainable forms of consumption and people's lifestyles, as well as indirectly to the re-designing of product lifecycles and associated supply chain services. Within the urban system, at least three different forms of consumption and use are shown: *U1* (primary consumption), *U2* (further circulation of used products; sharing economy), and *U3* (product modification or modularisation including upcycling into other forms of use; extended circular economy). *U2* and *U3* take advantage of the high degree of network density and interdependence (physical/ social infrastructure as well as high variability of available product-service systems) to effectively extend product lifecycles (Krumme and Melkonyan, 2019). *C* describes the conventional recycling of materials (simple circular economy) after the previous stages have been fully implemented. Closed loops in relation to the eco-industrial source (e.g., via re-manufacturing or refurbishment) are linked to all segments in the after-sales area. This also applies to deposits, whose integration into the closed loop has to be intensified, or their emission must be avoided by upstream 'precaution' qualities of the supply chain.

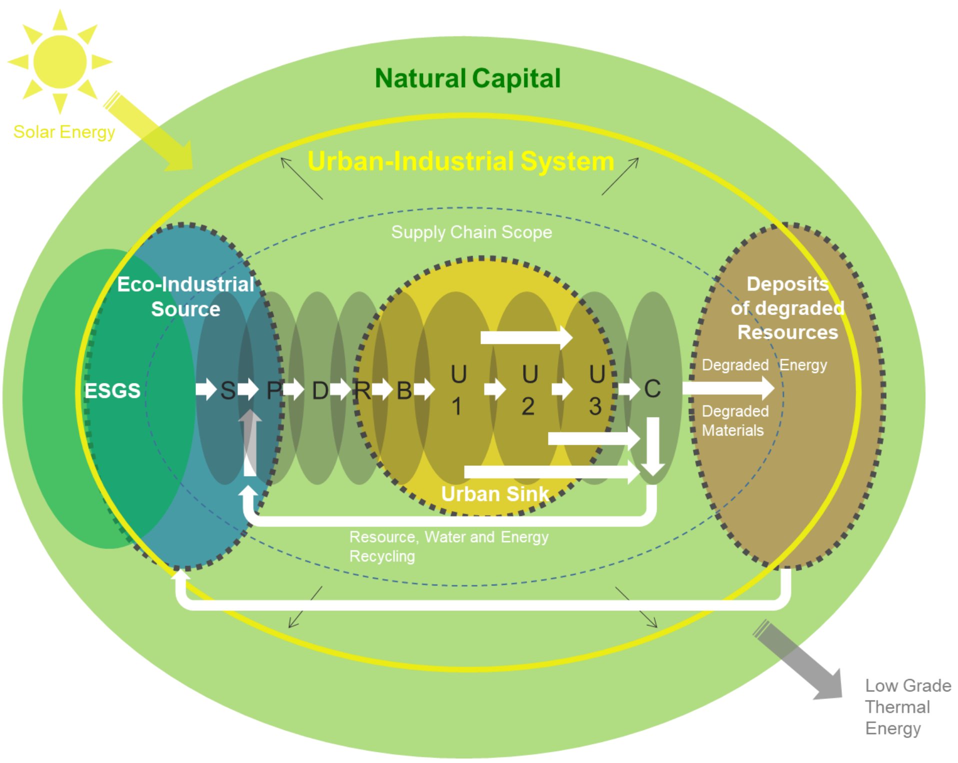

Figure 2.16: SUSY (Sustainable Supply Systems) based on the Urban-Industrial Metabolism (Source: Krumme, 2019)

It becomes obvious that realising such a transformative supply chain would involve innovated logistics skills as part of the business and service portfolios of a green (urban) economy. The service model of the 'Lead Sustainability Service Provider' (Gruchmann et al., 2018; Krumme and Melkonyan, 2019) represents a recently published framework for innovation that can support the needed transformations on the operational service level.

In its development, this business and service model is based on the evolution of system-oriented, knowledge-intensive archetypes of logistics and supply chain services, which are characterised by comprehensive digitisation of the supply chain and its corresponding systems (e.g. internet of things, internet of services in 'Industry 4.0', or newer 'smart city' concepts) (Krumme and Melkonyan, 2019). The Lead Sustainability Service does not focus on urban metabolism, but rather on necessarily sustainable supply chains, which, as explained, are characterized by urban-industrial systems on different scale levels. The Lead Sustainability Service Provider is capable of integrating different scales for operating such supply chains and refers to the need for telecoupling (e.g., between eco-industrial sources and urban sinks), as well as for innovation in the (often structurally urban) last or first mile of the supply chain.

2.4.3.2 Multi-Domain Framework of Sustainable Urban-Industrial Supply

The above has made clear that the inversion of the contradictory relationship between urbanisation, a globalised urban system, and global sustainability is a multi-layered problem. To create solutions, state-of-the-art concepts must be linked to new approaches in a nested system context. The paradigm shifts towards a focus on the global space of flows, such as those represented by WCN or GCC, raise the question – beside the already existing problem of the multiple and overlapping dimensions to be tackled – of what kind of transformation mechanism can take account of the interdependence of modern urban systems and global teleconnections (Liu et al., 2015, Seto et al., 2017). A first sketch of a framework therefore has to represent and connect the concrete levels of action domains and strategic tasks. It is important to understand that, based on the nested systems organisation theory, tasks and domains do not operate discretely on different scales. Rather, the levels of domains and tasks integrate different scales to achieve emergent network effects.

To perceive problems correctly in their comprehensiveness and to cope with complexity, systems thinking is a possible basis (Bossel, 2007; Meadows and Wright, 2008). In a systems-thinking approach the entities being investigated and their environment are seen as (sub)systems in relationships with other systems, placed at higher organisational levels. The features of this 'system of systems' can be detected in its sub-systems and it is described using the principles of nested systems hierarchies or nested systems organisation (Mesarovic et al., 1970; Findeisen et al., 1980; Bossel, 2007). All the interconnected systems, then understood as sub-systems within a greater complex system, are part and parcel of a dynamic environment.

Thus, our perception should turn towards principles of organisation with regard to analyses and transformation as the vital correlated parts of Sustainability Science (Wiek et al., 2012). The focus should not be primarily on whether specific system factors are included in assessment, planning, and management, but rather on the way in which the comprehensiveness of factors is organised to produce a sustainable (with regard to transformation) or unsustainable (with regard to analysis) interplay and performance.

The multi-domain framework proposed here responds to the complexity of the targeted real-world systems, as well as to the interfaces between the levels of organisation therein. The framework represents different analysis, understanding, and design levels of the nested organisation, which is connected to the urban 'Space of Flows'. Dedicated to a sustainability transformation process, the framework takes up several innovative conceptual elements discussed above (social-ecological-technological systems, urban metabolism, urban-industrial networks, ecological economics, sustainable supply chain management, lead sustainability service provider). The goal is to outline action domains and strategy task levels for a comprehensive approach to increasing the sustainability of urban systems through a multi-domain analytical lens and a transformational governance structure. This chapter offers a first orientation in this regard. Detailed future conceptual work and research are needed in order to expand this approach with further details.

To explain the multi-level framework for sustainable urban-industrial supply systems outlined for the first time here, action domains, strategic tasks, the macroscale, and the microscale are connected on seven (0 to 6) levels (Figure 2.17):

1. First of all, all real problem constellations exist across scales and are extremely complex (level 0). Levels 1 to 6 serve to break these down into actionable and necessarily coherent action and transformation levels.
2. Level 1 deals with the qualitative differentiation of system constitution and system boundaries in order to be able to recognise general system effects (the strategic task). The associated action domain, which is a tool in itself, contains frameworks such as social-ecological-technological systems (SETS, Krumme, 2016), which can map the impact dimensions and their interaction. The integration of technological-organisational

dimensions is particularly important in relation to urban systems (Krumme, 2016) and this level connects them in the sense of ‘third natures’ (Sassen and Dotan, 2011).

3. Level 2 identifies the interaction between demand and supply in integrated considerations of production, supply, and consumption. It identifies sources and sinks of material and energy flows. The urban metabolism (UM) concept loses its narrow city-related context due to the incorporation of global teleconnections, but henceforth, functionally refers to the global space of flows with respect to WCN and GCC. It thus corresponds to the extended metabolism models presented in this chapter (Figure 2.15 and Figure 2.16).
4. Level 3 deals with the network structures responsible for material, energy, and correlated information flows. In addition to industrial networks, non-industrial networks (for example, at the local or regional level, networks of small-scale and micro-production for local/regional consumption) can be included.
5. Level 4 combines the aforementioned levels of analysis with value-based normative strategies for a desired sustainability transformation. These are influenced, in particular, by using the strong sustainability models of ecological economics to determine a value and reference system (Costanza et al., 1992; Pelenc and Ballet, 2015).
6. Level 5 combines the strategic and operational management of material, energy, and information flows (or cycles) at the level of the expanded understanding of SSCM. In doing so, local, regional, and global chains in the sense of telecoupling (Liu et al., 2015) are all operationalised.
7. Level 6 fills the supply chain structures with services, in the sense of business capabilities of ‘Lead Sustainability Service Providers’. It is important to note that these services work within the framework of the parent levels. Thus, business is not detached, but acts in a broader environment of tasks and stakeholders in order to be ‘transformative’ and sustainable. Since the urbanised interplay of production, supply and demand, and consumerism is implemented through business rather than municipal institutions, the framework offers a different, more realistic focus than the state-of-the-art urban sustainability transformations.

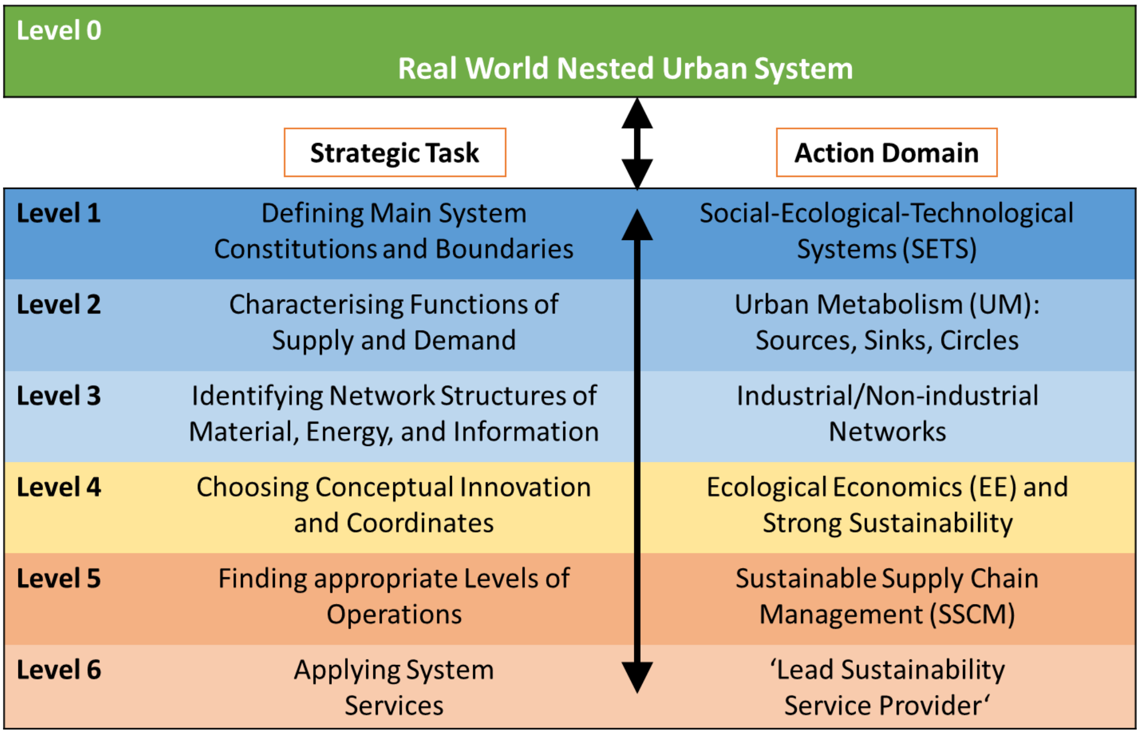

Figure 2.17: Multi-Domain Framework of Sustainable Urban-Industrial Supply Systems

2.4.4 Conclusion and Outlook: New Pathways in Urban Sustainability Science

Previous approaches to urban sustainability research have been predominantly city-centred without regard for complex teleconnections, understood as globalised network structures and flows, which are responsible for the global manifestation of urban un-sustainability. In principle, the established exploration of urban systems as a phenomenon of globalised networks (WCN, GCC), especially through the application of the organisational principle of nested systems, offers interesting starting points for mapping different strata of problem description (analysis) and finding solutions (transformation).

What is needed are frameworks and tools that can describe very precisely the respective network structures and flows in their unsustainable effects. The proposed integration of supply chains as a concept can be particularly powerful here. Conversely, supply chains can also be operationalised for urban sustainability transformations if their conceptual framework and methods are related to established Sustainability Science strategies (Krumme, 2019). One such opportunity is the integration of SSCM with alternatives to neoclassical economics, namely ecological economics.

The multi-domain framework outlined at the end of the chapter relates several domain levels to each other, but it is a preliminary sketch. Research and experimental applications need to be rapidly developed in the face of the urgency of global sustainability issues. Based on the outlined multi-domain framework, it is important to think and act within complex transdisciplinary research and transformation programmes, beyond individual projects. This includes several stakeholder groups in joint knowledge production, bringing together urban public authorities, civil society groups, business, politics, and academia. This would facilitate a more comprehensive view of cities in the context of global change, while integrating societal, economic, and ecological dimensions to generate a complex transformational process.

For academic stakeholders, there are two sides to this coin: to better understand needs and options for sustainable urban solutions through transition research, and to take part in promoting these by exploring new transdisciplinary methodological settings and experimental innovation designs as part of transformative research.

Following this idea there is much reason to ask the *'Mindset of Planning'* question of Castells (1992) again, but contextualised in a new form: *'The world has changed – can planning change?'* As Castells says, '*we are living in the midst of a fundamental process of historical change that is affecting the intellectual and social foundations of planning and its practice. The main elements of this multidimensional change are identified. The chances of the planning field responding to this historical mutation are evaluated and suggestions are offered about possible intellectual orientations.'*

One important issue, however, remains open: in addition to intellectual orientation and the strengthening of transdisciplinary capacities, it is above all urgent to implement alternative system patterns for sustainable multi-level urban development in a concrete way.

3 Empirical Analysis

3.1 Remarks and Synopsis

Chapter 2 delivered theoretical innovations in the overall concept of “Sustainable Urban-Industrial Supply Systems” with a focus on the fundamentals (e.g., resilience orientation), in supply chain management and in the elaboration of the Urban-Industrial Supply System.

This breadth cannot be fully reflected within the frame of the empirical research cases presented here as cumulative contributions. Instead, research focuses on systemic levers of the system connection between natural capital, production, supply chain and consumption are selected and addressed.

Part 3.2 is centred on resilience-oriented research of the adaptation of exemplary food/ agricultural production and supply systems to the impacts of climate change. In doing so, reference is made to key points of supply chain management as levers of change with reference to the consumer. The representation of the dynamic problem relationships via system dynamics (causal loop diagrams, CLDs) are broken down and the participatory approach of integrating the system agents via participatory systems mapping (PSM) is introduced. Parts of the presented work also refer to this earlier conference presentation:

Krumme, K., & Melkonyan, A. (2015, November 9–10). *Fertilizing Solutions on the Water Energy Food Security Nexus from a Sustainable Supply Chain Management Perspective*. BHP Billiton Sustainable Communities/UCL Grand Challenge Symposium Series: Global Food Security: Adaptation, Resilience and Risk, London, United Kingdom.

In 3.3 the role of system services on re-localized and regionalized food production systems in the regions of Linz (Austria) and Freiburg (Germany) is examined to find out which business models, or which elements in them, effectively support local food systems and make them scalable. The role of Supply Chain Coordination SCC (with regard to logistics and financial management) is given special priority. In addition, the importance of business-consumer communication is discussed. Business model CANVAS is introduced as a further participatory system-oriented method (3.3).

The research in 3.4 bases on the determining role of consumers emphasized in the previous contexts. The communicative interplay between retailers, service providers (logistics) in the supply chain and consumer target groups is examined in the context of “Sustainability Communication” via surveys. Certain sustainable logistics innovations are tested in communication scenarios with consumers in order to understand and to make the interaction more effective for sustainability-related solutions. In addition to the stationary food retailers, the fashion sector (in e-commerce) is examined as a second research case.

At least, in 3.5, the interaction of consumers and service providers as a decisive variable in the system context is related to the sustainability performance in the “Urban Last Mile” as an example. Both the scientific-strategic and the methodological basic orientation of Sustainability Science are tested and evaluated as an overall investigation approach. This includes the entire participation-based modeling process of PSM, via CLD in Stock and Flow Diagrams (SFD) and (semi-)quantitative simulation of the service provider-consumer interaction.

3.2 Sustainability Assessment and Climate Change Resilience in Food Production and Supply (Melkonyan, Krumme, Gruchmann, de la Torre, 2017)

The following chapter presents a peer-reviewed article in *Energy Procedia* by the author with Ani Melkonyan (University of Duisburg-Essen), Tim Gruchmann (Westcoast University of Applied Sciences) and Gustavo de la Torre (University of Duisburg-Essen), accepted for publication as a special issue on the 1st International Conference on Sustainable Energy and Resource Use in Food Chains (ICSEF), 19–20 April 2017, Berkshire, UK, published 2017.[16]

The publication refers to the research project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015).

Any reference to this chapter should be cited as:

Melkonyan, A., Krumme, K., Gruchmann, T., & de la Torre, G. (2017). Sustainability Assessment and Climate Change Resilience in Food Production and Supply. *Energy Procedia*, *123*, 131–13.

Abstract

Regional impact scenarios of climate change reveal a high risk of supply deadlocks in food supply chains. Accordingly, there is an urgent demand for "integrated" assessments and solutions considering related effects of resource scarcity, demographic change, and the resulting demand as well as accessibility shifts in the exposed regions on the basis of a systems approach.

Analyzing the structures of supply systems and their fundamental pattern of sources and sinks against the backdrop of climate change resilience makes the consideration of complex interconnected substructures of sourcing, production, distribution and consumption as well as closed loops (the "supply chain") highly necessary. To do so, Sustainable Supply Chain Management (SSCM) can fertilize the assessment of climate change impacts, supply risks and sustainability gaps. It can also guide corrections in operational and industrial action fields leading to proactive counter measures as well as policy improvements.

16 Klaus Krumme, together with Ani Melkonyan, provided the strategic orientation, structure of the paper and the basic interpretation of the research results. He also contributed to the theoretical foundations, the integration into the justification context of the research and wrote parts of the discussion.

To improve food security a conceptual integration beyond the scope of production in the agricultural sector due to examination of critical supply chain system compartments and levels of services ("integrated food production and supply systems") is proposed. Using System Dynamics modeling (SD) opens perspectives for supply chain and value creation alternatives with a higher climate change resilience and climate friendliness as well as operational robustness and efficiency and structural quality. Thereafter, implications can be derived for concrete business and value chain innovations in terms of infrastructure development, technology use, business models, operations, cooperation and service management as well as for transformation of the determining socioeconomic frameworks on upper levels.

For creating systematic results, a platform integrating various perspectives of experts has been established following the principle of triple helix stakeholdership (business practice, public management/ policy and also science). During a series of workshops, the main actors, success factors, challenges and communication strategies have been identified for shaping sustainable food supply chains under use of systems thinking and the application of Participatory Systems mapping (PSM). Three parallel workshops have been conducted for three key points: "Choice of the Distribution Channel", "Sharing Economy", and "Transparency in the Supply Chain". For these key points, a Causal Loop Diagram (CLD) has been developed using all the parameters highlighted by the platform participants transformed into a synthesis of logical feedback loops. Here, consumers with their lifestyles have been stressed on, assessing the relative attractiveness of new business models in comparison to conventional ones, the purpose of which was to gain new consumption patterns facilitating more sustainable food supply chains. In this line, the paper presents how "system maps" based on the method of PSM are used to gain insights into sustainable logistics services facilitating sustainable consumption patterns, enabling participatory considerations and the productive exchange of knowledge.

Keywords

Integrated Food Production and Supply Systems, Sustainable Supply Chain Management (SSCM), Climate Change Resilience, Sustainability Assessment, Logistics Services, Sustainable Consumption, System Dynamics (SD), Participatory Systems Mapping (PSM)

3.2.1 Introduction

The human society is facing complex and interrelated problems of unsustainability. An essential threat represents the ongoing destabilization of regional food systems' capacities due to a mix of interacting factors, such as climate change, population growth, overuse of resources, change of consumption modes, governance failures and problems in fair resource allocation and distribution under the increasing pressure and uncertainty. Currently 1.4 billion of the global population is living on less than 1 Euro a day, unable to adapt to an upcoming crisis; one billion of them is living in rural areas where agriculture is the main source of livelihood (World Bank, 2016). The ‘green revolution’ in agriculture, especially starting from the 1950s, increased agricultural productivity and contributed beside general economic growth in some regions of the world to reduced poverty rates, even if this progress is still patchy across countries. Stable improvement is heavily depending on local as well as international governance and investment policies as well as the implementation of fair economic trade rules in the globalized food and agriculture market. However, achievements were received without considering environmental externalities, leaving e.g. soils degraded and groundwater depleted, and have been undermining the ecological resource base. Moreover, many of the achievements strengthened the dependency on fossil energy and have led into less resilient production systems because of reduced crops diversity.

These underrepresented issues become more relevant in times of climate change and its regional impacts on agricultural systems. Taking into account two decades of underinvestment and vague innovation policies in agriculture, coupled with the growing competition for land and water and rising input prices, agricultural systems are now becoming more vulnerable than ever (IFAD, 2016). Therefore, it is expected that due to the world’s demographic development in its global differentiation, together with the significant effects of global climate change and resulting shifts for all organic production systems (agriculture, forestry, use of natural or semi-natural ecosystems), rural regions will undergo severe pressure in terms of their economic and ecological productivity, supply effectiveness of the population and the general societal prosperity in the next decades. From a systems perspective the situations also bear enormous risks for the globally expanding urban centers, because of their restricted self-sufficient food production capacities and critical dependencies on the already affected rural areas, with which they stand in a source-sink-relationship.

Sustaining the agricultural system is dependent not only on shaping sustainable production ways. The entire food supply chain must be analyzed systematically considering also further downstream and also upstream stages of the supply chain, industrialized combination of ingredients and further processing of food products, and in particular, their distribution, including the storage/ turnover and transportation to retailers and the consumer as well as the consumption phase and waste disposal (Hassini et al., 2012). In this context, logistics services are continuously expanded and adapted. Hereby, logistics service providers support in coordinating cross-company activities in a supply chain (Larsen, 2000). In the last years, social issues of sustainability (health and safety issues as well as employee income in developing and emerging countries) are increasingly questioning the producer and distributor business relations with the logistic industry and their Key Performance Indicators (KPI) after scandals and public debates were significantly raising the consumers' awareness. Thereby, a sustainable lifestyle (closely related to logistic services) is vitally important, because it favors reduction of resource consumption together with implementing technological and business innovations (Stengel, 2011).

Up to now the main objective of logistics services is to co-ordinate activities in a way that meets customer requirements at minimum cost (Esper et al., 2007). In the past, these costs have been defined in terms of the internal operations invest within the supply chain. As concern for the environment rises, companies must take more account of the external costs of logistics associated with climate change and further damage to the environment, e.g. due to various emissions and massive resource consumption (Spielmann and de Haan, 2008). Supply chain capacities to reduce environmental externalities represent a powerful lever to enhance ecological resource efficiency across the whole lifecycle of a food product and are finally a more commanding means than just the eco-efficient optimization of the production phase (Krumme et al., 2017).

Thus, this paper contributes to exploring ways of reduced externalities and to achieving a more sustainable ratio between economic, environmental and social objectives considering the operational functions of logistics. Through a better understanding of the interaction of consumer behavior and logistics services, the paper gives insights about relevant factors with regards to alternative last mile distribution modes as well as supply chain transparency by taking into consideration new forms of business models, such as the Sharing Economy (Spielmann and de Haan, 2008). Facilitating this aim, a platform was established to improve understanding among experts who make decisions on or contribute to a secure food supply system. Following the triple helix strategy the platform integrates business practitioners as well as policy makers/ public managers as well as science representatives and serves to understand the ways of minimizing the climate change impacts on food production and supply systems, organizing the agri-food supply chain in a sustainable way and, at the same time, providing long-term profitability.

3.2.2 Methodology

To understand the linkages between innovative logistics services and sustainable consumption/lifestyles, a systems thinking approach for integrating complex social, environmental and economic issues is required and applied (Krumme, 2016; Sedlacko et al., 2014). The main idea of systems thinking is that changes of an element can inevitably lead to changes in the other elements in the system, which makes the connections between system components explicit (Gießmann, 2010). To operationalize systems thinking the method of system dynamics modeling (SD) has a rich tradition not only in environmental and sustainability contexts, but also for decades in supply chain management (SCM). One option of a first implementation of SD is the development of Causal Loops Diagrams (CLD), which represent the general picture of a complex system (Sterman, 2000). In the particular context of the given study the proposed key points "Choice of the Distribution Channel", "Sharing Economy", and "Transparency in the Supply Chain" served as entrance gates into the further system mapping process. The CLDs comprise a set of nodes and edges, which represent a set of variables connected by arrows. These arrows denote the causal interrelations among the nodes. These relationships can be "positive" or "negative". A positive relationship means that if the cause increases, the effect increases above what it would otherwise have been, and if the cause decreases, the effect decreases below what it would otherwise have been. On the other hand, a negative relationship means that if the cause increases, the effect decreases below what it would otherwise have been, and if the cause decreases, the effect increases above what it would otherwise have been. Due to mutual interaction of combined functional relationships an emergent (sub-)systems behavior based on feedbacks can result into simple reinforcing or balancing loops. Here, further specific combinations of their feedbacks emerge into known "typical" SD archetypes of system behavior related to subsystems or the entire observed system. Such SD archetypes can be used for the diagnosis of a system.

Generally CLDs are very useful not only for capturing the feedback mechanisms among various system elements; they are also a good basis for information gathering and communication of the relevant issues and hypotheses in the system. To systematically gather all the relevant parameters, a series of workshops with experts have been conducted. The main purpose of these workshops was to define the actors, success factors, challenges and strategies to implement sustainable logistics in integrated food production and supply systems.

During the platform workshops the method of Participatory Systems Mapping (PSM) (Sedlacko et al., 2014) was used to apply the principles of systems thinking in a collaborative manner in terms of the production of CLDs. PSM is effective to receive information about relevant variables from experts that are connected to the system in various but concrete ways. The resulting CLDs served finding relevant interconnections between logistics infrastructures, services and consumer behavior, in particular for the key points *"Choice of the Distribution Channel"*, *"Sharing Economy"*, and *"Transparency in the Supply Chain"*.

3.2.3 Results and Discussion

3.2.3.1 Choice of the Distribution Channel

The focus of the workshop was narrowed on food supply chains as well as on the last mile logistics, since the last mile serves as important "matching point" of logistics services and consumer behavior, where interaction is intense and alternative options could be directly applicable. Moreover, the workshop participants were making a differentiation between two consumer lifestyles resp. groups of actors. The results of the workshop with regards to the choice of the distribution channel are shown in Figure 3.1.

Figure 3.1: PSM Results of the workshop "Choice of the Distribution Channel"

The first lifestyle was defined to be the *group of consumers who are working full-time and have limited time for grocery shopping accordingly* (for instance young and employed parents). Thus, they need to plan their shopping activities carefully. In this context, the workshop participant considered E-Food distribution channels, like "Click & Collect" and direct home shipments as very attractive for this actor group, mainly due to time savings. Within online retailing, logistics service providers have the best opportunity to interact directly with consumers. Vice versa consumers can place their demand for more sustainable last mile configurations more easily. Moreover, the participants claimed that the classical parcel delivery at home is not sufficient for food products, such that more personal delivery services including the handling of complaints should be offered, which could be coupled with Sharing Economy solutions. They also warned that parcel pickup concepts like “Click & Collect” present a business model to bypass the challenges in the last mile to the consumer. Here, the performance with regard to sustainability depends strongly on the mobility preferences of the consumer.

The second lifestyle was defined including *consumers not investing time in pre-consuming, but rather in shopping itself seeking to be inspired from the product offers in the market* (e.g. elderly people). Conventional “brick and mortar” retailers seem to be still the most relevant distribution channel for this consumer group. The participants argued that communication about sustainable mobility patters is very important for these lifestyles. Thus, including the consumers’ consumption and mobility preferences in the configuration of distribution channel, also for conventional channels, is crucial to achieve a better sustainability performance in the last mile.

3.2.3.2 Sharing Economy

From the interviewees’ point of view, the concepts of Sharing Economy have potential for a more sustainable configuration of supply chains in general and the last mile in particular. A

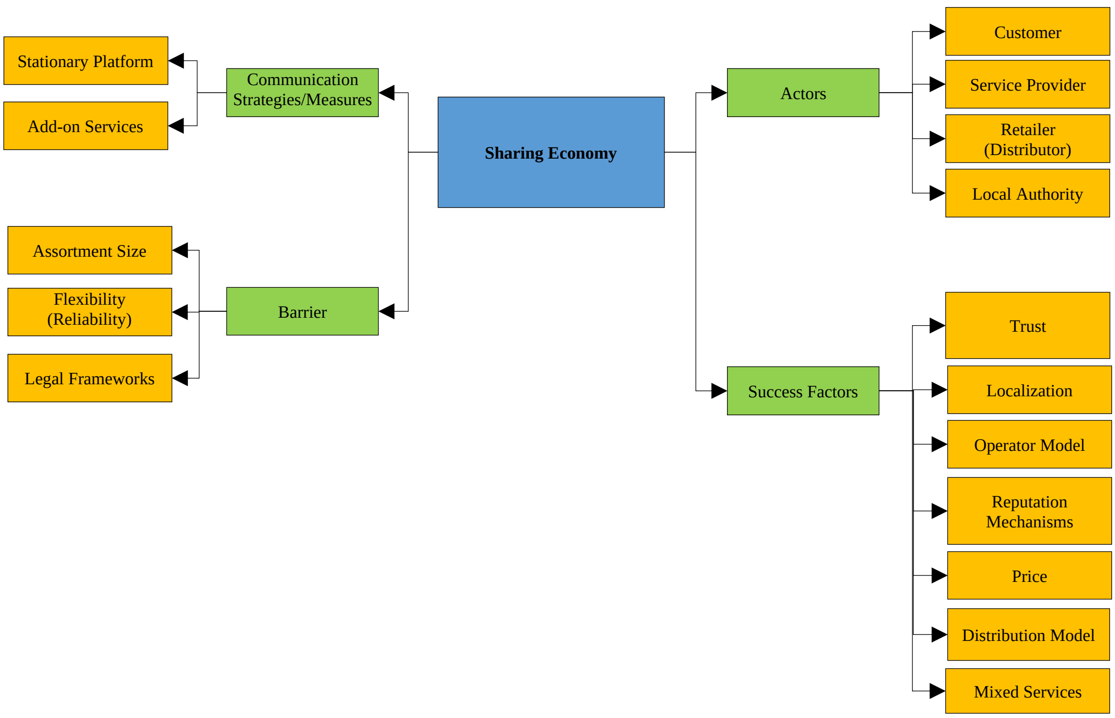

Figure 3.2: PSM results of the workshop: “Sharing Economy”

changed value perception, which highlights the trust in the others, meanwhile ranking the "using value" higher rather than "owing value", is the basis for Sharing Economy consumption patterns. In this context, consumers, logistics service providers, retailers and local authorities were identified as most important actors in accomplishing sustainable Sharing Economy solutions in the last mile. The participants named trust, reputation mechanisms and a localization of the services, e.g. local delivery services with low prices as important success factors. In contrast, major challenges are the type of the product (food is critical due to freshness and hygiene), spatial limitations (rural areas are hard to reach), and missing digital know-how (elderly people have difficulties in accessing digital applications). Further barriers were identified to be the limited size of assortment, legislative boundary conditions and limited flexibility. The detailed results of the workshop are included in Figure 3.2.

3.2.3.3 Transparency in the Supply Chain

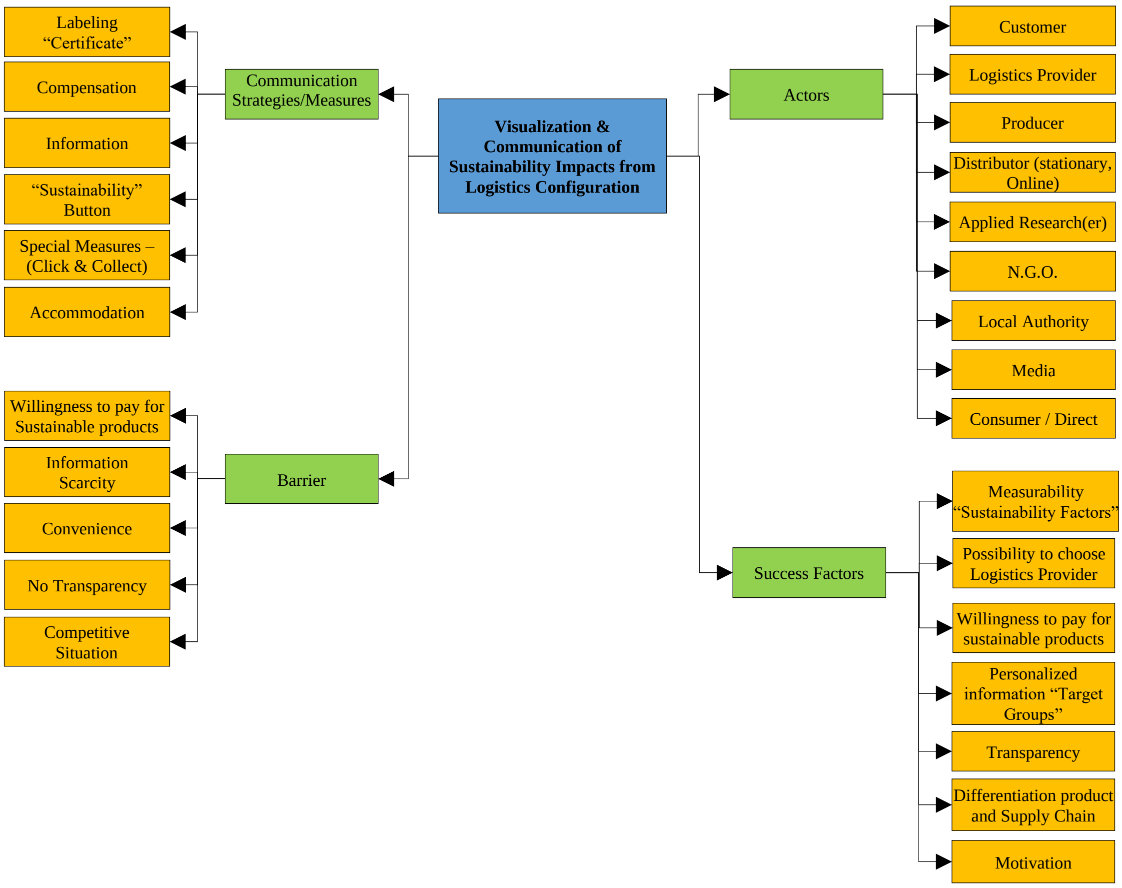

Figure 3.3: PSM results of the workshop "Visualisation and communication of sustainability impacts from Logistics Configurations"

The detailed results of the workshop considering the "Transparency in the Supply Chain", namely actors, success factors, challenges and communication measures are included in the Figure 3.3. The relevant actors are the consumers, logistics service providers, producers, retailers, NGOs, political decision makers, researcher, local authorities and media companies. Here, the readiness to pay for sustainable products was defined as a success factor, but simultaneously as a challenge. It was considered that a consumer, who is ready to pay more for sustainable products, will be possibly ready to pay more for sustainable logistics services, too. On the other hand, this was also considered as a challenge by the workshop participants, since a consumer has limited financial resources and once paying for the sustainable products, he/she will be left less money for affording sustainable logistics services.

In order to communicate sustainability aspects in the logistics, these aspects of sustainable logistics must be clearly defined to achieve measurability. Such measurability would make it much clearer for the consumer to make an informed choice. On the other hand, it was also mentioned that too much information could be a challenge overburdening the consumer. Nonetheless, providing sufficient information about logistics services and their sustainability impact was considered to be predominantly positive. Here, information is tightly connected to transparency, which was also considered as a success factor. In this context, labeling sustainable supply chain of a product was identified to be a possible communication strategy. It was also clearly stated that this might be a challenge, not only because of the “over-information” for the consumer, but also that the sustainability along the entire supply chain might be too hard to measure.

3.2.3.4 Causal Loop Diagram for Sustainable Logistics

Summarizing the results of all workshops, Figure 3.4 presents the CLD using all parameters highlighted by the participants linked with logical feedback mechanisms. As shown, there are six feedback mechanisms, which influence the dynamics of the system. The “Willingness to pay” feedback loop describes the stabilizing interconnection among the willingness to pay, performance and price of a sustainable logistics service in dependence on the consumer income. The feedback loop “Investment in infrastructure” shows the positive impact of demand in sustainable logistics service on investments in logistics infrastructure in dependence on available resources. The choice between the use of a private car and using logistical services is clarified with the feedback mechanism “Choice of the distribution channel”. “Sustainability image” shows that the image of the firm is very important for the supply of sustainable products. All the feedback mechanisms are summarized in the main feedback loop, which connects the awareness of sustainability in logistics service (thus also willingness to pay for that) with the image and reputation of the firm and thus supports sustainable consumption patterns.

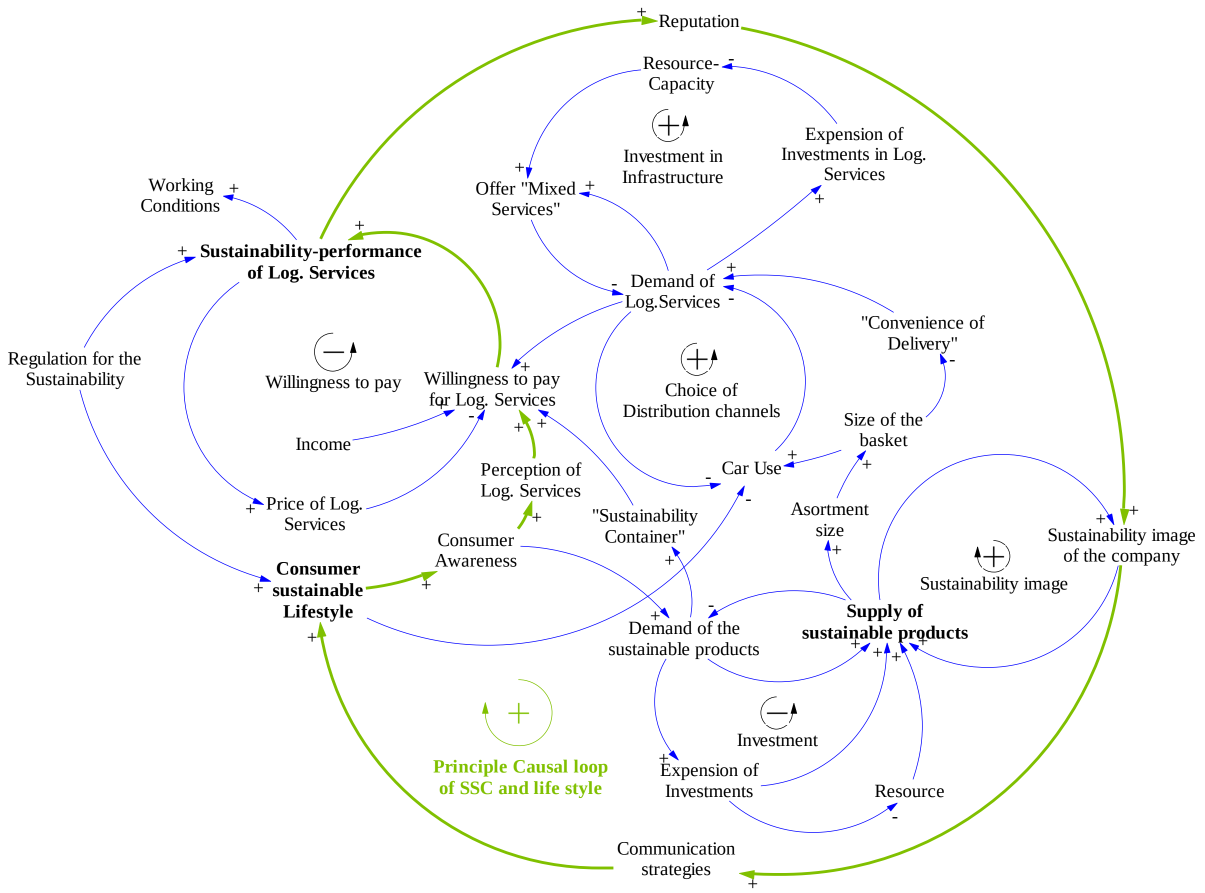

Figure 3.4: Causal Loop Diagram on Sustainable Logistics generated from all three workshops

3.2.4 Conclusions and Outlook

The paper has shown that more sustainable options in food production and supply, particularly with higher climate change resilience and resource efficiency, necessitate a systems thinking approach to integrate all vitally included components. The needed integration can be guided by principles Sustainable Supply Chain Management (SSCM) applied to the food sector. The process cascades of food supply, starting from production grounds across the entire supply chain structures and operations to finally the end consumer and modes of consumption can be displayed as an *integrated food production and supply system*.

On the way to identify sustainable system alternatives with respect to environmental and social externalities of food supply chains, the study has shown the significance of an approach that considers system thinking (A) in terms of understanding of system behavior and the applied methods, but (B) also under the integration of available system knowledge of experts “from the field” through a participatory approach. This combination produced system maps of integrated food production and supply systems based on the perceptions and implicit knowledge stocks of the actors participating. A key issue for sustainable alternatives is represented by the interplay of logistics services from the sphere of the supply chain and consumer behavior from the sphere of lifestyles.

CLD which describes the relevant parameters and their logical feedback mechanisms provides starting points for several next steps of future research. Thus, the CLD will be transformed into a Stock and Flow diagram, in order to simulate various scenarios using System Dynamics. The conversion of the CLD into a simulation model has the purpose to acquire a basic knowledge of stocks and flows as a modeling alternative by displaying the dynamic behavior of the system. Following the *principle of accumulation* within a System Dynamics simulation, this will provide a strong foundation for understanding the connections between CLDs as well as stocks and flows and add a methodical structure to an often chaotic process.

Furthermore, the process strengthens the stock and flow way of thinking by underlining the difference between information and material flows, and giving unit consistency throughout the model. The end result of the conversion process will be a computer model that can be used to experiment with different policies for a sustainable food production and supply system and see how the system might respond to different variables modifications. Based on the completed steps of work the model will allow the important integration of feedbacks between the production and supply sphere and the consumption and lifestyle sphere and could offer more integrated solutions than available until now in scientific literature. Accordingly, the simulation will provide further insights into the system, for instance into necessary pricing schemes for sustainable food production and supply systems, explicitly taking into account the consumer lifestyles as a main driver.

3.3 Local and Sustainable Food Businesses: Assessing the Role of Supply Chain Coordination (Gruchmann, Böhm, Krumme, Funcke, Hauser, Melkonyan, 2019)

The following chapter is a book chapter written by the author of this dissertation, Tim Gruchmann (Westcoast University of Applied Sciences), Madaleine Böhm (University of Freiburg), Simon Funcke (University of Freiburg), Simon Hauser (University of Witten-Herdecke) and Ani Melkonyan (University of Duisburg-Essen) in 2018.[17]

The publication refers to the research project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015).

Any reference to this chapter should be cited as:

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Abstract

In food supply chains, products and services are continuously expanded and adapted according to changing customer demands. As concerns for environmental and social issues within societies grow, sustainable business practices in supply chains are coming to the fore. Altogether customers' growing demand for local food has led to an increased importance of local food production and distribution networks. In this context, the present study analyzes sustainability-related practices in two local food production and distribution networks in Germany and Austria applying a multiple-case study approach to understand how business models can facilitate sustainable practices within the food industry. By comparing the selected cases, insights were derived with regard to sustainable business model elements in local food networks, in particular promoting logistics and financial coordination in the supply chain. Thus, the article builds on academic literature by identifying and describing key elements of sustainable business models in local food networks. At the same time, it can be argued that sustainable business models have to be accepted by consumers such that sustainability

[17] Klaus Krumme has taken over the discussion and revision of the book chapter for this publication. This has led to a structuring and positioning of the case studies in a stronger "regional geographic" context, whereby the link between local food trends and regional business model elements was established. Klaus Krumme introduced the "NetzWerk" case (Linz, Schachinger Logistik) to the research case.

advantage aspects need to be stressed through external communication. Managerial implications with regard to transferability and scaling of regional food businesses are provided accordingly.

Keywords

Sustainable business model, Local food, Supply chain management

3.3.1 Introduction

Local[18] food, understood as food production geographically close to the consumer, is a growing trend taking place mostly in Western societies (Feldmann and Hamm, 2015; Wenzig and Gruchmann, 2018). Specific methods of food production (e.g., fair farm labor, animal welfare practices, and the absence of chemical fertilizers or pesticides) as well as specific supply chain attributes (e.g., simplified and direct distribution, closer personal communication along the supply chain, and clear information about the products' origin via labeling) often characterize local food businesses. The reasons for this trend are manifold. According to Vermeir and Verbeke (2006), factors such as food scandals in the globalization of food supply chains as well as a commitment to support the local economy can be identified as reasons for the increasing number of concerned consumers who prefer to obtain their food from local sources. In addition, consumers associate local food products with freshness, higher quality, and healthiness (Khan and Prior, 2010). Consequently, more sustainable local alternatives that often involve organic food production as well as community-supported agriculture and farmers' markets have become increasingly popular (Feldmann and Hamm, 2015). However, it also can be seen that an insufficient integration and coordination of decentralized local food production networks still limits growth such that local food businesses often remain in a niche (Willer and Lernoud, 2013). Accordingly, the following research questions guided our study: How can supply chain coordination contribute to transferability and scaling of local food businesses and their sustainability efforts? How is this reflected in their business model?

Therefore, we aim to shed light on tapping further increases in sustainability-oriented business practices in local food business models and inquire how network coordination approaches can contribute to the success of regional companies and their sustainability efforts. Specifically, we are interested which business model elements in local food networks are promising to promote sustainability in the food industry. For the analysis, we focus on two regional food networks in Austria and Germany, their connections between the network members and the networks' central intermediary company. Both investigated networks aim at the promotion of sustainable food

[18] "Local" means the lowest political level of municipalities and districts.

production, regional distribution, and, to the furthest extent possible, a closing of regional value chains. The analysis of both cases follows the conceptualization of business models proposed by Osterwalder and Pigneur (2009), which we extend with regard to sustainability aspects according to Boons and Lüdeke-Freund (2013) and Upward and Jones (2016). Based on this analysis, we develop an extended business model conceptualization for local and sustainable food networks.

The structure of the study is as follows: Section “Literature Background” gives an overview of relevant literature with regard to (sustainable) business models. The research design of this contribution is presented in section “Research Design”. Next, section “Case Analysis” lays out the main results for the cases and provides a combined analysis of both cases that leads to a new sustainable business model conceptualization for local food networks. The last sections “Discussion” and “Conclusion and Outlook” discuss the findings against the literature on supply chain coordination and conclude them accordingly.

3.3.2 Literature background

Business models have been extensively discussed and defined in the literature (Zott et al., 2011). Linked to strategy and innovation literature, the business model approach describes the ways in which a business creates and delivers value to their customers through designing value creation, delivery, and value capture mechanisms (Osterwalder and Pigneur, 2002, 2009). These elements of business model design generally include features embedded in the product/service; determination of the benefit to the customer when consuming/using the product/service; identification of targeted market segments; confirmation of the revenue streams; and the mechanisms to capture value (Teece, 2010). Focusing on conventional business models, four main business areas were identified while discussing business models: in particular the value proposition, for which customers are willing to pay; the relationships with the customers; the infrastructure and network of the partners; and financial aspects (cost and revenue structures) (Ballon, 2007; Boons and Lüdeke-Freund, 2013).

The business model perspective can be linked to the context of sustainability and has been of growing interest to scholars (Stubbs and Cocklin, 2008) in recent years, since it highlights the logic of value creation and allows for new/rediscovered governance forms such as cooperatives, public-private partnerships, and social businesses (Schaltegger et al., 2016). Accordingly, Schaltegger et al. (2016, p. 6) define the role of a business model for sustainability as: “it helps describing, analyzing, managing, and communicating (1) a company’s sustainable value proposition to its customers and all other stakeholders, (2) how it creates and delivers this value, (3) and how it captures economic value while maintaining or regenerating natural, social and economic capital beyond its organizational boundaries.” Hence, the existing business model definitions have been aligned with the triple bottom line (TBL) approach (Carter and Rogers, 2008; Seuring and Müller, 2008) to not only foster economic but also social and environmental value creation. Extending the conventional business frameworks in accordance with the TBL, Boons and Lüdeke-Freund (2013) define the key parameters in sustainable business models as follows: (1) value proposition of products and services which should focus on ecological, social, and economic value; (2) overall infrastructure and logistics of the business guided by the principles of sustainable supply chain management; (3) interface with customers enabling close relationships between customers and other stakeholders to improve co-responsibility in production and consumption; and (4) equal distribution of economic costs and benefits among all actors involved. Broadening the systems' scope further, Neumeyer and Santos (2018) see business models as part of the whole entrepreneurial ecosystem, particularly dependent on the stakeholder's social network. Over the last few years, authors have started to consolidate the literature on sustainable business models by introducing sustainable business model ontologies and archetypes (e.g., Bocken et al., 2014; Upward and Jones 2016). Here, Bocken et al. (2014) distinguish between eight different sustainable business model archetypes, particularly promoting maximization of material and energy efficiency, creation of value from waste, substitution with renewable and natural processes, delivery of functionality rather than ownership, adoption of a stewardship role, encouraging sufficiency, repurposing products and services for society and environment, as well as the development of scale-up solutions. However, Lüdeke-Freund et al. (2016) see research in the field of sustainable business models as still rather limited, in particular with regard to empirical analyses. Moreover, industry- and branch-specific sustainable businesses need to be analyzed to access business model elements and archetypes that support the management of voluntary social and environmental activities in certain environments. Taking into account the different paradigms to include sustainability in a company's business model, the main contribution of this study is a comparison of two successful local food business networks and analysis of how sustainability aspects are reflected within single business model elements. Within the few frameworks given in the literature, the extended sustainable business conceptualization developed by Boons and Lüdeke-Freund (2013) is adapted and used as deductive coding scheme for the analysis. In this line, Table 3.1 describes the related sustainable business model elements, while Figure 3.5 depicts the adapted framework.

Table 3.1: Key elements in sustainable business models (Source: adapted from Boons and Lüdeke-Freund (2013))

Codes	Description
Value Proposition	The value proposition of a company is decisive for a customer's buying decision. Here, products and services form a bundle covering the needs of a specific customer segment (Osterwalder and Pigneur, 2009). According to Schaltegger et al. (2016), the value proposition has to create, deliver, and capture both environmental and social as well as economic value by offering products and services. Therefore, a sustainable value proposition must identify trade-offs between product and service performance as well as social and environmental effects (Boons and Lüdeke-Freund, 2013). So far, a reduced resource consumption and potentially increased ecosystem services are the core of sustainable business models to reduce the environmental footprint (Stubbs and Cocklin, 2008). Further key activities focus on the access to markets, the perpetuation of customer relationships and achieving positive revenue streams (Osterwalder and Pigneur, 2009).
Supply Chain	The company or its network partners need to have access to key resources as a prerequisite for value creation. These key resources can be generally categorized as physical resources, financial resources, human resources, and intangible assets (Osterwalder and Pigneur, 2009). This perspective is relevant as sustainable innovations may require changed terms of competition and collaboration among the actors engaged in the supply chain (Boons and Lüdeke-Freund, 2013). In this line, the importance of incorporating a stakeholder approach is increasingly understood in sustainable supply chains and sustainable business models (Seuring and Müller, 2008; Lüdeke-Freund et al., 2016). For instance, the stakeholder approach requires that a company engages suppliers in its sustainable supply chain management to tackle environmental and social issues (Boons and Lüdeke-Freund, 2013; Seuring and Müller, 2008). In this line, the last mile distribution can be considered to be one of the most complex units of a supply chain (Schliwa et al., 2015). This complexity is generated by tight delivery time windows and a growing number of small orders which have to be delivered to rural areas (Punakivi et al., 2001).
Customer Interface	Company relationships can motivate customers and other company stakeholders to take responsibility for their consumption behavior (Boons and Lüdeke-Freund, 2013). Accordingly, the customer interface enables close relationships with customers and other stakeholders to be able to take responsibility for the production and consumption systems (Schaltegger et al., 2016). In order to approach the customer interface individually, customer groups are segmented by differentiating between different customer characteristics. Business models can either target a specific customer segment or produce for mass markets (Boons and Lüdeke-Freund, 2013). Moreover, a company operating on multi-sided platforms (multi-sided markets) serves different customer segments independently, if applicable (Osterwalder and Pigneur, 2009). Hence, the customer interface might help to develop approaches to advance business models into platforms for multi-stakeholder integration and value creation (Lüdeke-Freund et al., 2016).

Financial Model	Value creation is linked to the use of resources and, consequently, linked to costs. In this context, sustainable business models foster the shift away from purely monetary-oriented paradigms of value creation (Lüdeke-Freund et al., 2016). Therefore, the comparisons of cost structures between similar business cases are essential to gain insights into how a business creates and delivers value to their customers (Osterwalder and Pigneur, 2009). Accordingly, the cost and revenue structure reflects the distribution of economic costs and benefits among actors in the business model (Maas and Boons, 2010). According to Stubbs and Cocklin (2008), shareholders often have to accept lower returns on investment in the short-term so that the company can directly invest profits into structural changes to support social and environmental improvements, which in turn can result in reduced costs. Thus, sustainable business models treat nature as a stakeholder, too, and promote environmental stewardship (Stubbs and Cocklin, 2008). In this line, renewable resources should be used instead of non-renewable resources (natural capital). Here, technological innovations should minimize and eventually eliminate non- recyclable waste and pollution. Related terms such as clean technologies are also used for innovations that have a superior environmental performance (Boons and Lüdeke-Freund, 2013).

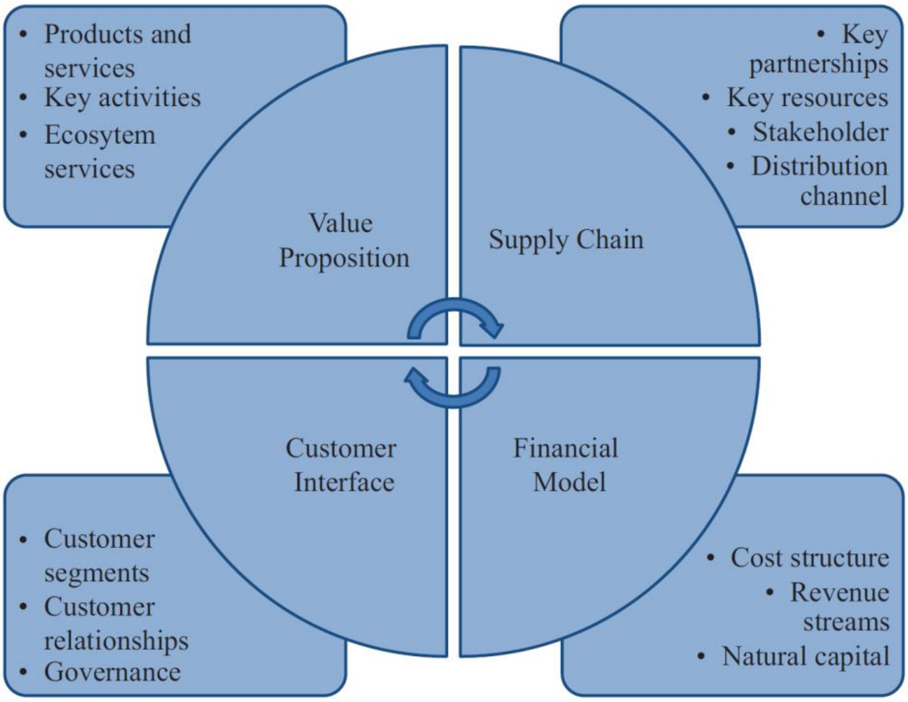

Figure 3.5: Key parameters in sustainable business models (Source: adapted from Boons and Lüdeke-Freund (2013))

3.3.3 Research design

Considering the aim of the study, particularly the identification of promising business model elements to further promote sustainability in food business models, a case study approach was used because the boundaries of the phenomenon and its full scope and context were not entirely described beforehand (Yin, 2009). Case studies are also well suited for complex structures as they allow intense interaction with the informant and draw on multiple sources of information leading to robust data (Eisenhardt and Graebner, 2007). Although the sustainability potential of local food supply networks is evident in the literature (Bosona and Gebresenbet, 2011), how to implement and develop sustainable practices in such networks are not clear. Hence, a combined case study and business model approach is used to analyze local food production and distribution networks in Germany and Austria.

Case Selection: In accordance with the scope of the study, two companies from the food sector, which act as a hub in their respective network, were selected. Both networks focus their operational activities on decentralized and organic food production and its local distribution. The cases NETs.werk[19] Hörsching and Regionalwert AG (RWAG)[20] Freiburg were chosen as they implement sustainability aspects at the core of their business models. Moreover, these business cases were selected to cover different parts of the supply chain (upstream and downstream) in order to gain insights into as many aspects of sustainability as possible during the value-creating process. The data collection from each case was stopped when no further significant new insights could be gained (Yin, 2009). Table 3.2 gives an overview of the observed business networks.

Table 3.2: Case characteristics

Attributes	NETs.werk Hörsching	RWAG Freiburg
Location	Linz, Region Upper-Austria, Austria	Freiburg, Germany
Start of operation	2014	2007
Scope	Production and online distribution of organic food products and groceries to support local farmers	Investment in and facilitation of companies producing, processing, and distributing organic food products
Number of independent companies in the network	36	25
Respondents	Farmer (F1), CEO (C1), Logistics service provider (L1, L2)	CEO (O1), three network companies (U1, U2, U3)

Data Collection: In qualitative research, interviews are generally used as a methodology for knowledge production (Alvesson, 2003). Based on an interview topic guide developed with the

19 "NETs.werk" can be translated as "network."
20 "Regionalwert AG" can be translated as "regional value public limited company".

help of a literature analysis, eight qualitative interviews were conducted. The interviews lasted up to 60 min and were tape-recorded and transcribed in their entirety. Quotations from the interviews are translated into English and used to exemplify the results in section “Case Analysis”; the interviewees were anonymized and labeled by using capital letters and numbers (Table 3.2). In addition, secondary data was collected from publicly available reports, internal company documents, web sites, and newspaper articles.

Coding and Data Analysis: Due to the complexity of qualitative interviews, careful interpretation of the interview results is necessary to analyze the extent to which the findings serve the research purpose (Alvesson 2003). Therefore, the transcripts were analyzed using a qualitative content analysis approach (Mayring and Fenzl, 2014; Schreier, 2014). To ensure methodological accuracy, the content analysis of the interviews was carried out in a structured manner by deductively using the business model canvas system adapted from Osterwalder and Pigneur (2009), Boons and Lüdeke-Freund (2013), and Upward and Jones (2016) (Mayring and Fenzl, 2014) (see Figure 3.6). Thus, the structural dimensions of the cost structure, customer relationships, customer segments, distribution channels, ecosystem services, governance, key activities, key partnerships, key resources, natural capital, stakeholder, revenue streams, and value proposition were chosen as themes in the coding of the interview transcripts. In terms of internal validity, the transcript coding was performed by two researchers, also ensuring intercoder reliability. The results of the deductive analysis can be found in sections “NETs.werk Hörsching” and “Regionalwert AG Freiburg”.

Comparative Analysis and Triangulation: In a second step, the results of the coding were analyzed inductively using a comparative process. Following Mayring and Fenzl (2014), the steps of clustering themes, determining the level of abstraction, and iteratively building new analytic categories were executed. To ensure the external validity of the comparisons, triangulation with the literature was conducted, as suggested by Riege (2003). To further strengthen the external validity, multiple expert workshops were carried out to discuss the results with other researchers. The results of the inductive, comparative analysis can be found in section “Analyzing Driving Factors and Barriers for Sustainability”.

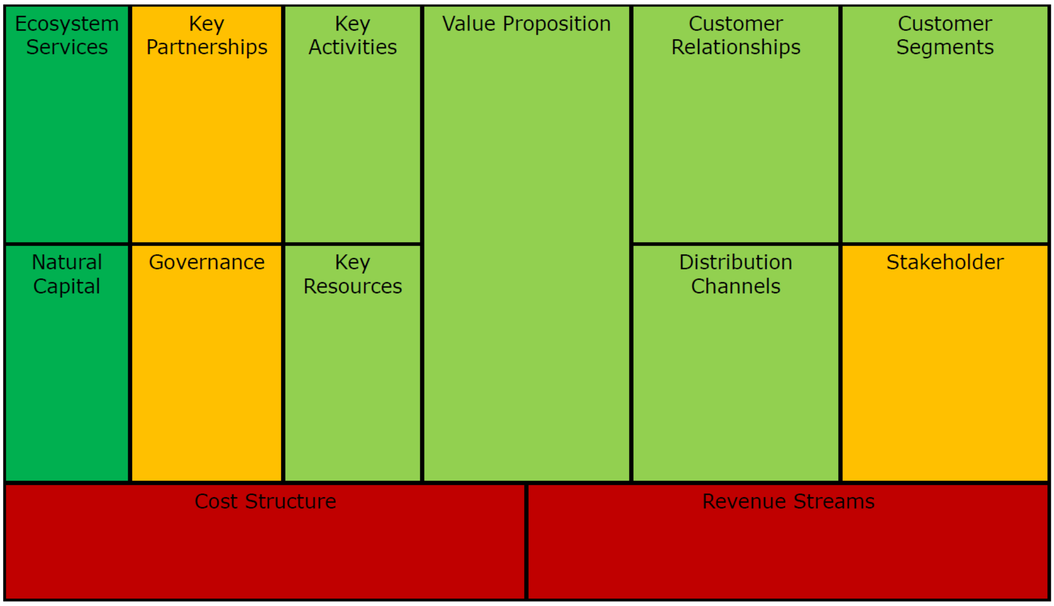

Figure 3.6: Deductive coding scheme (Source: adapted from http://www.flourishingbusiness.org)

3.3.4 Case analysis

For this contribution, we carried out an in-depth analysis of two cases of food production and distribution networks in Austria and Germany. All network companies intend to extend the production, processing, and distribution of local food in a coordinated manner. In addition, the cases focus exclusively on organic food products. In the following, the networks and the intermediary enterprises that govern the networks are described and analyzed. The analysis follows the deductive coding structure as presented in Figure 3.6. The cross-case analysis of the interview data is presented in section "Discussion".

3.3.4.1 NETs.werk Hörsching

NETs.werk is a farmer's cooperation with the mission to facilitate sustainable consumption patterns (http://hoersching.netswerk.at). To do so, NETs.werk runs an e-food online platform to distribute locally produced organic food from participating farmers in the Linz region in Upper Austria. So far, customers order once a week via an online shop and pick up their order by themselves at one of the NETs.werk branch offices.[21] To drive the environmental performance with regard to the last mile distribution, NETs.werk started a collaboration with a local logistics service provider to offer a direct delivery service operated by electric vehicles. The intention is to acquire new customers, increase the service quality, and decrease CO2 emissions by avoiding single consumers' car rides and bundling the goods flow. Accordingly, NETs.werk governs the supply network through logistics and technological coordination and achieves

[21] In this line, NETs.werk follows a click and collect approach.

positive environmental effects by integrating cleaner technologies. This partnership can be considered as a logistics coordination of the network.

“Right now, [...] the products are transported [...] by the farmers themselves. Then the products are commissioned and put into boxes. Afterwards every Thursday, Friday and Saturday 80 to 100 customers drive to the NETs.werk branch offices with their own car to pick up their boxes – worst case. Hence, the sustainability of the product [...] is gone.” (F1)

Besides the organic products themselves, the value proposition accordingly includes the local and sustainable delivery service allowing an expansion in new areas. Key activities to run the NETs.werk distribution network are the processing of the customer orders including payments, the temperature-controlled transportation of goods as well as the management of the returned packaging.

“The focus of the logistics service provider is clearly sustainability. Therefore, they encourage the electrification of their vehicles, also because consumers who particularly buy organic and sustainable food will require this. Hence, the mode of the delivery is very relevant.” (C1)

Customer segments are people who work full-time and have limited time for grocery shopping (e.g., young and employed parents) as this segment needs to plan their shopping activities carefully and is often sensitive toward health and sustainability-related issues. Future customer segments are expected in business-to-business supply of restaurants, kindergartens, and nursing homes. Although the customer interaction while ordering is automated, NETs.werk builds personalized customer relationships via the drivers of the electric vans to offer additional customer services such as claim and retour management. To avoid anonymity and increase the transparency of the local farmers’ production network, farm festivals are regularly organized, and a rating system will be installed on the online platform soon.

“This is also a possibility to win new customers. Therefore, we deliver on demand […] a low-carbon, organic product.” (F1)

“You need to communicate the benefits of fewer CO2 emissions which result from the bundled delivery to the customer.” (C1)

Key partnerships of NETs.werk are the local farmers and Schachinger Logistik, the local logistics service provider who is able to combine the afternoon business-to-customer food deliveries with a business-to-business parcel delivery service in the morning. Hence, the logistics service provider reduces operational costs per delivery by increasing the usage of the electric vans. In general, important key resources in the distribution network are the human resources, existing logistics infrastructure (such as trucks and warehouses) as well as NETs.werk's information and communication technology (ICT).

"NETs.werk wants to cooperate for transportation with Schachinger […] while commissioning and warehousing stays with the farmers." (L2)

"Schachinger Logistik is part of the DPD network in Austria. […] Therefore, more or less every B2B [business-to-business] parcel delivered in Upper and Lower Austria is done by Schachinger. […] In the end, it is about conducting B2B deliveries in the morning and […] B2C [business-to-customer] deliveries in the afternoon because the probability that the customer is at home is higher." (L1)

To operate this infrastructure, the main variable cost related to the energy consumption of the electric vehicle, driving and picking personnel, and running the online platform, while fixed costs are mainly related to investments into logistics and ICT infrastructure. According to the financial model, revenue streams are generated by charging the customers for a part of the delivery costs and co-financing the delivery service from the product margin.

"Delivery costs of 1.90€ are easily acceptable for the consumer to pay. 3€ is much harder. When you look at yourself, you don't want to pay 3€ for dispatch and delivery […] but 1.90€, particularly when you order products for 40 or 50€, that's okay." (L2)

To summarize the NETs.werk case, Figure 3.7 depicts the single business model elements.

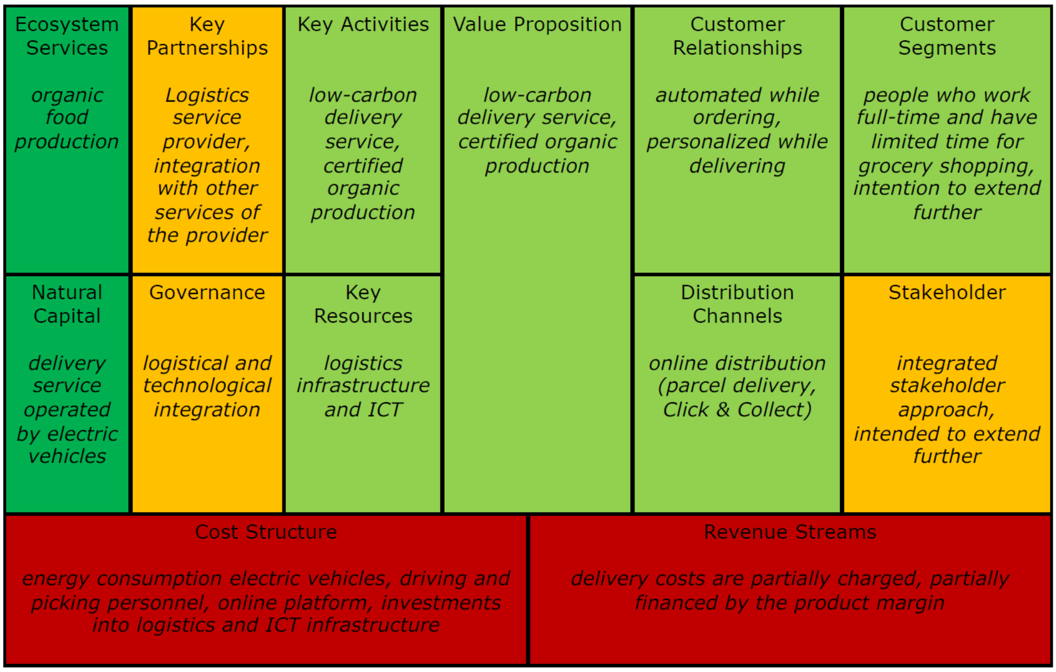

Figure 3.7: Sustainable business model canvas NETs.werk

3.3.4.2 Regionalwert AG Freiburg

RWAG was founded in 2006 and began its operation in 2007. By following the concept of a public limited company – without being listed at the stock exchange and mainly relying on local and regional citizens to buy shares of the network – RWAG strives to show the societal and ecological importance of locally produced and distributed certified organic food products (https://www.regionalwert-ag.de). It governs 25 companies along the supply chain financially or with organizational advice and strategically connects these companies in a regional network. Therefore, RWAG's main scope is "the participation (and share of capital), the support and foundation of companies in the field of ecological farming, forestry and wine agriculture. Also, the retail and wholesale trade sector in these fields and the food sector in the region of Freiburg should be enhanced with ecological goods" (Hiß, 2014, p. 41).

RWAG can be considered an intermediary between the network companies which are either partly owned by RWAG or licensed partners without financial involvement. For the co-owned companies, RWAG is becoming more than an intermediary but rather a strategic parent organization. This partnership can be considered as financial coordination of the network. In sum, RWAG's value proposition:

- Promotes certified organic food production and consumption and offers social and ecological returns to its mainly local stockholders and the region
- Offers potential financial return to its stockholders with the premise that all social and ecological goals are achieved
- Promotes the exchange between different companies along the value chain of certified organic food and their ability to work together
- Supports entrepreneurs in planning and financing their businesses in the certified organic food sector (production, processing, wholesale, and retail) as land and equipment are capital-intensive
- Creates awareness for the different benefits of certified organic food production besides monetary gains, such as ecological and social criteria

"I hope to be able to have a 'perfect' balance sheet in five years. A balance sheet with all the information one needs – whether social, ecological, regional-economical, or financial. […] We hope to have new tools in accounting as well, in order to be able to track those improvements." (O1)

While the network companies and licensed partners are also recipients of RWAG's value proposition, RWAG's customer segments are very heterogeneous, mostly due to the network organization. We understand the RWAG head-company as a hub for innovation, being the central actor in the network. Thus, its customers are primarily the particular network member companies that use the RWAG's services. Accordingly, the RWAG itself only holds shares of the network partners but does not engage with final customers on its own. End-customer relationships are only indirectly addressed through the network companies: The network's products are distributed to consumers in the region either via supermarkets stocking RWAG products, via restaurants run by the RWAG, via delivery services, or via farmer's markets. Interestingly, none of the network members relies completely on the RWAG network members, but especially the businesses on the first steps of the value chain – the ones in the agricultural sector – argue that RWAG is good to reach out to business customers.

"These customers are our most important customers. The "Frischekiste"[22] is our most important customer. Since last year, even Naturkost Rinklin [a wholesaler] is part of RWAG. This was the last really important customer that didn't use to be a part of RWAG." (U1)

RWAG has developed a unique financial model adapted to their business model. RWAG holds the majority of every network member that is co-owned by RWAG. Accordingly, these companies do not bear the entire economical risk themselves and can seek practical and additional financial help from RWAG. RWAG's financial capital stems from registered shares with restricted transferability that are mainly sold to private people in the region.[23] This makes RWAG an organization carried by mostly private actors and requires a high degree of transparency that is reflected in how figures are made public.

"We have grown a lot in the region in the last couple of years. The retailers, for example a supermarket […], they have tripled their economic turnover in five years, compared to their foundation. This is just one example. […] Even if you look at all network partners in one, the income is increasing, I think it is 17 per cent; some single ones are increasing their turnovers by 30 to 40 per cent. And these are important effects." (O1)

Concerning the supply chain, the RWAG is the central strategic actor in the network, while others – like the Regionalwerk UG – are the key to network cooperation by organizing workshops and spaces for network members to meet and get in touch. Its key partners in the sense of human and physical resources are mainly the businesses within the network. All companies along the supply chain are important, even though some might be more central to

[22] The "Frischekiste" is a delivery service of locally and organically grown goods. Their products are distributed to the door of each customer.
[23] The price for one share has differed between the last rounds of increase in capital. In 2016, one share was sold for 500 €.

the network than others (e.g., the producing partners; U1). A key activity for the network is, in addition, the administration of RWAG itself. They assist the network companies not only with capital but support the businesses especially in strategic questions and help to create future visions for them. In terms of financial resources, the RWAG's shareholders are crucial. They are essential for the business model to work because their investments are securing the RWAG's financial opportunities.

To summarize the RWAG case, it is important to keep in mind that every partner, member, or customer might have changing roles for the value proposition through the different key activities mentioned, as well as for other categories mentioned in the business model. This role depends on the perspective of the actor and on the activity in question and enforces the understanding of a network of companies working together, with the RWAG itself being the network's hub.

To summarize the RWAG case, Figure 3.8 depicts the single business model elements.

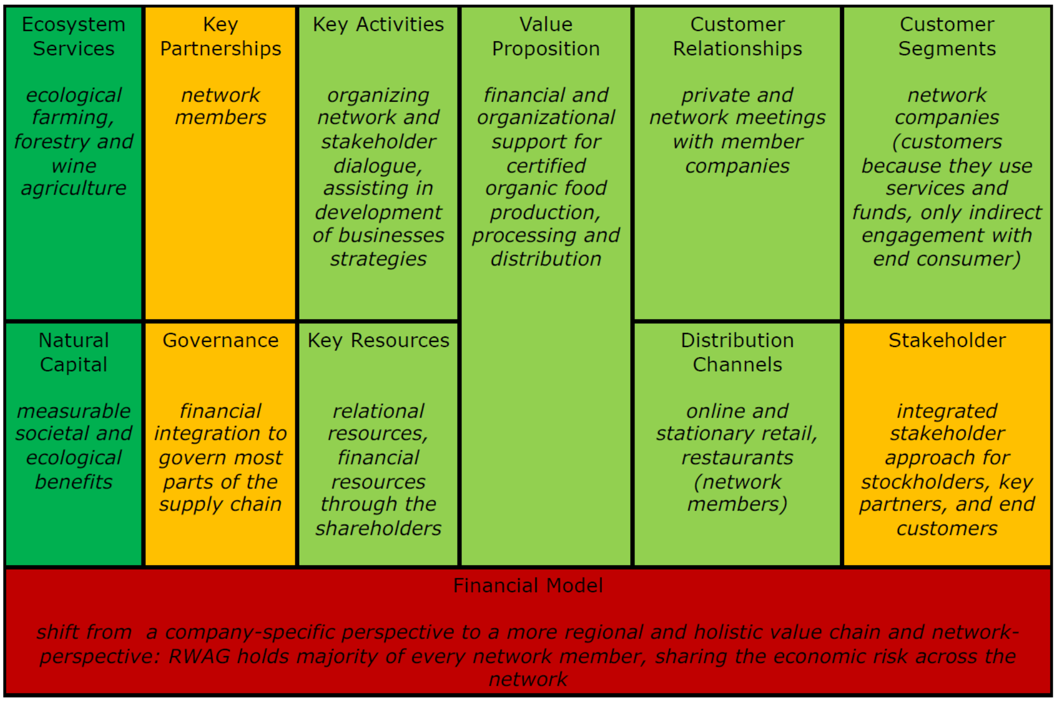

Figure 3.8: Sustainable business model canvas RWAG

3.3.4.3 Analyzing driving factors for sustainability

As the main aim of this study is to compare successful business models while using the sustainable business model framework adapted from Boons and Lüdeke-Freund (2013) (see Figure 3.5), driving factors and specific characteristics were identified which promote sustainability, transferability, and scaling of these regional business models. To summarize the findings, an archetypical business model is constructed depicting the single business model elements derived from comparing the NETs.werk and RWAG case (see Figure 3.9). In this line, the sustainable business model conceptualization by Boons and Lüdecke-Freund (2013) can be informed in the context of local food businesses. Analyzing both cases, the use of local resources has the potential to extend a conventional to a more sustainable value proposition, particularly in the food sector (Kneafsey, 2010; Collits and Rowe, 2015). In the case context, the investigated businesses include additional logistics and financial services in their value proposition. Accordingly, intermediary organizations within the networks can coordinate sustainable production and consumption patterns through these services.

With regard to the empirical findings, sustainability benefits can be leveraged through more professional operations resulting from logistics, technological, and financial integration, for instance, through standardizing procedures while keeping personalized relationships as well as extending the value proposition toward offering more sustainable last mile alternatives in the NETs.werk case. Here, more efficient operations in line with a lower ecological footprint due to regionalization result from shorter distanced and generally less complex supply networks, potentially leading to a lower energy consumption, fewer CO2 emissions, or a reduced water footprint among other positive benefits for sustainability (Hudson, 2007).

Another argument often used for regionalization is the support of local or regional value chains leading to positive impulses for regional economic development (Wiskerke, 2009) and strengthening the regional economy through stronger intra-regional communication within the networks (Paloviita, 2010). In terms of financial coordination within local food supply chains, the cases provide evidence that products and services can become more competitive compared to conventional and globalized food supply chains, in particular through sharing economic risks and coevolving of the supply chain partners. For example, the RWAG case fosters cooperation and exchange among the network members to build and keep (social) capital within the region.

Within the observed cases, potentials for sustainability deriving from financial and technological coordination of local food production and distribution networks still show room for further (green) expansion, for instance, by increasing the number of member companies and citizens in the RWAG case. However, the business cases indicate that logistics and financial supply chain services generally represent a driving factor for leveraging sustainability potentials in the investigated business cases. Here, supply chain services and the related infrastructure of network integrators demonstrated their relevance for the acquisition of new customer segments as well as to scale up (sustainable) businesses while contributing to necessary critical market shifts. Measurable effects in quantitative terms of sustainability benefits, such as CO2 emission reduction and generally higher resource efficiency, are enabled by the stronger network integration and coordination of small-scale farms and production sites. Further effects on social sustainability are enabled through integrative coevolution between production and (partly new) retailing structures as well as stakeholder-tailored business strategies to decrease (sustainability-related) risks and to build new (knowledge-based) capabilities. Accordingly, the investigated driving factors extend current empirical knowledge about local food networks.

The cases also have shown that there seem to be limits to the scalability of the mentioned effects since the number of producers and retailers in a certain region is limited and thus represents a hurdle for expansion. Thus, barriers could be seen in the cases which hinder transferability and scaling of regional food business models. In the literature on mass market companies, such barriers might be a less supportive organizational culture, employee resistance, and the time span from idea generation toward implementation (Melkonyan et al., 2017). However, the observed barriers in the cases are even more fundamentally embedded in the business model structure. Considering the value proposition, none of the observed cases can provide a full-range product offer (one-stop shop) so far. To avoid additional consumer shopping trips, full-range product greater than 2000 articles is required. Considering investments in supply chain infrastructure, higher volumes are necessary to build an independent (logistics) infrastructure. Accordingly, growth rates are relatively small, which might be a competitive disadvantage. Considering the consumer interface, consumers are used to paying cheaper sale prices in online markets although additional delivery services are offered. Due to this price transparency, parts of the trade margin are still used to cover additional logistics costs (Table 3.3).

Table 3.3: Driving factors for local food networks

Analytic category	NETs.werk Hörsching	RWAG Freiburg
Extending the value proposition towards additional services	Logistics service: Providing additional infrastructure to implement a new distribution channel.	Financial services: Supporting entrepreneurs in financing their businesses and cooperating in a local network; one of the foci is on succession of farms.
Personalization of operational processes	Providing additional customer services such as claim and retour management.	Network members meet four times a year for personal exchange (also for initiation of business cooperation).
Efficient and green operations with the help of network integrators	Service provider Schachinger as network integrator: consolidating and bundling of goods flows with the help of e-vans, increased resource usage through extending an existing service; NETs.werk as network integrator: access to advanced ICT.	RWAG as network integrator: access to financial resources through RWAG (production or use of organic products as precondition).
Co-evolution with local partners	Cooperation with local logistics experts.	Cooperation and exchange mainly with partner companies.
Sharing supply chain costs and risks among network members	Charging customers for a part of delivery costs and co-financing the delivery service from the product margin.	Diversified investments into the network companies help to reduce risks; a scheme for profit redistribution among members is planned.
Scalability on local level	Limited number of local farmers limits growth on the supply side, therefore there is only the possibility of multiplying the business model in other regions.	Through regional growth, diversification, and financial investments RWAG is able to increase the number of network member companies.
Investments in infrastructure	Use of Schachinger's existing infrastructure, higher volumes are necessary to build independent logistics infrastructure.	High investments are financed through profit sharing or new rounds of capital increase.
Acquiring new Customer segments	Business-to-business customers such as restaurants, kindergartens, and nursing homes.	Through new rounds of capital increase, citizens in the region can become shareholders.

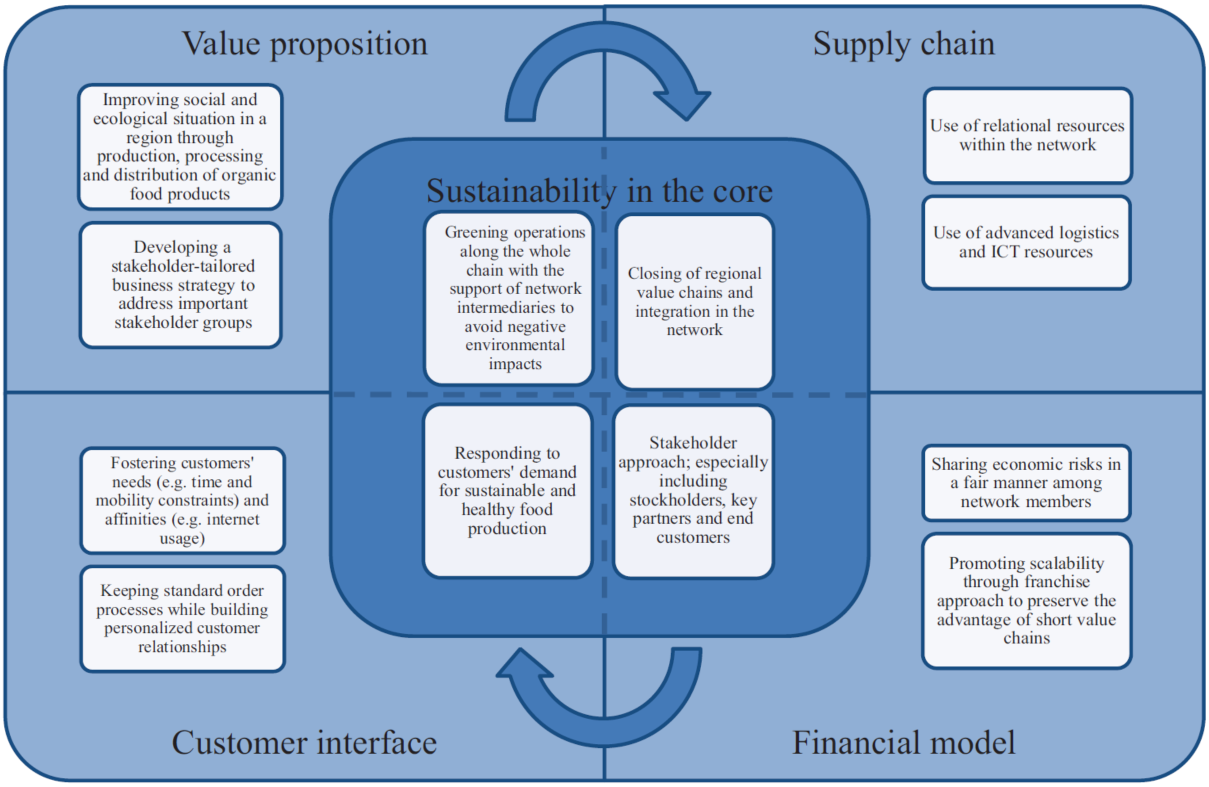

Figure 3.9: Conceptual sustainable business model framework for local food networks

3.3.5 Discussion

In this study, we were able to construct a framework for sustainable, local food business models by analyzing two networks with a business case closely connected to particular ideas of sustainability. Thus, we could show that a sustainable business case needs to be approached in a systematic manner. In this sense, the present study is generally embedded in the research stream of supply chain coordination (SCC) as coordination and planning between several entities of a supply chain take center stage in this research. Skjøtt-Larsen (2000) defines SCC as coordinated collaboration between several companies in a network to share opportunities and risks, using an integrated planning based on a common information system. Similarly, Simatupang and Sridharan (2002) see SCC as a collaboration of independent companies to operate more efficiently as if operations are planned and carried out separately. In this context, Kanda and Deshmukh (2008) provide an SCC classification model where specific coordination mechanisms are described. Regarding these SCC mechanisms, they distinguish between contractual coordination, coordination through information technology, coordination by information sharing, and joint decision-making. So far, the related literature highlights how effectively coordinated relationships can help manage potential economic supply chain risks (e.g., Scholten and Schilder, 2015). Therefore, logistics and financial coordination practices used to have a supportive role to primary functions such as purchasing, manufacturing, and sales in conventional business models (Halldorsson and Skjøtt-Larsen, 2004). Although the definition of logistics services has been expanded in the last years to also cover warehousing and transportation activities, purchasing, distribution activities, inventory management, packaging, manufacturing, and even customer service (Bowersox and Closs, 1996), they are still often analyzed from a purely economic point of view aiming to achieve competitive advantage (e.g., McGinnis et al., 2010). However, the necessity for logistics, technological, and financial coordination capabilities to facilitate sustainable practices and businesses is coming to the fore as concerns for environmental and social issues within the society and at consumer side rise. Consequently, these capabilities can be interpreted as a key determinant for sustainability in supply chains.

Including the extended sustainable business conception developed by Boons and Lüdeke-Freund (2013), drivers to further promote economical, ecological, and social sustainability in local food networks were identified on three main levels of the business model, in particular on the very core of the business model, its downstream SCC, as well as its upstream customer orientation. With regard to downstream SCC through technological, logistics, and financial integration (cf. Vachon and Klassen, 2008), the present study could show that such forms of collaboration do not just lead to a higher environmental performance but also contribute to the social dimension of sustainability. With regard to upstream customer orientation, service innovations play a major role in extending the value proposition of local food networks. In accordance to Kandampully (2002), three characteristics for service innovation promoted by SCC could be observed: (1) technology, (2) knowledge, and (3) relationship networks. The knowledge sharing and coevolution of the supply chain partners were enabled through deploying ICT technology in the Nets.werk case and through setting up a separate company in the RWAG case that is responsible for the personal exchange within the network. Hence, the central intermediary companies in the investigated cases do not just place considerable importance on relationships and networking downstream but also upstream the supply chain to enhance customer satisfaction and firm performance. Tackling the core of the observed sustainable business models, green process improvement could be achieved through redesigning structures and relationships, in the Nets.werk case particularly in the last mile. Moreover, social benefits could be achieved through incorporating stake- and shareholders in operational business activities and vice versa motivating farmers as well as retailers to become shareholders of the network, in particular in the RWAG case. Accordingly, the creation of logistically, technologically, and financially integrated networks improves the current business paradigms of local food networks by numerous green and social benefits such as the achievement of greater process efficiency, increased customer satisfaction, better strategic planning, as well as more flexibility and adaptation to market changes.

Highlighting these possibilities and the three core characteristics for service innovation discussed above, this work also shows the importance to shed light on communicating sustainability benefits. Sustainable supply chains need to be managed well internally – and thus well-communicated – and they need to be recognized externally as well. Lüdeke-Freund (2014, p. 311) was able to show that reputational effects were “the most important driver but also the most complex and hard to manage one.” This refers mainly to external communication, forming the basis for reputation. There are numerous approaches to external communication of social and ecological engagement: Ruppert-Winkel et al. (2017) published a brochure presenting the possible ways to communicate social and ecological measures externally. Among them are brands, sustainability reports, and the usage of social media. Their usage is vital to get recognition for the actions taken, and this might also be of importance for companies moving toward sustainable business models, because also their benefits need to be recognized. The academic debate in this regard is still only beginning and offers gaps for future research.

The same is true for internal communication. Companies operating with sustainable business models – just like the two network examples discussed in this paper – need to reinforce the values and norms incorporated in the business model. At the same time, the employees need to recognize the business model themselves and reinforce its authenticity. Therefore, also the communication internally is central for sustainable business models. Also, this aspect is highly under-researched. One possibility to approach this gap would be, again, to turn to literature on CSR communication, such as Stehr and Struve (2017).

Moreover, the empirical findings also indicate that the conceptualization of sustainable business model archetypes (cf. Bocken et al., 2014) becomes less important when talking about business model innovations in specific industry contexts. Considering the investigated business types, the combination of various business model elements from different business model archetypes becomes apparent. The cases combine certain technological, social, and organizational elements to at least partially attract different target customer groups.

3.3.6 Conclusion and Outlook

So far, only a minority of local business cases reaches international benchmarks of the food branch, since most local food production networks still operate in a niche and often lack integrated logistics and ICT designs and related skills to a large extent (Bosona and Gebresenbet, 2011). Hence, necessary logistics and financial capabilities can help local food networks to achieve a higher sustainability performance by leveraging the companies' embedded sustainability potentials in their core business. Moreover, enough coordination facilitates necessary investments in infrastructure and more innovative distribution channels, increasing the competitiveness against conventional food supply chains.

In addition, trends in various other industries parallel to the food sector show a tendency toward decentralization and a strong need for integrated and consolidated services on the operational levels of the supply chain, particularly with respect to future sustainable economic systems and transition pathways. However, how far the role of decentralization accompanied with logistics and financial coordination can be transferred into other branches (material and chemical industry, mobility services, fashion, electronic sector, etc.) is a matter for further research. The food sector shows a high potential for especially regional patterns of production and consumption, unlike other sectors, where such potentials might be much harder to implement.

Concluding the present study, it can be argued that SCC have a high relevance for small-scale local and organic food business networks to achieve upscaling effects in regional markets. It was demonstrated that specific sustainable business model elements can effectively contribute to a sustainable value-added chain for the main interacting supply chain partners: local food producers, processing and distributors, network integrators, and (responsible) consumers in a regional market. Accordingly, the study at hand shows that in particular logistics and finance can play a fundamental role in pointing out alternative operational modes in business models of a future green economy system, with respect to the content instigated in the food industry.

3.4 Communicating Sustainable Logistics Innovation to various Consumer Groups (Lubjuhn, Bouman, Lutkenhaus, Krumme, 2019)

The following chapter is a book chapter by the author of this dissertation with Sarah Lubjuhn (Centre for Media and Health, the Netherlands), Martine Bouman (Erasmus University Rotterdam/ Center for Media and Health, the Netherlands) and Roel Lutkenhaus (Center for Media and Health, the Netherlands), published in the peer-reviewed *Springer Nature Volume "Innovative Logistics and Sustainable Lifestyles"*, edited by Ani Melkonyan (University of Duisburg-Essen) and the author in 2019.[24]

The presented research was part of the project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015).

Any reference to this chapter should be cited as:

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Abstract

Advancing sustainable logistics processes requires transitions on consumer side too, i.e., changes in knowledge, attitudes, and lifestyle behaviors. With this perspective, the scientific field of sustainability communication has demonstrated the importance of tailor-made (sub-) target group communication that goes beyond the frequently used "one-size-fits-all" communicative approach.

Up to now, little is known about how to effectively communicate sustainable logistics innovations to relevant consumer groups. This research study aims at designing adequate communication strategies that make potential innovations such as a fair logistics label for products or a sustainable logistics button for online shopping attractive for consumers. The following research questions are answered:

[24] Klaus Krumme contributed to this chapter the interdisciplinary research strategy and the methodological approach of the underlying project. In this contribution, he was specifically responsible for reflecting and discussing the research results from the perspective of sustainable supply chains and for service providers in the field of logistics and retail.

(RQ 1) What are target group-specific patterns with respect to sustainable logistics processes?

(RQ 2) Based on RQ1, which communication scenarios facilitate the use of sustainable logistics innovations of various consumer groups?

This article presents six consumer communication scenarios in the field of online fashion and sustainable products in grocery stores. The development of these communication scenarios is based on a qualitative pre-study (N = 10) and a quantitative study (N = 355) with consumers aged between 20 and 40, who order fashion online and who buy sustainable products in grocery stores.

Based on (a) the analysis of knowledge, attitudes, and practice, (b) media and communication preferences of the target group members, as well as (c) their preferences for various sustainable logistics innovations and how they should be shaped in practice, the communication scenarios were developed to effectively reach these groups.

Keywords

Communication strategies on sustainable logistics innovations, Target group specific patterns, Consumer groups, Consumer lifestyles and behavior, Sustainable logistics, Communication scenarios

3.4.1 Aim and Research Question

Advancing sustainable logistics processes requires transitions on consumer side too, i.e., changes in knowledge, attitudes, and lifestyle behaviors (Krumme et al., 2015). With this perspective, the scientific field of sustainability communication has demonstrated the importance of tailor-made (sub-)target group communication that goes beyond the frequently used “one-size-fits-all” communicative approach (Reinermann et al., 2014; BMUB and UBA, 2015; Lubjuhn and Bouman, 2015). Up to now, little is known about how to effectively communicate sustainable logistics innovations to relevant consumer groups (Mont, 2007). This research study aims at designing adequate communication strategies that make potential sustainable logistic innovations (such as a fair logistics label for products or a sustainable logistics button for online shopping) attractive for consumers. The focus of our research is on shopping online fashion and/or buying sustainable products in the supermarket. The following research questions are answered: (RQ 1) What are target group-specific patterns (including media preferences, knowledge and educational level, and values) with respect to sustainable logistics processes among different consumer groups? (RQ 2) Based on the findings of RQ1, which communication scenarios can facilitate the use of sustainable logistics innovations of various consumer groups? The answers to these questions result in the design of communication scenarios presented in this article.

3.4.2 Theoretical Framework

There are two theoretical notions integrated into the framework of the research process: the stages of behavior change theory (Prochaska et al., 1992, 2002) and the sources of influence model (Grenny et al., 2013). The stages of behavior change theory assume that target group members follow different stages of behavior change with respect to a problem: (stage 1) no knowledge/awareness of the problem, (stage 2) knowledge/awareness, (stage 3) intention to act, and (stage 4) action and maintenance. The idea behind the model is that first the stage of behavior change of a target group member must be identified before measures can be developed to address and reach them. Four different stages of change have been formulated for the field of “sustainable logistics and online fashion” as well as “buying sustainable products in the supermarket.” These stages were used in the process of developing various communication scenarios based on the results of the qualitative and quantitative studies. The communication scenarios, which are described below, include recommendations on how to address target group members to reach the next stage, respectively, to maintain their behavior change on long term. The source of influence model (Grenny et al., 2013) differentiates between six main influential factors that allow change to happen: (1) personal motivation, (2) personal ability, (3) social motivation (are there, e.g., people in the environment who facilitate or who hold someone off?), (4) social ability (is someone dependent on others to act a specific way?), (5) structural motivation (are there, e.g., legislations who facilitate a specific behavior or not?), and (6) structural ability (are there, e.g., special means to perform a behavior which are not accessible to someone?). The source of influence model shows how complex behavior change can be. In practice complex problems (and their solutions) are often treated as simple ones, and it is assumed that solutions are easy and linear (Papa et al., 2006; Westley et al., 2007). Grenny et al. (2013) assume that the tipping point to complex problems is reached when four out of the six influential factors are tackled. Then the probability is high that complex problems can be solved and behavior can be changed. For this research the sources of influence model structure were applied through tackling the six relevant factors that are crucial to behavior change for each communication scenario.

3.4.3 Method

3.4.4 Participants

The following target group members (or study participants) for this study have been selected: people aged 20-40 years, who buy online fashion and/or who are interested in buying sustainable products in the supermarket. Beside these two main categories, the criteria “degree of urbanization” and the “educational level” of the target group members have been taken into account (SINUS, 2017). Also, it was important to know whether the study participants live in a relationship or not and whether they have children or not, because this can be of influence on their shopping behavior.

3.4.5 Research Methodology

In order to be able to design communication scenarios for sustainable logistic innovations, we conducted two research studies: First, an explorative qualitative study (N = 10) has been implemented, followed up by a larger quantitative study (N = 355). The results from the explorative qualitative study, were used to design and pretest the survey questionnaire. Study participants of the quantitative study were enrolled via an online panel. Both studies had three different research topics: (1) knowledge, attitudes, and practices of the study participants with respect to shopping online fashion and/or buying sustainable products in the supermarket (including stages of change); (2) knowledge and attitude toward sustainable (future) logistics innovations; and (3) communication and media channels that are used by the study participants. In this larger quantitative survey, we incorporated questions about the various stages of change. Respondents could score on various items, such as: “I am aware that I have to consider sustainable transport and delivery conditions when buying fashion online, but at the moment I don’t do it.” (stage 2, knowledge/awareness) or “When I order fashion online the next time, I would like to place a sustainable order” (stage 3, intention to act). This information can help to design communication interventions that can guide target group members from, e.g., stage 2 (knowledge/ awareness) to stage 3 (intention to act) or even to stage 4 (action and maintenance). Table 3.4 gives an overview on the sustainable logistics innovations that were selected for this study on the consumer criteria: relevance, convenience, costs for the consumer, and applicability in everyday life.

3.4.6 Results

The communication scenarios, being focused on sustainable logistic innovations (described in Table 3.4), are presented in this section. They are developed for various stakeholders such as business companies, nongovernmental organizations, and policymakers. They aim to give an overview on the potential actions, which might be taken by these stakeholders in practice. The choice for the target group for each scenario, the recommendations for the implementation, and the communication and media preferences are based on the qualitative and quantitative study results (see also Lubjuhn and Bouman, 2017a, 2017b; Lubjuhn et al., 2017).

Table 3.4: Overview of sustainable logistics innovations

Aim[a]	Sustainable logistic innovation	Online Fashion (OF), sustainable products in the supermarket (SPS)	Does it already exist?
Creating transparency	Sustainable logistic seal	SPS	No
	Information terminal, "sustainable logistics" in the supermarket	SPS	No
	Information on the shopping receipt[b]	SPS	No
Optimize logistic chains	Sustainable Logistic Button (SLB)	OF	Sometimes
Reduce return orders	High-quality visualization fitting tool in online-shops	OF	Sometimes
	Bonus system for consumers who do not cause return orders	OF	Sometimes

a Also compare DCTI (2015)
b This innovation was originally integrated in the explorative qualitative study. However, this was later skipped in the quantitative study because study participants did not find it useful to introduce this option in practice

3.4.6.1 Communication Scenario 1a: Sustainable Logistics Button (SLB) for the Target Group Members Who Buy Clothes in Online Shops of Lower Price Segments

Target Group

- Women
- Especially: women with a lower educational level (German "Real- or Hauptschule" degree).
- Especially: women with less money available.
- This target group buys clothes, e.g., at kik, bonprix oder C&A.

The primary aim of this communication scenario is to optimize the logistics chain through the application of a sustainable logistics button (SLB). With a SLB we mean a sustainable alternative to the conventional order, which takes, e.g., into account environmental impact of the product delivery or if the deliverer has acceptable working conditions.

Stage of Change

This female target group is in the stages 1 and 2 "(no) knowledge/awareness." The majority of this group is not aware of the fact that either sustainability issues in general or sustainable logistics can be taken into consideration when shopping fashion online. Target group is willing to use a SLB under specific circumstances, if they have no disadvantages from it.

I would use such a button (SLB). I am always willing to do something good, however, there should be less or no disadvantages for me.

Ordering Process

During the online ordering procedure, this group wants to situate the SLB at the location where the ordering details are checked and the order is placed. In addition, this group wants to be informed at the beginning of the ordering process that there is a sustainable alternative, e.g., when they get interested in a fashion item. They want to be reminded several times that there is the SLB available. I would place the SLB on the website where you check everything. On this site I am always very concentrated and calm (she laughs). I check if the size is correct, I check my address, the price, my bank details and everything. At this point, I would like to have the option for the SLB.

Willingness to Pay Additional Costs and Have a Longer Waiting Time

Women who buy low-price online fashion are not willing to spend additional money for a sustainable logistics delivery. However, they are willing to wait longer for the sustainably delivered fashion item. Approximately 40% of the female participants indicate that they are willing to wait 1–3 days longer for a sustainable delivery. Approximately another 40% would wait 4–6 days longer, and the rest would wait even 7 days or more. Hence, if it is not a rush order, e.g., if the clothes are urgently needed for an upcoming wedding or party, longer waiting times are accepted for a sustainable logistics delivery. It would be an option to combine the application of a SLB with a bonus system (see “Communication Scenario 3”), so that the incentive to use this sustainable logistics innovation is even higher for this target group.

Background Information

This group likes to receive background information on the SLB, if this information is short and understandable for them. Also, they want to receive background information on the same website where one can activate the SLB. External links with more information about the SLB are not welcome.

Communication and Media Preferences

It is important to address this target group through specific items in the web shop. A short information box including a checklist can catch the attention of these females. Moreover, storytelling elements combined in a short awareness-raising clip are useful to make the SLB attractive to the target group members. Elements of the entertainment-education strategy

(Bouman, 1999), in which entertaining and educational elements are combined, are recommended to be used. The qualitative research showed that this female target group is keen to have a short clip that portrays everyday life. They can, e.g., very much relate to the topic of the deliverer's working conditions. Thus, a possible story could address which things would change for the deliverer if the client orders her clothes with the SLB. I would love to have a short video clip, which entertains and also informs me. Maybe a pop up, which I have to watch before proceeding my order (she laughs). The clip should be emotional, moving and short. This target group enjoys watching TV, especially private broadcasting channels. They like to watch entertainment shows, especially soaps and telenovelas, they read TV guides and women magazines (offline and online), and they frequently use Facebook, Facebook Messenger, as well as WhatsApp.

Starting Points for Change

Which matters should be taken into consideration to sensitize this target group for the SLB? The following overview (Table 3.5) shows measures, which enhance the probability that the female target group members, who buy low-price online fashion, can be effectively addressed through a SLB.

Table 3.5: Communication Scenario 1a: Sustainable Logistics Button

	Motivation	Ability
Personal	To motivate the target group personally… • Framing: "do something good" and "order sustainably and only wait a little longer". The use of Nudging elements could also be effective here.	To enable the target group personally… • Short and easy to understand information about the SLB. • Take preferences on background information and ordering options into account. • Make sustainable logistic orders possible through "one click".
Social	To motivate the target group socially (use group dynamics)… • Take "Tell-a-friend"-option into consideration incl. Facebook (site-share), Facebook-Messenger and WhatsApp. • Use the option "Clients, who ordered this item also used the SLB".	To enable the target group socially… • Service offers of the fashion web shop e.g. a service hotline. A service team could assist if a target group member is thinking of using the SLB, but has questions about it, e.g. about the ordering process or how to order it technically. This group of women often feels embarrassed when having questions. It is thus recommendable to create an offer for them that addresses this challenge (indirectly).

Structural	To motivate the target group structurally… It is helpful to consider the following questions before introducing the SLB in the web shop: • (1) Is a SLB accepted by different stakeholders in the company? (2) Which consequences does the answer to this question have for the design and implementation of the SLB? • In how far does the SLB fit to the holistic sustainability/CSR strategy of the company?	This level plays a less significant role.

3.4.6.2 Communication Scenario 1b: Sustainable Logistics Button (SLB) for the Target Group Members Who Buy Clothes in Online Fair and Eco-Fashion Shops

Target Group

- Women and men having a higher educational level (in Germany above “Mittlere Reife”).
- Women and men with more money available.
- This target group, e.g., buys clothes online, e.g., at Hessnatur and/or Armedangles.

The primary aim of this communication scenario is to optimize the logistics chain through the application of a sustainable logistics button (SLB).

Stage of Change

This target group is (well) informed about sustainability topics and fashion, and these women and men buy clothes (more or less often) in fair and eco-fashion web shops. This group already acts sustainably (stage 4, action/maintenance), and it is important to give them incentives to maintain their behavior. This group of people welcomes innovations like the SLB and is willing to use them. Fair and eco-fashion shops can be recommended not only to introduce the SLB as an alternative to the conventional delivery but to consider the SLB as the only delivery option, as several fair and eco-fashion shops already do in Germany.

Ordering Process

Women and men who can be targeted through this communication scenario already have made some experiences with sustainable logistics options such as “DHL GoGreen” or “CO_2 neutral delivery.” During the ordering process, they want to situate the SLB at the point where they check their ordering data and place their order. Moreover, it is recommendable to already address the SLB option when they put items in the shopping basket.

Willingness to Pay Additional Costs and Have a longer Waiting Time

This target group is willing to pay more for a sustainable logistic delivery. The costs should not extend 4 euro per each delivery. Also, this group is willing to wait up to 6 days longer for their sustainable logistics delivery (some group members would even be willing to wait longer). I would definitively wait longer for my products, if it would not take a month or so. In general, men of the target group are less willing to wait longer for their sustainable logistics delivery in comparison to women. It would be an option to combine the application of a SLB with a bonus system (see "Communication Scenario 3"). This option would especially be attractive for those target group members who are not yet regular customers at fair and eco-fashion web shops.

Background Information

This group is interested in receiving background information about the SLB. They find it attractive to receive this information on an external website. The link to this external website should be situated where the target group members check their order details and place the order. This group also explicitly asks for additional information about the SLB with various links available. I would trust such an initiative without asking. However, background information on the SLB should be available. This would be important for me, so I can check the information when I have some time.

Communication and Media Preferences

This target group needs to be addressed through the web shop itself. In comparison to the other groups, the women and men probably use the SLB without initiating additional communication activities. They are already aware of sustainability (logistics) topics in the field of fashion and act on it. When introducing the SLB, it is important to give information on this sustainable delivery alternative clearly and transparently. For this target group, it would be attractive to receive background information about the SLB by using an animated short clip. The clip should give various facts about the measures the company implements in the field of sustainable logistics. This target group prefers television (public and private broadcasting stations), social media (especially Facebook and Pinterest), and messenger services (such as WhatsApp, Facebook Messenger, Threema). These are good channels to use for follow-up communication.

Starting Points for Change

Which starting points can be used, so that the target group (increasingly) uses the SLB? As mentioned earlier, this group of women and men is easy to reach. They only need little, if no additional, incentives to use the SLB. The following overview (Table 3.6) shows examples of measures, which fair and eco-fashion companies can implement in their web shops to address this target group with a higher educational level and who (by tendency) have more money available.

Table 3.6: Communication Scenario 1b: Sustainable Logistics Button

	Motivation	Ability
Personal	To motivate the target group personally… • Address the awareness of sustainability. The use of Nudging elements could also be effective here.	To enable the target group personally… • Detailed information on SLB • Consider background information and ordering process preferences.
Social	To motivate the target group socially (use group dynamics)… • Take “Tell-a-friend”-option into consideration incl. Facebook (site-share), Facebook-Messenger and WhatsApp.	To enable the target group socially… • Offer services on SLB in the fashion web shop (e.g. hotline, chat function etc.).
Structural	To motivate the target group structurally… • Give a more detailed overview on the sustainability (logistic) activities of the web shop. • Inform about the SLB via newsletters, Social Media and other channels.	This level plays a less significant role.

3.4.6.3 Communication Scenario 2: High-Quality Visualization Fitting Tool in Online Shops for the Target Group Members

Target Group

- Women, who do not (yet) buy items in online fair and eco-fashion shops.
- Especially: women with one or more children.
- Especially: women, who live in a relationship.

The primary aim of the communication scenario is to reduce the reverse logistics through the use of a high-quality visualization tool for virtual fitting rooms in online shops.

Stages of Change

Target group members of this communication scenario are mainly in stage 1 or stage 2 having “(no) knowledge/awareness” of the issue. They are less or not aware that sustainability aspects in general, and especially sustainable logistics aspects, can be taken into consideration, when doing online fashion shopping. If this group can save time and/or money through a high-quality visualization tool in a virtual fitting room, they are willing to use this tool on a regular basis under specific circumstances.

Content Virtual Fitting Room

This group of women has some ideas about how such a virtual tool can look like; however only a few of them have used such a fitting tool in practice, e.g., for sunglasses. Most of the target group members think that such a tool works in a following way: the client uploads a picture of the whole body, and with this picture, it is possible to t various fashion items. Women from this target group would be willing to use such a high-quality fitting tool for t-shirts, shoes and boots, skirts and dresses, sweaters/waistcoats, jackets, accessories (e.g., hat), trousers, or glasses.

Use of the Tool and Return Orders

Especially those women with children and those who live in a relationship indicate that such a virtual fitting tool would help them to reduce their rate of return orders as well as to make better choices when ordering clothes online. At the same time, they are not sure if such a tool is able to realistically depict their body measurements. Thus, when implementing such a tool in reality, it is very important for the target group members to have a high-quality fitting tool, which deals with the wishes and needs of the target group. In the future it, e.g., would be possible to involve virtual or augmented reality elements for this tool to guarantee a more authentic visualization.

I think I would put less into the shopping basket when I have such a high-quality fitting tool. I could then see ‘okay, this woman is also not really thin like me and the t-shirt e.g. does not suit that well in this size’. However, it really must be a high-quality tool, otherwise it makes no sense for me.

If I could see how the fabrics are, how the skirt let’s say ‘moves’, that would be great. I would definitively be willing to try and use the tool and I can imagine that it would help me to reduce my rate of return orders.

This group of women has less time, and they want to use a tool that gives them a quick overview and makes it possible to facilitate their decision to (not) order a fashion item. A virtual fitting tool where the clients need to measure their own size is not an option for the target group. It must be a tool where time can be saved, e.g., through a webcam that automatically measures the body size and gives recommendations for specific fashion items.

Data Privacy

A small minority of the target group thinks critically about the high-quality virtual fitting room, because they do not want their body measurements to be shared with the online shop. When introducing such a tool, it would be very important to address such an issue, e.g., through letting the target group members decide on their own, if they want their personal data to be saved in the web shop or not. These kinds of measures enhance the probability that the target group members can effectively be addressed through a high-quality virtual fitting room.

Communication and Media Preferences

In the case of the virtual fitting tool, the target group should be addressed through the web shop itself. The client can, e.g., be advised to use the tool, when she virtually enters the fashion web shop or when she is interested in a fashion item. For the target group, it is appealing to create a short clip, which describes how the visualization tool works and which advantages the client has from using this tool. Target group members can be effectively addressed through social media (especially Facebook). In addition, women from this group frequently watch private broadcasting channels and especially entertainment media shows such as soaps or telenovelas. Many of them like to read TV guides and women magazines (offline and online), and they frequently use messenger services such as WhatsApp.

Starting Points for Change

Which starting points for change can be applied so that the target group members frequently use a high-quality virtual fitting tool with the aim to reduce the rate of return orders? The following overview (Table 3.7) shows examples of measures that can strengthen the motivation and the ability of the targeted women with children and/ or living in a relationship.

Table 3.7: Communication Scenario 2: Online Fitting Tool

	Motivation	Ability
Personal	To motivate the target group personally… • Address the saving in time: The tool enhances the probability that the "right" fashion item can be found quickly. • Rate of return orders can be minimized. To send the fashion items back sometimes also can be hectic for the targeted woman. • Address that the target group members can do something for the environment (e.g. to help the company to act more sustainably in the field of logistics). • For target group members, who like to fit clothes: Make it fun! Addressing the "fun-factor" and the authenticity of the tool. • The use of Nudging elements could also be effective here.	To enable the target group personally… • Detailed information on the virtual fitting tool. • A short clip and/or pop-ups that describe(s) how the tool works.

Social	To motivate the target group socially (use group dynamics)… • Take "Tell-a-friend"-option into consideration incl. Facebook (site-share), Facebook-Messenger and WhatsApp. • Show experiences of other clients who have used the tool. • When successful, spread the word about the innovative visualization tool via media (magazines, TV, newspapers) wherever possible.	To enable the target group socially… • Offer services for the innovative tool (a hotline, chat function etc.).
Structural	To motivate the target group structurally… • Show why it is important in general to reduce the reverse logistics and why the company is working on this. • Use newsletter, Social Media and other channels to inform about the virtual visualization tool.	To enable the target group structurally… • Implement different versions of the innovative tool: e.g. there could be a version for clients having "fast internet access" with Virtual or Augmented Reality elements, and a slower version e.g. for mobile internet.

3.4.6.4 Communication Scenario 3: Bonus System for the Target Group Members Who Do Not Cause Return Orders

Target Group

- Women and men who buy or do not (yet) buy items in online fair and eco-fashion shops.
- Especially: women and men, who live in rural areas (<20.000 inhabitants). The primary aim of this communication scenario is to reduce the reverse logistics through increasingly establishing bonus systems in fashion shops.

Bonus System as a Reward for All Target Group Members

A bonus system for clients who do not cause return orders is very popular among the members of the target group. Not only those women and men who order a lot but also those who only sometimes order fashion online are interested to use such a system. The main success factor is the reward that everyone gets when using such a bonus system. I do not order so many clothes online. Only now and then, and I almost never send them back. However, if I have to pay as much money as someone who often returns her/his orders, I would be angry. Such a reward system is different. I like the idea very much.

Stages of Change

The Target Group Is on Different Stages of Change:

- Women and men who do not (yet) buy items in online fair and eco-fashion shops: stages 1 and 2 – "(no) knowledge/awareness"
- Women and men who buy items in online fair and eco-fashion shops: stage 4 – "action/maintenance"

What all target group members have in common is that they think very positively about the introduction of a bonus system for clients who do not cause return orders.

Reducing Return Orders

Women and men from the target group highly agree on the statement that such a bonus system would be an incentive for them not to order (in different sizes) and return less fashion items. This is also true for the target group members living in rural areas of Germany.

Whether such a bonus system really can be an incentive (especially for clients who order and return a lot) depends on the implementation of the system in the web shop and how the bonus system fits the needs of the respective clients.

Implementation

Target group members find different bonus systems attractive. This could be a system that gives a price reduction on the next item to buy, when an order is not returned. Another idea is that the client can collect smaller amounts of money or points, and she/he decides when to use the bonus points. For the target group members, it is very important that they have an additional bene t using the bonus system. To become more aware of how an additional bene t can look like for the client, it is recommendable that the web shop implements a client survey before launching the bonus system. The results may show how a bonus system should look like in order to decrease return orders for this specific client group.

Variables with an impact on the behavior of ordering fashion and returning it include the value of the reward one receives, the validity time frame of the bonus, and the reminding options of the web shop to use the bonus.

For every fashion item you buy you get three euro on your bonus account. This money you can use when you buy the next item. This bonus you can use for three months, otherwise the three euro are gone. This time frame is too short and three euro is not enough. This is not an incentive for me. I continue to order a fashion item in different sizes and return the stuff that does not t. The target group members would be willing to use such a bonus system, either when a web shop introduces such a system on its own or when a web shop collaborates with the other web shops, so that the client can collect bonus points at various shops. The advantage from a collaboration is seen in the fact that more bonus points can be collected. The advantage of collecting the point in each shop is seen in the fact that the personal data of the clients is not shared with the others.

Communication and Media Preferences

There are a lot of possibilities to address the target group members with such a bonus system. When ordering in the web shop, the client can be pointed to the bonus system if she/he gets interested in a fashion item and/or when the client puts the item into the shopping basket. A big advantage of this innovation is that it is easy to explain and understand. Also, the probability is high that target group members like the bonus system very much. Given this, the bonus system has a high potential to show the clients the importance to stimulate sustainable logistics processes in the fashion industry and the necessity to reduce the reverse logistics. To explain this, an animated short clip would suit to target group members who already buy in fair and eco-fashion shops. For those clients who do not yet buy in fair and eco-fashion web shops, a clip with storytelling elements would be more appealing. For targeting group members outside the web shop, it is crucial to consider the media preferences of the group. The following bullet points give some examples:

- Video channels: via YouTube, target group members having a higher educational background can also be addressed via Vimeo, Periscope, Ooyala, and Brightcove.
- Social media: especially Facebook and Instagram. Men more often use Twitter; women of this target group use more often Pinterest. Twitter, Pinterest, and LinkedIn are mainly used by target group members who have a higher educational background.
- Storytelling and entertainment-education elements especially for such subgroups, who are not yet interested in sustainability information and who do not buy in fair and eco-fashion shops (subgroup who are on the stage of change 1 and 2 (no) knowledge/awareness):
- Using videosoaps, vlogs, blogs
- Using entertainment media on private broadcasting channels such as soaps, mainly watched by women
- Magazines: male target group members are especially interested in news magazines or magazines for a specific interest. Women like to read TV guides and women magazines (offline and online).

Starting Points for Change

Here the question on how such a bonus system should be implemented in a web shop in order to actually reduce return orders, is as important as the question how to get target group members to use the bonus system. The following overview (Table 3.8) documents the measures on the level of motivation and abilities of the target group members.

Table 3.8: Communication Scenario 3: Bonus System

	Motivation	Ability
Personal	To motivate target group members… • Address the award when not returning orders. • Exemplify through calculations how fast using such a bonus system can pay off. • The use of Nudging elements could also be effective here.	To enable the target group members… • Clear and understandable information about the bonus system in the web shop.
Social	To motivate the target group socially (use group dynamics)… For those who not buy in Fair and Ecofashion shops: • Take "Tell-a-friend"-option into consideration incl. Facebook (site-share), Facebook-Messenger and WhatsApp to show which savings/awards the client has gotten and how much she/he increased the ecological footprint. • Document through calculation examples (e.g. a clip) which fashion item the clients bought from her/his bonus.	To enable the target group socially… • Establish services for the bonus system (Hotline, chat function etc.)
Structural	In the web shop… To motivate the target group structurally is helpful… • To show why it is important to reduce return orders and why the company is working on this. • To offer a reminder to redeem the bonus. • To use an animated clip or a video with storytelling and Entertainment-Education elements to exemplify sustainable logistics and awareness raising for Reverse Logistics at the web shop. • To inform via newsletter, Social Media and other channels about the bonus system.	This level plays a less significant role.

3.4.6.5 Communication Scenario 4: Sustainable Logistics Supermarket Quality Label for the Target Group Members

Target Group

- Women and men, who buy sustainable products in the supermarket.
- Especially: Men and women, who are aware of sustainability topics and who often buy sustainable products (consumers, who are aware or convinced).

The primary aim of this communication scenario is to create transparency in the field of sustainable logistics.

Acceptance

Target group members like the idea to introduce a sustainable logistics quality label. They can easily be addressed through such a label.

Stages of Change

Target group members are in different stages of change. There is a subgroup, the so-called nonconsumers or the coincidentally consumers (Ökobarometer, 2016), who consume less or no sustainable products in the supermarket. They are on the stage of change "(no) knowledge/awareness" (level 1–2). However, especially those people who consume sustainable products and who are on the stage of change "action/maintenance" (level 4) are interested in this quality label. Those people can be called the aware consumers or the convinced consumers (Ökobarometer, 2016).

Initiator of the Quality Label and Implementation

The majority of the target group wishes to have the government or a related institution as the initiator of the quality label. For me it would be important that the quality label is established in collaboration with a renowned organization and is supported by the federal government. When implementing such a label, it is recommendable to give short information about the sustainable logistics on the back of the product. The target group members wish to receive additional information on a specific website (e.g., compare the website of the quality label Blauer Engel). This information will be mainly used by consumers who are aware of the problem (stage 4). Especially men of the target group with a high educational background would use such a website with additional information. With respect to such a label it would be very important for me that the initiator communicates 'hey, this quality label stands for transparency and when you buy it, you buy a product with sustainable logistics behind'. And the quality label should also clarify how unsustainable other products are which do not have this label.

Building Confidence

Transparency, credibility, and high-quality standards are central pillars for the success of the sustainable logistics quality label. They are very important for the target group members. The majority of the target group does not like the development that various companies invent their own quality label. Thus, for a sustainable logistics quality label, the regulation of a renowned organization and/or government is crucial. This quality label should be regulated by the government or a comparable organization (…). So that everyone knows, okay, I can really count on this. A fair logistics quality label would be important for me. It is true, there are many labels. But if sustainability and fair logistics are important to me, then I have to get into this topic in detail.

Communication and Media Preferences

How to communicate about a sustainable logistic label is dependent on different factors. The following media preferences give examples of what is interesting for the target group members. A campaign for a sustainable logistics label should take these and other factors into account to holistically address the target group. The target group members (stage of change 4 action/maintenance") can effectively be reached by TV and newspapers. The following aspects can be especially taken into consideration:

TV:

- The target group members with a higher educational level and those who live in a city >100.001 inhabitants often watch public broadcasting programs.
- Men more often watch magazines (e.g., Frontal 21; Titel Thesen, Temperamente) and knowledge programs (e.g., Quarks & Co; TerraX) on public broadcasting channels in comparison with women.
- Men more often watch sport programs (e.g., Sportschau), whereas women prefer soaps and telenovelas (e.g., Sturm der Liebe; Rote Rose; Gute Zeiten, schlechte Zeiten; Unter uns). This is true for TV programs on public as well as private broadcasting channels.

Newspapers:

- Newspapers such as Süddeutsche, FAZ, and Welt are more often read by the target group members with a higher educational background.
- Newspapers are more often read by men than by women. This is especially true for the following newspapers: Süddeutsche, FAZ, Welt, and Handelsblatt.

Target group members who are on level 1–2 "(no) knowledge/awareness" and who are not yet interested in sustainability topics can effectively be addressed via TV and social media. For instance, target group members with a lower educational level (Real- or Hauptschule degree) mainly watch private broadcasting stations. This is true for those who live in more rural areas in Germany. This target group can be effectively addressed via Facebook and YouTube. This group of target group members buy products with a sustainable logistic quality label, e.g., because they like the design or the colors of the label, but not because they want to support sustainable logistics patterns in the first line.

Starting Points for Change

The following overview (Table 3.9) shows motivating and enabling measures for target group members that need to be taken into account when introducing a sustainable logistics quality label.

Table 3.9: Communication Scenario 4: Sustainable Logistics Label

	Motivation	Ability
Personal	To motivate the target group… • Co-creation of the seal including an awareness campaign together with target group members. • Address the added value when buying a product with the sustainable logistic seal. • Integrate storytelling and animated video clip elements where necessary (stage 1 and 2). • Use celebrity endorsement. • Use Social media and You-Tube, as well as TV, Newspapers and other media channels for the campaign. • The use of nudging elements could also be effective here.	To enable the target group… • give clear information on the product and on a website with additional information.
Social	To motivate the target group socially (use group dynamics)… • consider a “Tell-a-friend”-option, incl. Facebook (site-share), Facebook-Messenger and WhatsApp.	To enable the target group socially … • consider a Q&A option on the website of the sustainable logistic seal. • consider an exchange option for clients with the initiator of the seal to pose questions or give comments.
Structural	• Holistic integration in societal discourse: Why is sustainable logistics of products important and what needs to be done? • If necessary adaptation of legislation with respect to topics of sustainable logistics, to facilitate more (behavioral) options for consumers.	• Availability: Products with a sustainable logistic seal should be available in a variety of supermarkets and stores on the long run, so that different sub target groups can buy them. • Price: Ensure on the long run that not only (more) expensive products have the sustainability logistic seal with the aim to reach various target groups.

3.4.6.6 Communication Scenario 5: Information App and Sustainable Logistics in the Supermarket for the Target Group Members

Target Group

- Consumers, who are aware of sustainability topics and who often buy sustainable products.
- Especially: men, who are aware of sustainability topics and who often buy sustainable products (consumers, who are aware or convinced).

The primary aim of this communication scenario is to create transparency in the field of sustainable logistics through an information app.

Acceptance and Doubts

45.4% of the target group members have doubts if they would use an informational terminal or an informational app in practice. 36.9% of the target group indicate that they want to use this innovation to increase sustainable logistics processes. Because the acceptance rate is higher for an information app, in comparison to an informational terminal at the supermarket, this communication scenario is based on the information app.

Stages of Change

Target group members who can effectively be addressed through the information app are those who are aware of sustainability themes. They can be considered as “aware consumers or the convinced consumers” (see Ökobarometer, 2016) and are on the stage of change “action/maintenance” (level 4; also see “Communication Scenario 4”).

Implementation

Target group members are not sure if they want to use this sustainable logistic innovation. They like the idea to have an information app where they can scan the product code. Through the app it is thus possible to receive information about sustainable logistics when and wherever the target group wants. Men can better be addressed with the information app than women. In addition, it would be crucial to explore how far synergies of an information app and a sustainable logistics quality label (“Communication Scenario 4”) can be used. I do not like the idea of a terminal in the supermarket where you get information about sustainable logistics, but I like the idea of an information app. I want to have a look at that information at home or somewhere else.

I do not like doing grocery shopping. When using the terminal, I have to stay in the supermarket. No, this is not for me.

Aspects of a Sustainable Logistics

Target group members who indicate a willingness to use an information app say that it is very important for them to know where the product comes from. Also, the target group members want to have more information on the transport distances (how many kilometres did the product travel?) and about working conditions along the logistics chain. The aspect of how the product has travelled (via train, airplane, etc.) and the CO_2 footprint of the product are less important to the target group members.

Communication and Media Preferences

The target group members who are aware of sustainability themes and who are in stage 4 “action/maintenance” can effectively be reached via TV and newspapers (see “Communication Scenario 4”). The following overview shows media preferences of especially male target group members that are interested in sustainability themes:

- The target group members with a higher education level watch more public broadcasting programs in comparison to those with a lower level.
- On public broadcasting programs, men more often watch political and consumer magazines (e.g., Frontal 21; Titel Thesen, Temperamente) and knowledge series (Quarks & Co; TerraX) than women.
- Men more often watch sport programs (e.g., Sportschau) than women. This is true for public and private broadcasting programs.
- Target group members like to watch PayTV, especially Amazon Instant Video and Net ix. Men watch more PayTV than women.

Newspapers:

- Newspapers such as Süddeutsche, FAZ, and Welt are more often read by the target group members with a higher educational background.
- Newspapers are more often read by men than by women. This is especially true for the following newspapers: Süddeutsche, FAZ, Welt, and Handelsblatt.

Magazines:

- Also, men can more effectively be addressed through news magazines (e.g., Spiegel, Stern) and magazines for a specific interest (e.g., cars, technic, travelling, photos) offline as well as online. Men more often read these magazines than women.

Starting Points for Change

Table 3.10: Communication Scenario 5: Information App plus Supermarket

	Motivation	Ability
Personal	To motivate the target group … • Co-creation of the seal including an awareness campaign together with target group members. • design of an attractive and easy to use app. • Addressing the added value when buying a product. • Use TV, Newspapers and other media channels. • Answering the question in how far it is effective to combine a sustainable logistic seal with the information app.	To enable the target group… • clear information at first sight. It also would be possible to classify products through the use of simple categories (such as gold, silver and bronze). Through such categories it would be very easy to access for the target group members to what extend sustainable logistic processes have been taken into consideration.
Social	To motivate the target group socially (use group dynamics)… • consider a “Tell-a-friend”-option, incl. Facebook (site-share), Facebook-Messenger and WhatsApp. • Integrate examples how easy the target group members have used the information app.	To enable the target group socially … • consider Q&A option for the app. • consider to pose questions or give comments about the app.
Structural	• Holistic integration in societal discourse: Why is sustainable logistics of products important and what needs to be done?	• Availability: Ensure that the app runs on different operation systems. • Price: Ensure that the app does not cost much or nothing.

3.4.7 Conclusion and Outlook

This article depicted different sustainable logistics communication scenarios for various consumer groups:

- Communication Scenario 1a: Sustainable logistics button (SLB) for the target group members who buy clothes in online shops of lower price segments
- Communication Scenario 1b: Sustainable logistics button (SLB) for the target group members who buy clothes in online fair and eco-fashion shops
- Communication Scenario 2: High-quality visualization fitting tool in online shops for the target group members
- Communication Scenario 3: Bonus system for the target group members who do not cause return orders

- Communication Scenario 4: Sustainable logistics quality label in the supermarket for the target group members
- Communication Scenario 5: Information app “sustainable logistics” in the supermarket for the target group members

These communication scenarios give recommendations for target group-oriented sustainable logistics innovations in the field of online fashion and sustainable products in the supermarket. They show the importance of taking a variety of factors into account for contributing to a change in knowledge, attitude, and behavior of consumer groups when it comes to sustainable logistics processes. The majority of consumers want to add a sense of meaning to their behavior. They are willing to make a (small) contribution without restricting themselves. A central prerequisite for this is to consider their point of views and their stories. Their living environment and the ones of their partner, family members, friends, and colleagues play a decisive role in discovering what is (not) important for them. Changes in knowledge, attitudes, and behaviors are complex processes. At the same time, these transition processes can be influenced to some extent. For doing so, it is crucial to address consumers in (sub-)target groups. The communication scenarios described in this article aim to maximize the chances to change knowledge, attitudes, and behaviors of various consumer groups in the field of sustainable logistics processes. They show that beside the communication with the target group, there are several enabling and disabling, as well as (de)motivating, factors for fostering sustainable logistics behavior which come into play on a personal, social, and infrastructural level (also compare Grenny et al., 2013). This can be summarized as the principle of “knowing, being able, wanting, and being allowed to do it”: target group members must be aware of the sustainable logistics innovation, they must be able to use it, they must want to do it, and their new behavior should be socially acknowledged and allowed by their family and peers. These factors enhance the chances that the desired behavior will be performed. It is noteworthy that the survey found considerably longer delivery time tolerances in the field of E-commerce (e-fashion) for specific consumer groups investigated. The contrast between these reported consumer attitudes and the actual performance parameters of the logistics service providers, or the offered delivery speeds of web shops (for example, “same day”/ “next day”) is remarkable. In recent years, the delivery speed in the logistics and E-commerce sector has not only been highlighted, but delivery times have been steadily shortened. While delivery reliability (such as agreed delivery time windows) is known to be even more important in consumer satisfaction, delivery time is a conditional and fundamental function upon which other logistics performance parameters are based. As there are significant sustainability potentials in a deceleration of the supply chain (for example through better consolidation and capacity utilization) a central anchor point for higher sustainability gains in logistics might be found, without evidently disappointing customer expectations or generally creating competitive disadvantages. However, this only applies on the condition that both logistics services and their sustainability/unsustainability potentials are appropriately communicated to (or better “with”) consumer groups with respect to their personal needs, attitudes, knowledge backgrounds and wider social affinities. The study has identified a number of ways that can be integrated into the service portfolios of various cooperating supply chain partners to enhance sustainable logistics innovations. An open research challenge, however, exists in evaluating whether, in the face of heterogeneous performance characteristics of service providers in this area, specific consumer groups would still ultimately behave “sustainably” through de-speeded delivery. The study shows willingness of the investigated specific consumer groups and illustrates the need for intensified business-consumer communication. Whether this, building on the gained knowledge, with appropriate communication measures, maybe even can produce competitive advantages, would have to be investigated more deeply. However, this result also shows that e.g. changed framework conditions over all service providers (for example, by legal regulations or industry agreements) need not necessarily be negative for E-commerce rms.

3.5 A System Dynamics based Simulation Model to analyze Consumer Behavior based on Participatory Systems Mapping (de la Torre, Gruchmann, Kamath, Melkonyan, Krumme, 2019)

The following chapter is a book chapter by the author of this dissertation with Gustavo de la Torre (University of Duisburg-Essen), Tim Gruchmann (Westcoast University of Applied Sciences), Vasanth Kamath (T.A. Pai Management Institute, India) and Ani Melkonyan (University of Duisburg-Essen), published in the peer-reviewed *Springer Nature Volume "Innovative Logistics and Sustainable Lifestyles"*, edited by Ani Melkonyan and the author 2019.[25]

The presented research refers to the project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015).

Any reference to this chapter should be cited as:

de la Torre, G., Gruchmann, T., Kamath, V., Melkonyan, A., & Krumme, K. (2019). A System Dynamics-Based Simulation Model to Analyze Consumers' Behavior Based on Participatory Systems Mapping – A "Last Mile" Perspective. In A. Melkonyan & K. Krumme (Eds.), *Innovative Logistics Services and Sustainable Lifestyles: Interdependencies, Transformation Strategies and Decision Making* (pp. 165–194). Springer.

Abstract

The complexity of the term sustainability is encouraging both policy makers and industry, to expand their methodology of solving environmental, social, and economic issues. In the field of applied science, sustainability-related research is thematic, and policy driven; therefore, involving the widest possible range of stakeholders is of importance. High uncertainty problems and high-risk decisions such as sustainability-related topics are difficult to analyze and solve with conventional scientific approaches and tools. Accordingly, discrete, simple, and short-term systems regarding one specific problem are increasingly being replaced by dynamic, complex, long-term, real-time, interdisciplinary models. This peculiarity requires decision-makers to have a system thinking approach.

Participatory systems mapping (PSM) is, in this context, a methodology in which a structured process is used to design cause-and-effect relationships between different factors and

[25] Klaus Krumme introduced the method concept SD/ PSM to the project, which was implemented and developed here under the leadership of Gustavo de la Torre. He also contributed to the revision of the chapter.

elements in a defined system. It provides a multi-perspectival understanding of problems and can help to formulate effective policies for complex sustainability issues. This will be represented, in a first instance, as a causal loop diagram (CLD) and, subsequently, as a stock and flow diagram (SFD) which is an equation-based system dynamics (SD) modeling technique. This will be of assistance in developing strategies and recommendations for the food industry, where consumers are creating a dynamic environment through quickly adapting their consumption habits which are currently characterized by a growing demand for sustainable food production. As a result, this increasing importance of local and organic food logistics networks has a direct impact on the last mile and its sustainability performance. Therefore, the present study intends to contribute to the understanding of the system dynamics in local food logistics networks.

Keywords

Causal loop diagrams · System dynamics · Sustainability · Participatory systems mapping · Last mile distribution · Word of mouth · Innovation diffusion

3.5.1 Purpose of the Study

The purpose of this chapter is to discuss the relevant system elements, their interactions, and their future possible changes, combining and evaluating systems for future sustainable development under consideration of logistics services along the food supply chain. This is a system thinking-oriented holistic approach, optimizing the processes from environmental, consumer, and political perspectives (Jackson, 2003; Wolstenholme, 1990). With the help of participatory systems mapping (PSM) as a system thinking approach which has emerged in the last few years, participants jointly devise diagrams on a topical issue and develop policy recommendations. In this line, the paper discusses an experiment which applies this method concerning the issue of sustainable consumption in conjunction with the analysis of the supply chain of a case study. To analyze these practices systematically, the scope of the study was narrowed to the last mile, since the last mile serves as the “meeting point” of farmers/retailers and consumers’ behavior (Gruchmann et al., 2016). For this purpose, a case study has been analyzed. It is important to mention that system mapping has many significant features that can enrich participatory methodologies. However, the participatory potential of systems mapping might be limited because it can be demanding for groups with lower levels of knowledge. The structure of the chapter is as follows. In the next section, the relevant literature streams of supply chain and marketing research in the last mile as well as SD modeling and simulation are introduced. Section “Research Design” describes the research design, while section "Results and Discussion" presents and discusses the results. Section "Conclusions" concludes the chapter accordingly.

3.5.2 Literature Review

This subchapter looks at the current industrial and academic development in the supply chain, specifically, the last mile distribution regarding E-commerce, and the application of system dynamics modeling as a decision-making tool based on word of mouth (WoM) communication theories.

3.5.2.1 General Supply Chain Research

Gudehus and Kotzab (2012) believe more complex interconnected substructures of sourcing, production, distribution, and consumption as well as closed loops in the supply chain are necessary (Kumar and Nigmatullin, 2011; Dowlatshahi, 2010). Michael Porter introduced the concept of the industry or business value chain in 1980, and it has been cited in recent years to establish the foundation of new business sustainable strategies (Daneshpour and Takala, 2016; Nicolò and Jean-Vasile, 2016; Rahdari, 2017).

Instead of describing the business as a set of sequential operations, the value chain perspective proposes a set of processes jointly carried out by numerous actors, who work together to produce value for a common end. The sustainable supply chain is a system based not only on economic drivers with a focus on productivity but also including socio-ecological aspects along with economic ones. This complex system consists of interaction between and within human environments including the social outcomes of their activities. These interactions follow a general structure of the product ow through a particular path, which depends on the product characteristics, size, and market power of the supply chain members (Maloni and Brown, 2006). Therefore, the single supply chain components are not constants but are affected by several trends over time, in particular affecting:

- Consumer consumption patterns: In the past decades, demand shifts have been observed, leading to more health-conscious, as well as environmentally aware, consumption behaviors.
- Policy regulations: Internal (company made) and external (government made) standards seem to be on the rise to prove a high degree of supply safety with less environmental degradation.
- Decision-making processes: Focusing on improving efficiency along the supply chain while keeping the cost to a minimum generally has a negative impact on the environment, causing negative feedback mechanisms (Armendáriz et al., 2016).

- Technology use: Advances in information technology (IT) and electronics have made it possible to provide uninterrupted tracking within the supply chain to improve delivery service (Bowersox and Daugherty, 1995).

3.5.2.2 Last Mile Distribution

The existing efforts and research endeavors related to the interaction of last mile supply structures, last mile logistics, and E-commerce solutions have been mainly of contingent character (Esper et al., 2003; Punakivi et al., 2001). Even though such explorations prove and develop a better understanding of the cause and effect of those structures, these are not able to capture the system dynamics and the correlation between the different elements in a given system (Flynn et al., 2010). Therefore, a holistic approach can support a traditional approach by enhancing the existing knowledge and at the same time offer new insights on the subject. There are several publications and studies which address the structure of the last mile. The periodical analysis of global trends and strategies focus specifically on the courier, express, and parcel market (CEP) (Straube and Pfohl, 2008). Klaus et al. (2011), Kille and Schwemmer (2012), and Salehi et al. (2011) concentrate their research on the analysis of the demand of CEP providers, whereas Esser and Kurte (2014) as well as Bogdanski (2015) carry out a more in-depth analysis with the consideration of future deliveries in city centers. Other efforts explicitly consider the logistics to supply the end consumer (business-to-consumers, B2C) and the commercial logistics transactions of companies (business-to-business, B2B), dealing with innovative conditions of E-commerce service solutions from the perspective of production and logistics (Petermann, 2001). Helmke (2005) addresses two aspects of the general supply chain, supply and demand, examining in particular service level customers' satisfaction and loyalty to these business models. During the last 10 years, the economic, environmental, and social aspects of transport and distribution as well as the time-based demand structures for B2C, B2B, and recently customer-to-customer (C2C) business models have increasingly been focused on the dynamic development of E-commerce and its impact on society and supply chain. In this respect, Henschel (2001) and Popp and Rauh (2003) investigate the location factors of E-commerce and study the interactions and dependencies between consumers, producers, retailers, and logistics providers from a perspective of SD to identify the main key elements of the system. In a similar way, Farag (2006) explores which factors influence purchasing behavior in E-commerce and in retail stores. In addition, he examines the geographical distribution of inter-net users and online shoppers (relative distance between customer and shops/picking stations).

In summary, the abovementioned analysis and studies offer a holistic overview of the last mile and the stakeholders involved. With the help of these approaches, structures and interdependencies between the main elements of the system can be analyzed in detail. These existing databases with regard to supply and demand as well as E-commerce patterns are to be used to parameterize the SD model.

3.5.2.3 Word of Mouth

The concept of "word of mouth" (WoM) plays a key role in SD models, addressing the reduction of risks and uncertainty in customer acquisition and retention (Murray and Schlater, 1990). WoM can be defined as a communicational, informal, C2C strategy taking into consideration the characteristics and parameters of a business or a product. It helps consumers to use informational and regulative influences on the service or product evaluation and purchase behavior of fellow consumers (Bone, 1995; Ward and Reingen, 1990). As a rule, consumers acquire information about specific business models, products, and services from online platforms (online communities, blogs, and online product reviews). Studies have shown that consumers increasingly rely on WoM.

Previous studies on WoM have primarily focused on studying the factors that initiate participation of consumers (sending or receiving information) in WoM activities and the impact of information on consumers' buying decisions (Chatterjee, 2001; Chen and Xie, 2005; Chevalier and Mayzlin, 2006; Dellarocas, 2003; Godes and Mayzlin, 2004). Consumers tend to rely significantly on other people's experiences and opinions during the decision process of adopting a new business model or service. This is especially the case when the transparency of the business model is high, the business model is new, the criteria for an objective evaluation of the product are difficult, and the perceived risk is high. Past studies have also explored WoM activities in relation to factors such as satisfaction, loyalty, quality, commitment, service level, trust, and perceived value of a specific product or business model. Harrison-Walker (2001) comes to the conclusion that the significance and value of WoM, whether it is positive or negative, is an important dimension that may exercise a huge impact on buying decisions. WoM is particularly convenient when the population used for the simulation is heterogeneous or when the structure of the interactions between individuals in the system is complex and heterogeneous (Garcia, 2005). Likewise, it allows the incorporation of insights from another stream of literature that focuses on the role of individual differences and social network structures as critical variables for explaining the process of WoM (Bohlmann et al., 2010), as well as trying to identify which stakeholders play key roles in the WoM process at different stages of the innovation diffusion process (Chatterjee and Eliashberg, 1990).

3.5.2.4 Innovation Diffusion

Innovation diffusion is a well-established theory which has been in existence for several years. Diffusion models have traditionally been used in marketing for the analysis and evaluation of life cycle dynamics of a new product, business model, or service. It is also used for forecasting the demand for a new product and as a decision tool in making prelaunch, launch, and post-launch product strategic decisions (Radas, 2005). The basic models of innovation diffusion had been established by the 1970s. The most famous models are the logistics model (Mansfield, 1961) and the Bass model (Bass, 1969). Subsequently, model development focused on modifying these basic models by including a higher level of detail and, therefore, extensive interpretation and practicality. The main modifications and developments include the introduction of marketing variables in the parameterization of the models and generalization of the models in the context of diffusions in application areas and through the use of up-to-date technologies. In practice, the main application areas are centered on the introduction of consumer durables and telecommunications innovations. The task at hand is to include sustainable and logistic parameters into these models in order to create a sustainable decision tool in respect to consumers' behavior and logistics aspects. The Bass diffusion model has become one of the most popular models for new product growth and the introduction of new business models (Chandrasekaran and Tellis, 2015). It is extensively used in marketing, strategy, management of technology, and in this case specifically sustainable process development. Bass (1969) solved the start-up problem by assuming that potential adopters become aware of the innovation through external sources whose extent and influence are constant over time.

3.5.2.5 System Dynamics Modeling

The traditional approach to system dynamics focuses primarily on supply chain management, which concentrates on inventory planning, reordering policy development, lead time optimizing, demand analysis, supply chain design, capacity planning of the remanufacturing networks, integration of recycling into the supply chain design, vendor-managed inventory on transport operations, bullwhip effect and inventory oscillations, and international supply chain management (Coppini et al., 2010; Disney et al., 2003; Minegishi and Thiel, 2000; Özbayrak et al., 2007). Similarly, Saad et al. (2003) present a discrete event simulation approach for the contextual load modeling of a packaging industry supply chain system. Their main focus is to examine how tactical decision policies would provide stability in the presence of disturbances, as well as evaluating the effect of disturbances on the system (Saad et al., 2003).

In order to gain input information for the design and development of system dynamics models, it is necessary to operationalize techniques of system thinking methods such as PSM into SD modeling, which has been proven to have a rich tradition not only in a sustainability context but also for decades in traditional SCM (Tako and Robinson, 2012). In this context, SD modeling is seen as a tested instrument to analyze problems of dynamic complexity in a wide range of settings (Sterman, 2000). Forrester (1968, 1977) was the first author who scientifically described SD modeling, namely, as “the investigation of the information-feedback character of industrial systems and the use of models for the design of improved organizational form and guiding policies” (Forrester, 1977, p. 13). Moreover, Wolstenholme (1990), who incorporates the quantitative simulation concept, provides an extended definition. He defines SD as a “rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies, which facilitates quantitative simulation modelling and analysis for the design of system structure and control” (Wolstenholme ,1990, p. 3). Interpreting these definitions, SD modeling leads to a profound understanding of complex issues and systems as well as their circumstances. Sterman (2006) calls these issues “needle-in-a-haystack problems” when complexity arises from finding the right path among a high number of possibilities. Accordingly, SD modeling deals with nonlinear behavior of complex systems over time (Morecroft, 1992) aiming to describe systems with the help of qualitative and quantitative models but also to understand how feedback structures determine a system’s behavior (Coyle, 1996). So far, SD modeling has established itself as a computer-aided simulation method. Here, feedback structures are actively created, and decision-making rules are derived from the knowledge learned through simulation. According to Davis et al. (2007), SD simulation is also increasingly used as a methodology for theory development. Particularly for longitudinal and nonlinear processes, simulation can help to build a more comprehensive and precise theory from the so-called simple theory (Davis et al., 2007). Although CLDs are not part of the original process described by Forrester (1977), it is one of the most important qualitative modeling methods (Coyle, 1996; Sterman, 2000). Generally, CLDs comprise a set of nodes and edges, which consist of a set of variables connected by arrows denoting the causal influences among them. Here, a feedback loop contains two or more related variables that relate back to themselves. These relationships can be either positive or negative. In this context, CLDs fill the knowledge gaps in SD models to gain a sense of nonlinear systems’ behavior based on feedback structures and to identify assumptions and underlying mechanisms in mental models (Sedlacko et al., 2014). Therefore, CLDs can be considered as the basis for simulation modeling. They additionally fulfill the central task of bringing people closer to understanding systems in the sense of “systemic thinking” (Coyle, 1996). These are currently used prior to simulations to illustrate the basic causal behavior over time in order to articulate a dynamic hypothesis of a system as an endogenous consequence of feedback structures. CLDs constitute a good foundation for system modeling (Haraldsson and Sverdrup, 2003). However, the transition to a simulation model is not simple. The information for the SFD is hidden in the CLDs, implicitly encrypted in links and elements. Extracting stocks, flows, and auxiliaries from a CLD involves additional analysis of the links and what they represent. This procedure could increase the number of factors in the system.

3.5.3 Research Design

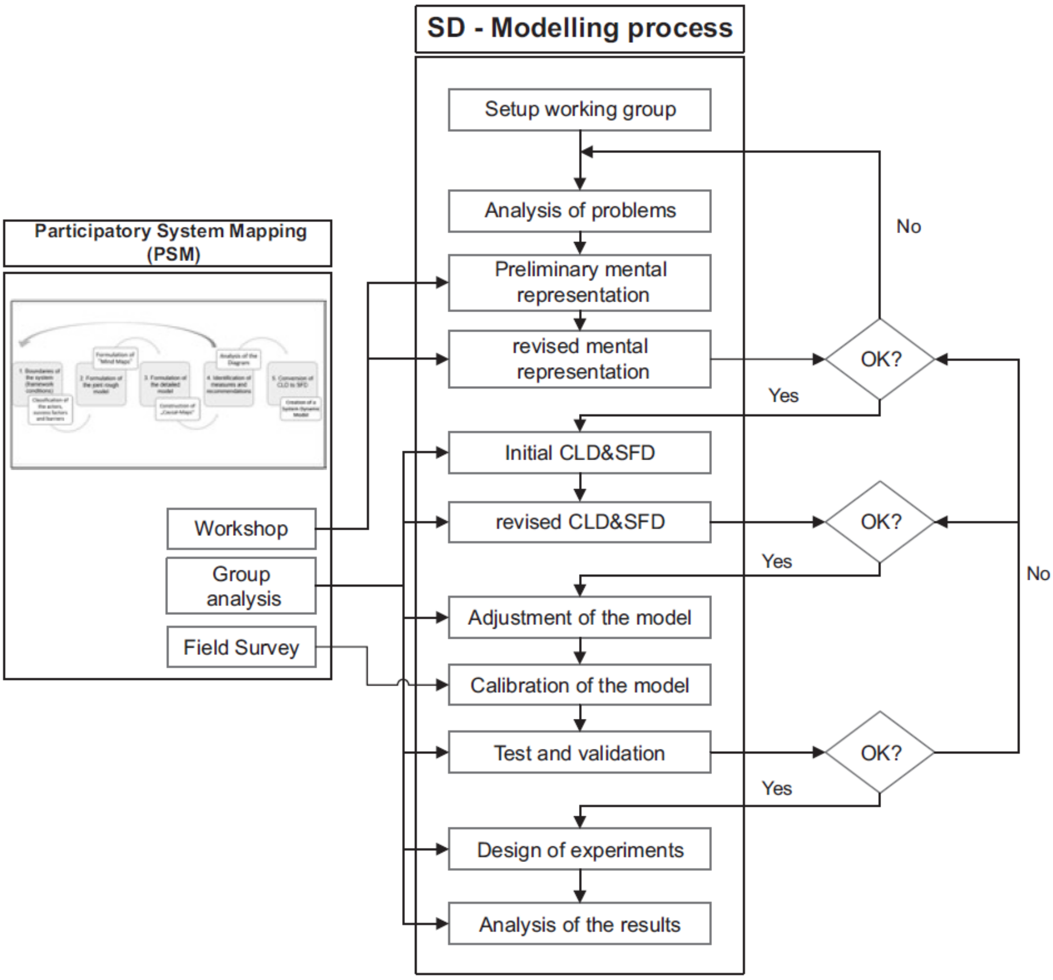


Figure 3.10: Modeling process – participatory mapping and system dynamics. (Source: Own illustration based on Wang and Cheong (2005))

Developing a reliable model to explore a new sustainable alternative model and examine the behavior of the market development from the consumer point of view is becoming increasingly important. This study provides a methodological framework which is practical in building confidence, namely, through SD modeling of a local food supply network. The operations of this network are in the hands of the food cooperation NETs.werk, which runs an e-food online platform to distribute locally produced organic food from small farmers in the Linz region in Austria. This framework is designed to enhance the model's reliability by combining group process techniques, like workshops, group discussions, brainstorming through the application of PSM, and fieldwork with SD modeling (Melkonyan et al., 2017). The framework covers three stages of the model-building process: PSM, modeling, and simulation (see Figure 3.10).

3.5.3.1 Participatory Systems Mapping

The complexity of sustainability issues is encouraging both policy makers and industry to expand their methods on solving environmental, social, and economic sustainability problems. In applied science, sustainability-related research is thematic- and policy-driven, so involving a broad spectrum of stakeholders is vital. High uncertainty issues and high-risk decisions such as sustainability research can hardly be conducted with conventional scientific approaches and tools. PSM in this context is a new, participatory process in which a structured process is used to design CLDs on a current topic and through their results develops strategies and recommendations (Sedlacko et al., 2014). Thus, PSM generally aims to develop and analyze CLDs to provide insights into a particular issue while using a facilitated group process to connect the mental models of participants through structured discussions (Sedlacko et al., 2014). Accordingly, participants work in groups and follow a predefined script over a certain period of time guided by a moderator developing a mental representation, identifying the related CLD and SFD with which a simulation model can be developed. Mental representations were drawn in workshops attended by a group of industry stakeholders and researchers who draw knowledge from experts by soliciting their judgment. Subsequently, the following concrete steps were conducted:

In a first step, participants are given the opportunity to discuss the scope and boundaries of the subject for investigation and are also introduced to the basics of SD. The main task is to identify relevant variables in the system and to classify them into categories (actors, success factors, barriers, and communication measures) in order to create a mind map. In the next step, participants are instructed to determine causal connections to establish cause-effect relationships between the variables, followed by an attempt to lead back these effects directly to the causes (creating feed-back loops). Consequently, the mappings in the third step are based on suggestions from the participants to incrementally add and connect new variables to the CLD. This often leads to group discussions about causal connections and the corresponding supporting evidence. During the process, the participants experience effects of combined feedback loops, identify cascade effects (if present), and take new standpoints on emergent systems behavior. Through the inclusion of participants from different disciplines, the group has the opportunity to obtain new input and is able to test the impact of the model and identify knowledge gaps. Consequently, knowledge sharing and breakthroughs usually take place in the fourth step. During this step, remaining knowledge gaps are identified in order to find out where further research is necessary to complete and specify the CLD. The last step of the process is the conversion of the CLD into an SFD. To summarize the integrated approach, Figure 3.11 graphically illustrates the described steps.

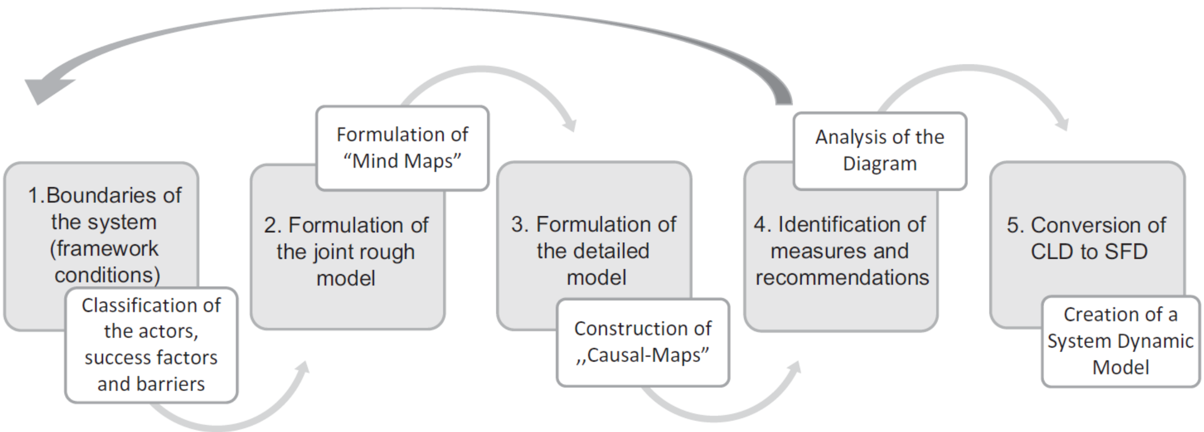


Figure 3.11: Formulation of mind mapping and creation of causal maps (Source: Own illustration based on Király et al. (2016))

3.5.3.2 Modeling Process

Setup Working Group of Participants

In order to address a certain topic or issue, a group process needs to be established. Due to the diverse and different connotations of the analyzed topic, involving different participants with different backgrounds is recommended, depending on the complexity of the topic to be solved. The main questions to be answered at this stage are: who the participants of this exercise are, how the participation process should be structured, and to what extent the results affect the final decisions. The participants of this exercise should be able to communicate freely with each other within the discussion workshops. For instance, the working group dealing with questions on sustainable logistics can be composed as follows: a project management expert, a logistics expert, a sustainability expert, an experienced SD modeler, one market analyst from a consultant company, a government representative, and at least one industrial representative. Additionally, one of the members of the group acts as the moderator, organizing discussions, disseminating information, and analyzing data. As soon as the group has been established, a detailed list of tasks is planned to guide the participants and to achieve the proposed objectives.

Problem Analysis

The problem analysis is a set of systematic tasks meant to increase the working groups' understanding of a certain situation. Considering the proposed objectives, the working group will define the research questions in order to determine the boundaries of the system to be analyzed. A qualitative question will be used to describe the objective of the study. This question will then be subdivided into several exploratory sub-questions. The scope of the questions will help choose the boundaries of the target system or subsystems. The main technique employed in this step is based on a number of workshops with different groups, in which the discussed topics are approached from different strategic levels. In this particular study, the purpose is to develop a model that can be used to explore the behavior of potential customers when adopting a new sustainable business model based on a local food supply network. Factors like affordability, average distance to stores or pickup stations, frequency of delivery, marketing measures, and the effect of word of mouth will influence the relative attractiveness of the new model taking into consideration logistics aspects as exogenous components of the system. This study will focus on examining the processes within the last mile delivery that might contribute to the development of new business models dependent on the behavior of consumers, changing the dynamics of a traditional distribution process. Specifically, the influential endogenous factors that will be identified might provide policy makers and planners with insights on how to understand local food networks and their expansion in the future.

Initial Mental Representation

The initial mental representation was based on the input of the participants during the first workshop. The brainstorming results were compiled in mind maps and structured according to the following elements: actors, success factors, barriers, and communication measures. This information represents the foundation and is an important step in conceptualizing SD modeling (Forrester, 1992; Randers, 1980). The purpose of this step is to develop an initial general overview of the elements interacting in the system and their dynamic interrelationship. An analysis of the boundaries and identification of the state factors involved in the last mile delivery logistic process was included.

Several workshops should be conducted afterward. If possible, the participants should be diverse in terms of age, work experience, work field, education, origin, etc. The number of participants and the number of workshops should be adapted according to the requirements and budgeting of the study and are determined by the working group. System boundaries and the state of involved variables and components are listed for further analysis with the help of mind maps. The working group should combine the mental representations from all the workshops and draw a diagram describing the boundaries and the state factors. In this study, the boundaries of the food supply network are of a geographical nature, the Upper Austrian region near Linz. The main influential factors include potential consumers, logistic service providers, logistic infrastructures, performance indicators, marketing measures, behavioral analysis, etc.

Revised Mental Representation

The mental representation of the study is presented in the form of mind maps, which are further enhanced through the application of PSM during several workshops with different participants. The transition of mind maps to CLDs takes place gradually after feedback from the participants. These mind maps illustrating the mental representations are then provided to the selected experts for further discussion. In order to model this specific case study, it is preferable to have experts selected from academia, industry, government and, if possible, communication experts. These participants will act as the basic research team. After several rounds of discussions, an agreement can be reached, and the new findings can be stored as an optimal option of the mental representation of the system. Nevertheless, this mental representation is not the definitive structure representing the system. It will be used as a preliminary milestone and basis for the next steps, due to the iterative nature of the modeling process. The structure and dynamics of the mental representation in the modeling process will be continuously analyzed and adjusted in the next steps.

Initial Causal Loop Diagram and Stock and Flow Diagram

The variables or factors included in the mental representation can be classified in four general categories: level variables, rate variables, auxiliary variables, and exogenous variables (Sterman, 2000). A level variable also known as “stock” determines the state of the system at a point in time. A rate variable also known as “flow” changes a stock over time. An auxiliary variable provides information on level and rate variables and defines intermediate concepts involving stocks and flows at a given time period. An exogenous variable is an outside variable that is not part of the internal dynamic of the system and therefore not affected by the behavior of the system. Whether the exogenous variables are applicable or not should be determined after some iterations and simulations. As was previously done in the step of the initial mental representation, each member of the working group will classify the variables and together with a system dynamics modeler attempt a first draft of a CLD, and later, through the inclusion of the list of variables and their definitions, the CLD will be converted into an SFD. A discussion takes place among the group members to reach agreement on the initial CLD and SFD.

Revised Causal Loop Diagram and Stock and Flow Diagram

In this step, the working group will attempt to interpret the initial CLD and SFD together with the insights of the application of PSM and the workshop results which are of genuine practical relevance. Critical analyses of the initial CLD and SFD based on the case study and its applicability are designed and provided to the group of experts. This process can be performed alongside other surveys concentrating on customer behavior. After discussion, the group will implement the changes into the new CLD and consequently to the new SFD.

General Structuring of Knowledge: Formalization

This step aims to establish the relationships between variables appearing in the CLD and SFD from a mathematical and logical point of view. The main objectives in this step are the implementation of valid practical theories, the modification of existing models, and, through these, the development of new concepts and recommendations. Based on Wang and Cheong (2005), the examination of the relationships between variables and any existing models and theories that are applicable is recommended. If there are no models or theories that address the analyzed topic, the participants of this study have to develop their own theories after interviewing experts in the relevant discipline and update the mental representation and consequently the CLD and SFD.

Calibration

A middle-sized system dynamics model could consist of many variables and even more parameters. These should be adjusted before the model simulations run. The parameters used in the model could be classified as non-sensitive and sensitive parameters (Wang and Cheong, 2005). The non-sensitive parameters are of independent character, affecting a model without being affected by it, and whose qualitative characteristics and method of generation are not specified by the modeler. Their values or range of values can be determined by common sense or judgment because of their non-sensitivity. Due to their properties, most of the non-sensitive parameters are also classified as exogenous (affecting the model from the outside). Sensitive parameters are further divided into available parameters and unavailable parameters. The values of available parameters are extracted from external sources such as previously conducted studies, input information regarding case studies, or generally available databases. Unavailable parameters could be obtained through data collection during the application of the PSM methodology or surveys with possible consumers with different backgrounds and also representatives of the industry: logistic service providers, supply chain stakeholders, etc.

Testing and Validation

Testing and validation is the process of determining if a model implementation and its related data accurately represent the original conceptual description and specifications. This phase focuses on understanding the behavior between the elements of the real system and the corresponding elements of the simulation model and on determining whether the differences are acceptable compared to the intended purpose of the model. If a satisfactory agreement is not reached, the cause of the problem must be identified, the model adjusted and rectified, and the conceptual model validation performed again. This is an iterative process and is conducted until no more problems are identified. Finally, the CLD presented in Figure 3.12 depicts the relationships between the essential elements of the SD model analyzing consumer behavior. As outlined, the CLD was transformed into a SFD (see Figure 3.13 and Table 3.11) based on the extended research on the subject (Binder et al., 2004). The results of the system dynamics simulation are presented in the next section.

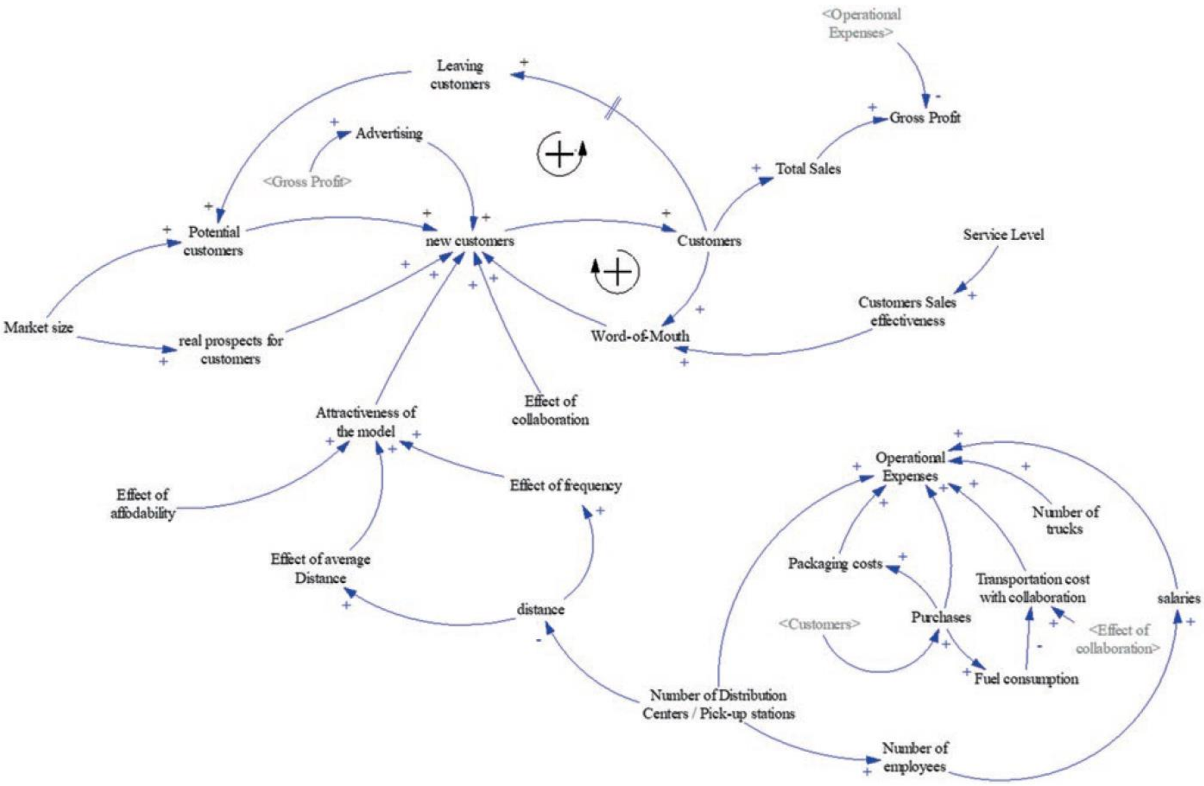


Figure 3.12: Causal loop diagram of consumer behavior based on PSM methodology. Own illustration based on the conducted workshops

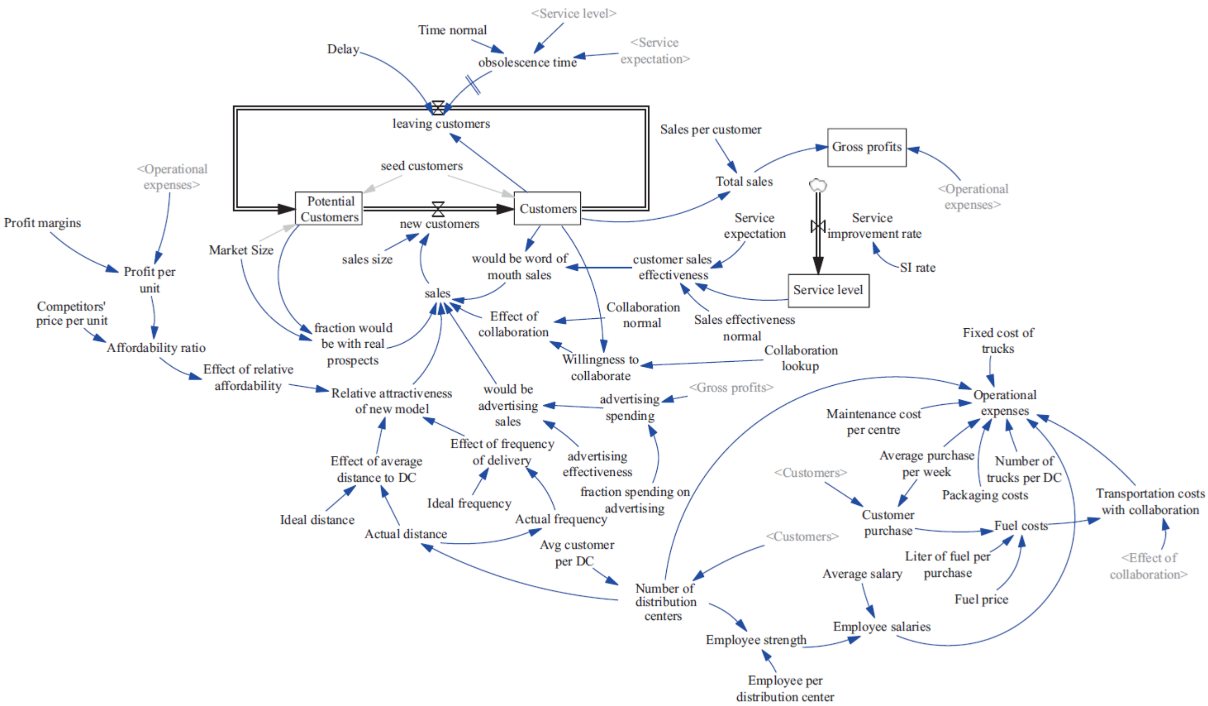


Figure 3.13: System dynamics model of consumers' behavior considering logistics aspects and the diffusion of innovation

Table 3.11: List of variables used in the system dynamics model – basic scenario

Name	Definition	Units
Market size	598,000 (Households Upper Austrian Region)	customers
Fraction would be with real prospects	Potential Customers / Market Size	-
Seed customers	375 (Households)	customers
Time normal-obsolescence	52 (1 year)	weeks
Potential customers	INTEG (leaving customers - new customers, Market Size - seed customers)	customers
Customers	INTEG (+new customers-leaving customers, seed customers)	customers
Leaving customers	DELAY1I(Customers / obsolescence time,100, 0)	customers
Fuel price	1.20	€ / liter
Fixed cost running DC	18,000	€ / DC/year
Packaging cost	0.5	€ / purchase
Sales per customer	44	€/ customer

Number of distribution centers (DC)	WITH LOOKUP (ABS(Customers/Avg. customer per DC)	DC
Number of trucks per DC	2	truck
Fixed cost trucks	12,000	€ / truck
Average purchase per customer week	10	Units/week/customer
Customer purchase	Customers*Average purchase per customer per week	Units/week
Liter of fuel per purchase	0.85	Liter /purchase
Fuel cost	Fuel price*Liter of fuel per purchase*Customer purchase	€
Total sales	Sales per customer*Customers	€
Gross profits	Total sales - Operational expenses	€
Employees per distribution center	3	employees
Performance employee	210	Units / day
Hours per shift	7.5	Hours/week
Employee strength	Employee per distribution center*Number of distribution centers DC	employees
Average salary	225	€ / week
Employee salaries	Average salary*Employee strength	€
Operational expenses	Employee salaries+(Fixed costs of running DCs*Number of distribution centers DC)+Fuel costs+(Packaging costs*Average purchase per annum)+(Fixed cost trucks*number of trucks distribution)	€
Service level	INTEG (Service improvement rate, 0.5)	-
Service improvement rate	SI rate/52	-
SI rate (Service improvement)	0.05	-
Service expectation	0.95	
Customer sales effectiveness	IF THEN ELSE(Service level/Service expectation<=1, 0.1 , 0) *Sales effectiveness normal	-
Word of mouth sales	Customers * Customer sales effectiveness	widget / year

Sales	(would be word of mouth sales + would be advertising sales) * fraction would be with real prospects*(1+Relative attractiveness of new model)*Effect of collaboration	widget / year
New customers	Sales / sales size	Customers/ year
Sales size	1	Widget/customer
Relative attractiveness of new model	(Effect of average distance to DC*Effect of frequency of delivery)+Effect of relative affordability	-
Effect of frequency of delivery	IF THEN ELSE(Actual frequency<Ideal frequency, 1 , 0.1)	-
Ideal frequency	*1*	Delivery/week
Actual frequency	(1/Actual distance)*3	Delivery/week
Effect of average distance to DC	WITH LOOKUP(Actual distance/Ideal distance)	-
Ideal distance	*2*	km
Actual distance	*1/Number of distribution centers*15*	km
Effect on collaborative delivery	*Willingness to collaborate/Collaboration normal*	-
Collaboration normal	*1*	-
Willingness to collaborate	Collaboration lookup(Customers)	-
Advertising spending	Gross profits*fraction spending on advertising	€/week
Fraction spending on advertising	0.05 (5%)	-
Would be advertising sales	advertising spending * advertising effectiveness	widget/week

3.5.4 Results and Discussion

The simulation was conducted for a pilot case study with an Austrian company that aims to adapt new sustainability practices into the regional distribution of local sustainable products. The influence of the strategic changes on the simulated model was studied in the form of various scenarios and the results and behavior of the system analyzed and interpreted. The model makes use of real input data and input information gathered during several workshops as well as assumptions and theoretical values. The simulation was made for an assumed market size based on the number of households in the Upper Austrian region, which is around 598,000 (Statistik Austria, 2018). The current number of customers is only 375, which means that the possible theoretical number of potential customers would be (598,000-375 = 597,625 customers). The logic behind the model is that potential customers are transformed into effective customers as soon as a sale of a product is made (see Figure 3.14).

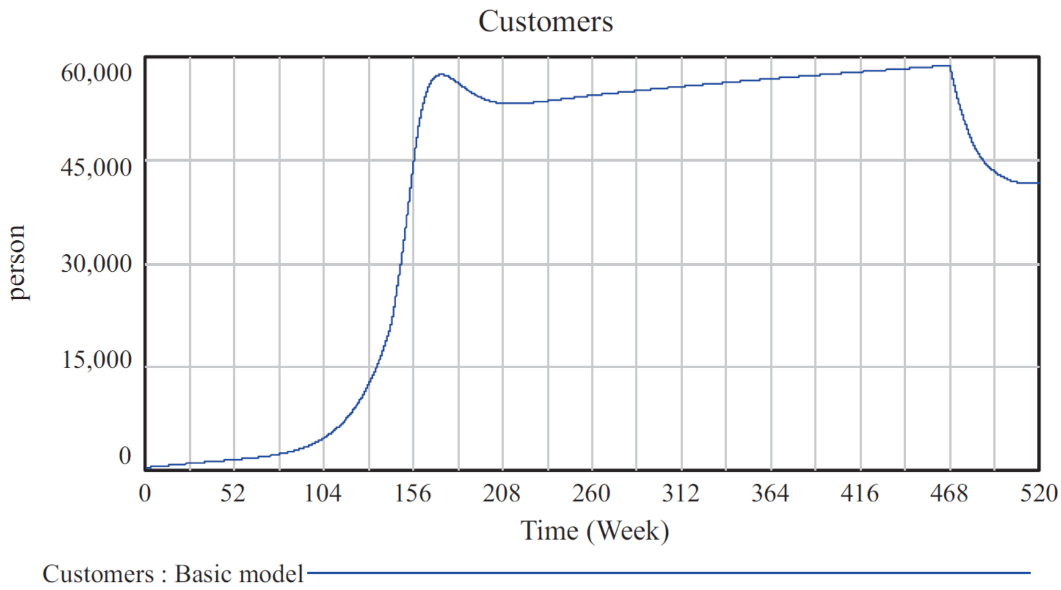


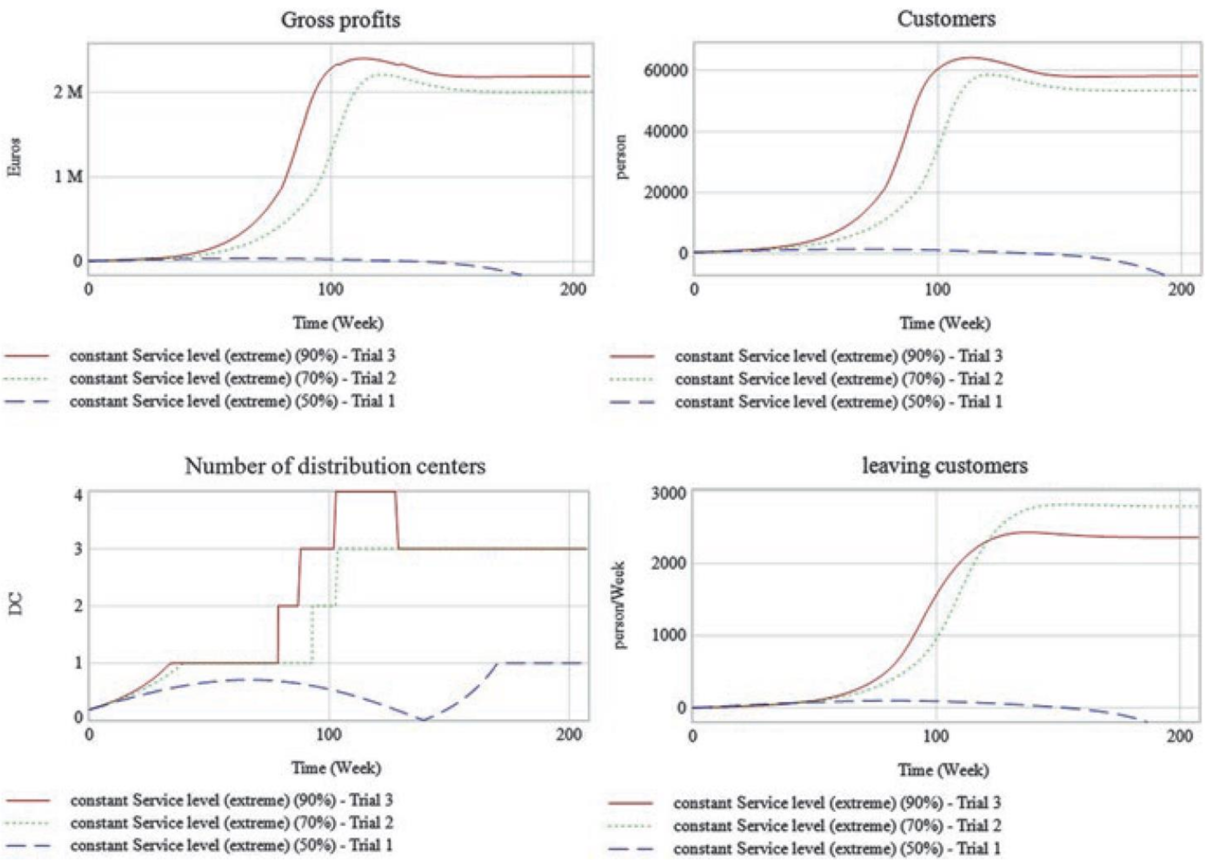
Figure 3.14: Evolution of number of customers over time

In the model, the sale of products is directly linked to the profit of the company. Part of this profit will be invested in sustainability advertising and image. These investments represent a fundamental key factor to develop new strategic measures and policies which will prove to be indispensable in improving the overall performance of the company. Thus, the change and adjustment of the new business model and its smooth transition are time dependent. The main structure of the simulation focuses on the relative attractiveness of the proposed model. This attractiveness is dependent on the following adopted properties: the sales arising from word of mouth, the sales through formal classical advertising, the effect of collaboration, the effect of relative affordability compared to competitors, the effect of average distance to the pickup points, and the effect of frequency of delivery. The basic concept behind the relative attractiveness is that an offered service or product cannot fulfill the expectations of every customer. In theory, it means that if a company offers the best service in terms of every possible applicable attribute, the market will increase its demand beyond all capacities and eventually turn into a less attractive option on the market. This concept is a variation of the “limits to growth” archetype (Meadows et al., 1992), while “limits to growth” concentrates on limits regarding capacity from a more general perspective, the relative attractiveness concentrates on capacity levels of specific aspects and their dynamics over time. Demand-generating activities (word of mouth, marketing) create reinforcement loops, which increase customer demand. Customer demand, as mentioned earlier, is also affected by overall relative attractiveness (effect of collaboration, the effect of relative affordability, effect of average distance to the pickup points and frequency of delivery). The hypothesis is that, as demand increases, it will reach the limits of the analyzed properties, thus decreasing the overall attractiveness and consequently the demand for products. The objective of the system dynamics model is to respond to the deteriorating overall effectiveness and attractiveness of the model. This will be accomplished by means of different measures aiming to restore the overall effectiveness over time. In order to achieve this, a set of attributes should be systematically chosen, aiming for a more sustainable strategy. The implementation of sustainable strategies, not only into more logistic-related issues (e.g., delivery process of products to customers) but also toward the corporate identity, is expected to have a direct impact on the total sales and customer acquisition. In the same manner, the relative attractiveness of the model and its attributes are expected to have an indirect impact as well. Based on the model presented in Figure 3.13, four simulation scenarios were performed:

a. Constant service level with no improvement of any kind
b. Constant service level with a variation of the time-related business model acceptance
c. Variable service level and variable customer acceptance (volatile scenario)
d. Sensitivity analysis and optimized scenario with a constant customer retention policy over time under consideration of logistics aspects

3.5.4.1 Constant Service Level with No Improvement of Any Kind

In this first simulation run, the evaluated company was assumed to be maintaining a constant service level regarding the implementation of sustainable measures into a new business model, with no improvement over time. Three different scenario runs were simulated (Figure 3.15). The first trial was conducted with a service level of 0.5 (50%). It can be observed that the customers' curve is a flat, almost horizontal curve tending to 0 after 2 years (around 110 weeks). It is obvious that customers preferring more sustainable solutions would leave, since the sustainable implementation, improvement, and expectations are not fulfilled and consequently there is a loss of profits as well. Due to the number of customers to be served, it is also clear that a single distribution center would be enough to serve customers.



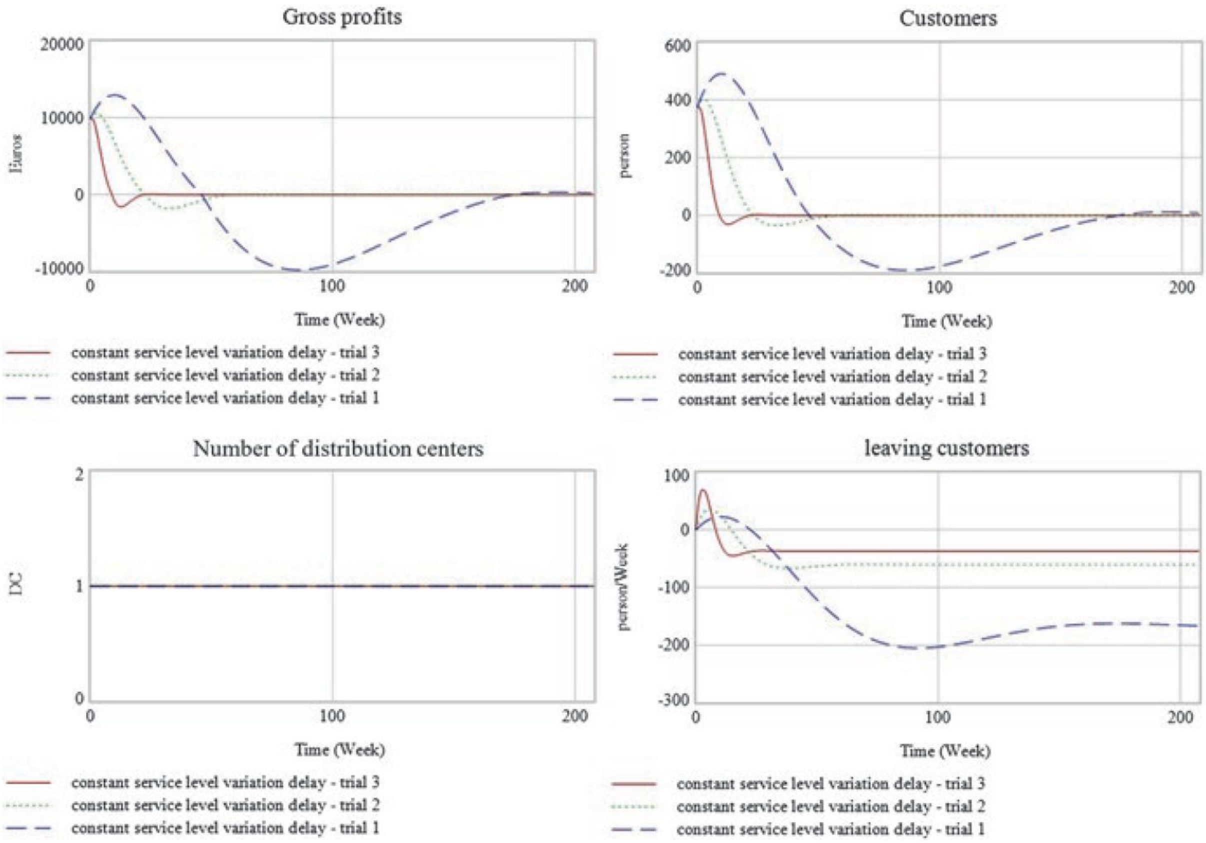
trial 1, 50%; trial 2, 70%; trial 3, 90%

Figure 3.15: Constant sustainability efforts/service level

The second trial was conducted with a service level of 0.7 (70%). In this trial, it is observed that there is a significant increase of customers in comparison to trial 1 and the customers' curve already shows the typical s-shaped curve of innovation of diffusion. The curve rises during the very first 52 weeks (first year) in a more conservative and reserved manner. Between the first and second year, the graph shows a rapid growth in demand due to a significantly better service level overall. After the second year, the curve reaches the saturation point of around 60,000 customers and stabilizes over the coming weeks. The profit curve correlates to that of the customers. Due to this increase in demand and customers, it is advisable to expand the logistic infrastructure around the end of the second year and open a third distribution center shortly afterward in order to be able to fulfill the demand. Finally, in the third case, a service level of 0.9 (90%) was assumed. It gives the simulation a similar s-shaped curve for customers, in which the number of customers increases even earlier within the second year and with a peak value at the beginning of the third year, smoothly stabilizing after the second year. In this run it is advisable to establish even a fourth distribution center for the last mile network. In summary it can be seen that the curves of customers and profit over time with a constant service level with no improvement actions will tend to reach a saturation point and afterward, due to the lack of strategic countermeasures, inevitably reach the value of zero. This can be mainly attributed to inadequacies and the lack of sustainable strategies, not only for the products but also for the provided services, since the business model tries to acquire sustainability conscious customers. Without a proper strategic sustainable planning, the regular customers will start leaving, and the acquisition of new customers will prove to be challenging.

3.5.4.2 Constant Service Level with a Variation of the Time-Related Business Model Acceptance

In this scenario, the company was assumed to be maintaining the relative optimized sustainable service level at 80% (Figure 3.16). The second simulation run was conducted for variable time-related acceptance (time normal) and obsolescence time before the customer leaves the business model for the competitors on the market (delay). Similarly, three runs were simulated. The runs were conducted with the following setups: trial 1, time normal = 12 weeks, delay = 8 weeks; trial 2, time normal = 8 weeks, delay = 4 weeks; and trial 3, time normal = 4 weeks, delay = 2 weeks. It can be observed that the effect of service level expectations and also the time-related acceptance and delay of adopting and leaving a certain business model significantly affects the strategic customer acquisition through a possible implementation of sustainable best practices. The form and slopes of the three curves are different. The first trial shows a customers' curve with a maximum value of around 500 customers within the very first 1 to 2 months, showing a steady reduction of customers and a complete loss of customers within the first 52 months (1 year). Due to a nonnegative restriction in the model, the system's behavior shows a theoretical negative number of customers over the second and third year. Shortly after, the curve starts to stabilize at around 200 weeks of the simulation (balancing effect).



Trial 1: time normal = 12 weeks, delay = 8 weeks; Trial 2: time normal = 8 weeks, delay = 4 weeks; Trial 3: Time normal = 4 weeks, delay = 2 weeks

Figure 3.16: Constant sustainability efforts (service level) with a variation of the time-related business model acceptance

Consequently, there is also a direct proportional loss of profit as a result of leaving customers. The second and third trial, with more aggressive and impatient customers, both depict a faster decay in the customers' and profit curves in an even faster period of time (within the first 12 and 6 weeks of simulation, respectively). Due to the quantity of possible customers in the model and their demands, it is advisable to only use one distribution center and its corresponding assets in order to fulfill the demand. Summarizing the second scenario, one can observe that the shorter the acceptance time toward a new innovative business model on the market and its delay, the easier it is for the company to lose customers. Although the model runs with a service level of 80% (above average), this is not enough to retain customers on a long-term basis. This is perhaps due to skepticism on the part of the potential customer or decision factors such as price, service level, availability, environmental image, and word of mouth, or even a poor marketing campaign could be possible.

3.5.4.3 Variable Service Level and Variable Customer Acceptance (Volatile Scenario)

In this run, the company was assumed to have an improvement policy over time regarding the service level. The company was assumed to be maintaining its service improvement rate per year (SI rate) at 0.05, 0.1, and 0.2. The simulation was conducted or variation of the acceptance time with a constant delay of 12 weeks (3 months): trial 1, time normal = 24 weeks; trial 2, time normal = 12 weeks; and trial 3, time normal = 4 weeks. These variations represent considerable volatile scenarios in order to observe the quick response of the model (Figure 3.17). As previously, three runs were simulated. The first trial was conducted with a yearly service improvement rate of 5% and a normal acceptance time of 24 weeks with a delay of 12 weeks. In this run, it can be observed that there is no significant fluctuation of customers over time but rather a smooth transition within the first 3 years of simulation (Figure 3.17). Despite the company's moderate improvement policy, it can be observed that a longer acceptance time will increase the quantity of customers in the first year (week 34) and fluctuate over the next 2 years without reaching a value of zero. Because of the quantity of customers acquired over this time period, just one distribution center would be needed. In fact, half of the calculated area per distribution center will be needed in order to fulfill orders of customers under this scenario. The second case was conducted with a service improvement level of 10%, a normal acceptance time of 12 weeks, and a delay of also 12 weeks. In this run it was observed that there is an increase in the fluctuation of customers in comparison to the first trial: the costumers' curve is rather unstable, reaching a value of zero for customers within the first 28 weeks of simulation and oscillating over the following 30 weeks. The system itself never stabilizes, and the customers' curve finally decays beyond zero after 2.5 years. Finally, in the third trial, the company maintains an improvement service level of 20%, the normal acceptance time of 4 weeks, and a delay of 12 weeks. The simulation shows a hasty and volatile behavior compared to the first two runs. The system takes more than 200 weeks (3.5 years) to stabilize at a rather unfavorable value, since the oscillation is taking place closer to the value of zero. Although the improvement policy of the company was assumed to be exceptionally higher than in the other runs (service level improvement of 20% per year), just like in the previous scenario, the skepticism of potential customers and the expectation of a high service level in new business models are responsible for the customers' decision to leave and perhaps go back to more traditional competitors on the market, which have either a better service level or are able to provide similar products at lower prices. Naturally, this will reduce the profit and thus the possible investment toward sustainability which would be necessary to improve not only the service level but also to contribute to a more sustainable image of the company.

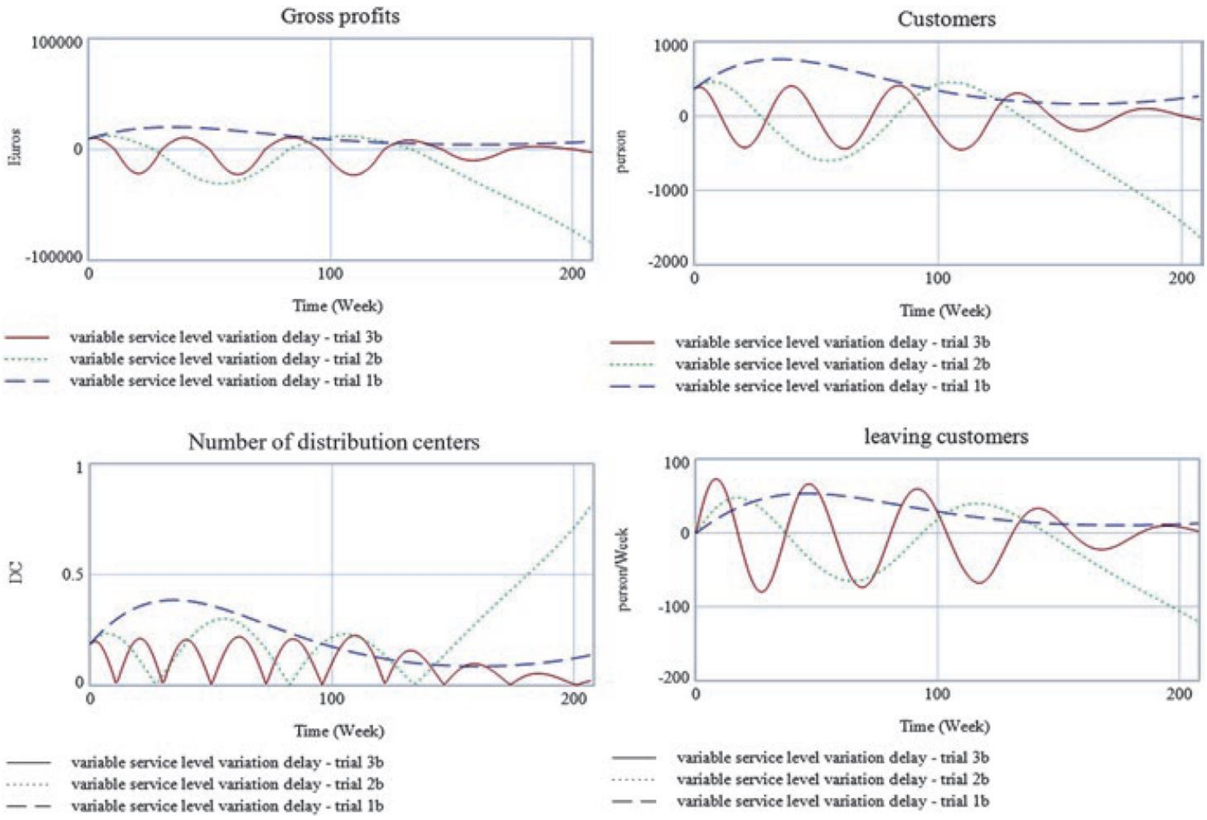


Figure 3.17: Variable sustainability efforts/service level and variable customer acceptance (volatile scenario)

3.5.4.4 Sensitivity Analysis and Optimized Scenario with a Constant Customer Retention Policy Over Time Under Consideration of Logistic aspects

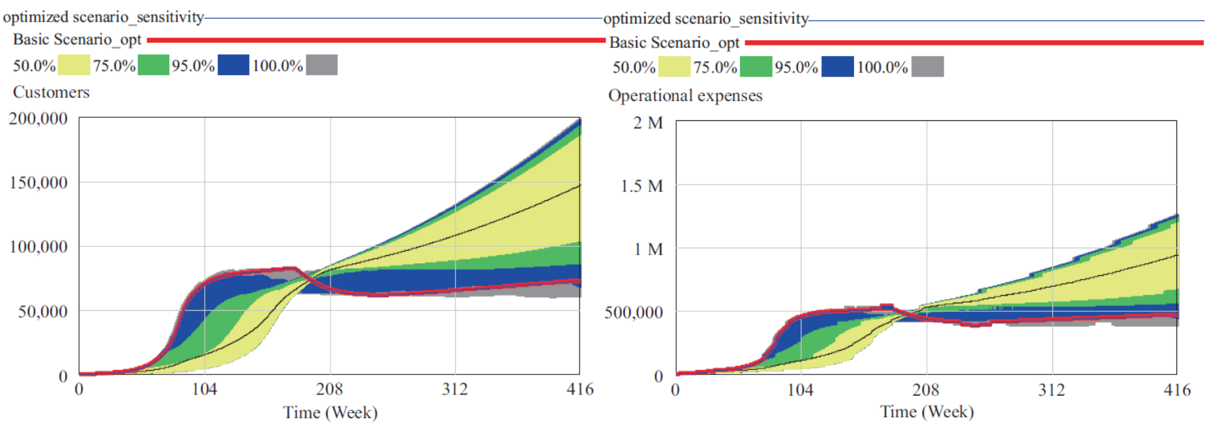


Figure 3.18: Sensitivity analysis of the system dynamics model of consumers' behavior considering logistics aspects and the diffusion of innovation

Finally, a fourth scenario was developed based on the basic scenario. The main contents are the results of sensitivity analysis and optimization of the system with the help of the software Vensim. The main model, as previously shown, contains many parameters. It is interesting to examine the effect of the variation simulation outputs. For this purpose, some parameters were selected, and different value ranges were given with a random distribution over which to vary them to see their impact on model behavior. Vensim has a tool which can execute such sensitivity simulations. The main idea of this task is to calculate the correlation between model input and total model output. This is done by calculating the total model uncertainty with Monte Carlo simulation. The so-called Monte Carlo multivariate sensitivity works by sampling a set of different values from within given boundaries. To perform univariate and multivariate tests, the distribution for each specified parameter is sampled, and the resulting values used in a simulation. When the number of simulations is set, in this case, at 200, this process will be repeated 200 times. In this particular case, the sensitivity analysis was performed under the following conditions and to answer the following question: how sensitively does the model react depending on the service improvement rate over time? The SI rate was given a random uniform distribution with a maximum value of 100% and a minimum of 1%, and two main outputs were analyzed: the number of customers and the operational expenses of the new business model (Figure 3.18). The chosen confidence bounds for this analysis were 50, 75, 95, and 100%. The graphs in Figure 3.18 show the generated confidence bounds for both of the selected output values that were generated when the analyzed parameter was randomly varied in terms of its distribution. The outer bounds of uncertainty (100%) show maximum values of approximately 200,000 customers and a minimum value of approximately 60,000 customers at the end of the simulation, which also will increase the operational costs in the same time span. For the optimized scenario under Vensim, the following elements based on the sensitivity analysis were considered for the definition of the “payoff policy” of the system dynamics model:

- Maximizing the number of customers
- Minimizing the total operational expenses
- Maximizing the relative attractiveness of the model

With the following results:

$$\begin{gathered}\text{Initial point of search}\\ \text{SI rate} = 0.05\\ \text{Time normal} = 52\\ \text{Delay} = 12\\ \text{Simulations} = 1\\ \text{Pass} = 0\\ \text{Payoff} = -2.82925 \times 10^{11}\end{gathered}$$

Maximum payoff found at:

$$\text{SI rate} = 0.05$$
$$\text{Time normal} = 26$$
$$\text{*Delay} = 4$$
$$\text{Simulations} = 50$$
$$\text{Pass} = 3$$
$$\text{Payoff} = -1.40212 \times 10^{11}$$

A first optimized solution was calculated with the following results: with a moderate service improvement rate per year of 5%, the optimal acceptance time should be from around 26 weeks (6 months); that means that the company should be aiming to improve its service within the first 6 months in order to retain the customers, thus avoiding losing them to the competition. The delay time until the decision has been taken was set to 4 weeks (1 month). This can be, for example, a termination period of a subscription for a weekly delivery of products. Figure 3.19 shows what the new customers' curve looks like in the first 408 months of the simulation run. During the first 4 years, the curve behaves like a typical s-shaped curve on innovation where the model depicts a rather modest increase of customers in the first year, followed by a rapid increase of customers to a point of saturation, decreasing afterward where the system itself tries to stabilize over the next 2 years, due to a prompt intervention by the company and possible strategic countermeasures.

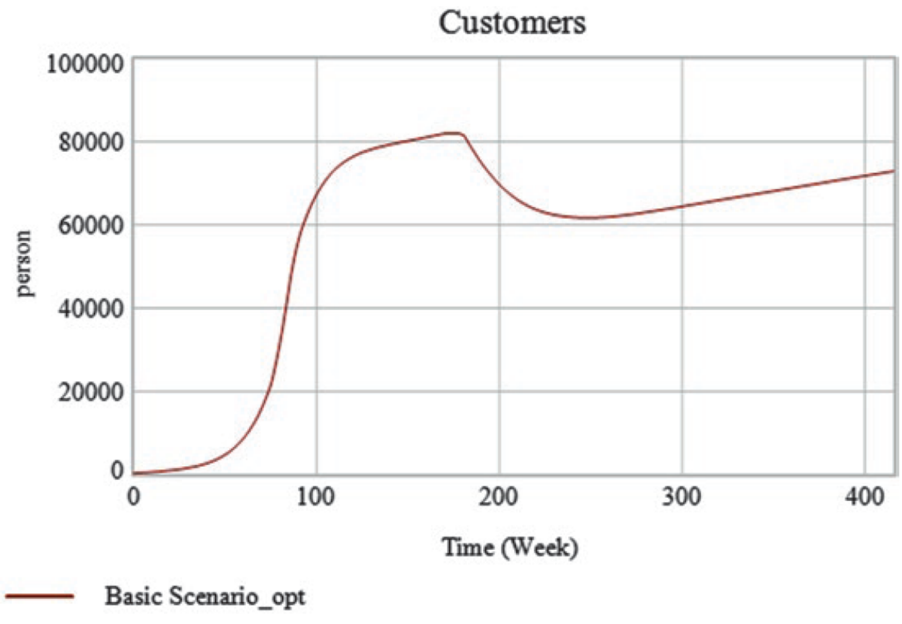


Figure 3.19: Customers: optimized scenario

3.5.5 Conclusions

Overall, the proposed system dynamics model can serve as a “what-if decision-making tool” to observe and study processes and relationships between customer acquisition and retention from the perspective of the company and the logistics service provider. At the same time, the tool can be used as a template to exemplify different scenarios with different concepts and also to discern the potential of a system dynamics approach in designing and studying the interaction between the consumers, their behaviour regarding preference and lifestyle, and the industry, represented in the last mile as the final stage of the distribution process by service providers, producers, and forwarders along the supply chain. Innovation can be defined as a product, service, idea, process, behaviour, or any other object which is considered new by customers. The term innovation requires acceptance from customers in order to be successful, but it also requires considering customers’ behavioural patterns and habits, in this specific case sustainable aspects. Innovation is sometimes resisted by customers because of barriers such as the price of the product or the service, sustainable image, etc. In such a case, some modification can facilitate its acceptance. Another interesting way to analyse the scenarios is the use of the calculation of customer retention rate, which is a metric that represents the number of customers that are “loyal” to a business in one way or another. The word loyal in this case means that customers are satisfied and decide to adopt the business model for a while. The lesson of the methodology is to recognize that being “all things to all people” is not a sustainable strategy and that the main strategic process is to develop a structure with a chosen set of attributes in which the current business model achieves an overall higher performance and profits from retention of consumers and customers, which are driven by the most attractive alternative. From the abovementioned discussion of the SD model, two distinct tracks of exploration can be observed in which improvements in diffusion modelling can be made: (a) further research and work on time-varying parameters and (b) improvement in model forecasting and calculation of cumulative adopters over time. Aside from parameter variation and forecasting issues, there is another way in which the SD model can be improved – specifically, the consideration of other models besides the Bass model, since this does not consider seasonal variations in sales. One way to apply seasonality is to use real yearly data, as has often been done in the past, and to simulate those scenarios with real life conditions. Nevertheless, the current circumstances in the competitive market result in the shortening of product life cycles and dynamically changing business models, which do not allow managers and decision-makers to wait for several years before attempting to forecast the life cycle. Critical decisions have to be made soon after the product’s launch. In this way, simulation models that require less time-based data would be much more useful to decision-makers than long-term yearly data. Such models should be able to describe and represent seasonal variations in sales predictions.

All these proposed improvements for further research have the common goal of creating suitable diffusion models that would be more flexible, easier to use and easier to estimate, and could consequently provide users with the necessary tools for better decision-making.

4 Transformation Designs

4.1 Remarks and Synopsis

Based on empirical findings, specific further scenarios for transformation designs can be developed. Here, as for the empirical part, the success of transformation efforts depends on participatory collaborative approaches to developing results. Therefore, all contributions in this part of the dissertation take a participatory method into account. For transformative concepts of functional integrations for sustainability, in the sense of the comprehensive supply and welfare function of this dissertation, three highly interrelated transformation aspects stand in the foreground of the research:

As examined in 4.2, dynamic capabilities of companies in terms of competence and knowledge are a basic requirement for creative dynamism and ultimate success, to adapt to the requirements of sustainability on the one hand, but also to take on creative roles on the other. An integrated understanding between (strategic) corporate development and (tactical) operations management in companies is of key importance. Service providers in the supply chain play a central role as facilitators, also for value-added partners. The business stakeholders are interdependent on their own corporate development, the development of value-added relationships and societal developments. PSM is used to uncover gaps in knowledge. Within the context of the connections in production, supply and consumption systems, the publication demonstrates central capabilities in relation to the last mile, the sharing economy and consumer awareness.

In 4.3 and 4.4, the concept of the "Lead Sustainability Service Provider" (6PL) as a system service of PSC Ecosystems plays the central role and represents the first research worldwide on this sustainability-oriented business archetype. This is also related to preliminary work that was presented at conferences:

Krumme, K. (2016, April 12). *Logistics, the Energy Transition and a Future Green Economy: Challenges, Needs and Opportunities*. 3rd German-Dutch Logistics Conference, Duisburg, Germany.

Krumme, K., Hanke, T., & Melkonyan, A. (2016, September 6–9). *Resilience and Sustainability as Drivers for a Conceptual Transformation in Logistics: Shared Options for Green Economy Research and Practice*. 7th International Sustainability Transitions Conference (IST): Exploring Transition Research as Transformative Science, Wuppertal, Germany.

In 4.3, the reactive and proactive abilities of service providers in the supply chain are examined in the concrete implementation context of the Linz region (Austria). In the process, both obstacles and opportunities are systematically collected, evaluated, and presented in stakeholder groups and in the system context of the sustainable economy. Based on the application of optimization and simulation methods in a specific regional context, a roadmap to the “Lead Sustainability Service Provider” (6PL) is developed.

4.4 sets macroeconomic and international reference points beyond the specific regional reference and uses an integrated assessment of the production, supply and consumption ecosystems. The assumptions of Ecological and Environmental Economics are of fundamental meaning to do so. With key stakeholders of the system, structures and services of the supply chain are related to both economic and societal trends using scenario techniques. In the sense of the scenarios, which provide for strong sustainability developments on the consumer demand side and in terms of regulatory governance, the 6PL can not only be shown to have a positive development perspective but can also be assigned a proactive design role in the sustainable economy via transformative supply chains.

The idea of the “transformative supply chain” goes back to the following conference contribution:

Krumme, K., Noche, B., Hoene, A., & Wang, N. (2011). Global-demographischer Wandel - Perspektivierungen vom Standpunkt der Logistik. In T. Wimmer & T. Grosche (Eds.), *28. Deutscher Logistik-Kongress: Flexibel - sicher - nachhaltig. Flexible - secure - sustainable. Kongressband 2011*. Bundesvereinigung Logistik (BVL).

4.2 Mapping Logistics Services in Sustainable Production and Consumption Systems: What Are the Necessary Dynamic Capabilities? (Gruchmann, de la Torre, Krumme, 2018)

The following chapter was published as a book chapter by the author of this dissertation with Tim Gruchmann (Westcoast University of Applied Sciences) and Gustavo de la Torre (University of Duisburg-Essen) in the peer-reviewed *Palgrave Macmillan Volume "Sustainable Operations Management – Strategies, Capacities, Methodologies and Theory Building"*, edited by Poul Houman Andersen (Aalborg University, Denmark) and Luitzen de Boer (Norwegian University of Science and Technology) 2018.[26]

The presented research refers to the project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015).

Any reference to this chapter should be cited as:

Gruchmann, T., de la Torre, G., & Krumme, K. (2019). Mapping Logistics Services in Sustainable Production and Consumption Systems: What Are the Necessary Dynamic Capabilities? In L. de Boer & P. Houman Andersen (Eds.), *Operations Management and Sustainability* (pp. 223–246). Palgrave Macmillan.

Abstract

Facing the challenges of sustainable development in production and consumption systems, there is a significant necessity for advanced capabilities to fertilize sustainable corporate development on the level of strategic management and to enhance and enable effective change on levels operations management. Thus, the paper at hand describes the approach of participatory systems mapping (PSM), a combined method of participatory modelling and systems thinking, to fill knowledge gaps for required dynamic capabilities in the field of sustainable supply chain management (SSCM) and logistics. Accordingly, this methodological approach in its ability to contribute in solving issues in complex systems is applied to the research question how logistics services can contribute in creating more sustainable production and consumption systems. To support the systemic understanding of logistics services in sustainable production and consumption systems, the results derived from several

[26] In this publication, Klaus Krumme has taken the role of discussing and revising the study results, with the connection to the "triple helix" perspective in the sense of suitable innovation settings or co-creative knowledge formation being in the foreground. This also stimulated theory building. Klaus Krumme conceptualized the methodological orientation System Dynamics and PSM in the project, which was the prerequisite for the methodical focus of PSM implemented and coordinated by Mr. de la Torre.

conducted workshops were mapped into a causal loop diagram describing relevant variables and their causal relations with each other. Finally, these relations are discussed in a broader SSCM context in order to promote further theory building by use of the concept of Dynamic Capabilities (DCs) with regard to Logistics Service Providers (LSPs) and to facilitate a needed sustainability transition in and across integrated systems of production, supply and consumption.

Keywords

Sustainable Production and Consumption Systems, Sustainable Supply Chain Management, Participatory Systems Mapping, System Dynamics Modelling, Dynamic Capabilities

4.2.1 Introduction

In recent years, logistics service providers (LSPs) had to respond to the increasing demand for sustainability of their stakeholders (Carter and Jennings, 2002). To meet this demand, LSPs can either reduce their ecological and social impacts in the supply chain, for example by building alternative supply chain infrastructures, implementing technological innovations and improving working conditions (Chapman et al., 2003; Lieb and Lieb, 2010), or support the sustainable transition of other supply chain members. In this vein, it has also been recognized that end consumer behavior influences sustainability performance along the supply chain (Vitell, 2015). Consumers might exert this influence by supporting sustainable logistics strategies with their monetary "votes" (e.g. Shaw et al., 2006) or by changing their own consumption behavior, such as using an ecological alternative to reach the supermarket. In this context, consumers can also be understood as agents carrying out meaningful practices (Sedlacko et al., 2014). Accordingly, the interdependence between corporate social responsibility (CSR) and so-called consumer social responsibility (ConSR) is referred to as shared responsibility which requires mutual support and co-operation (Schmidt, 2015). To support responsible actions, there is a demand for sustainable production and consumption systems and, in this vein, appropriate capabilities considering the related effects of ecological and social trends as well as shifts in consumption patterns. To do so, sustainable supply chain management (SSCM) (cf. Carter and Easton, 2011; Seuring and Müller, 2008) can promote the analysis of sustainability gaps at LSPs, in particular corrections in operational management practices as well as policy improvements in sustainable production and consumption systems. Although SSCM mainly focuses on the manufacturer and retailer (Huemer, 2012) rather than favoring the LSP perspective, a sustainable logistics management can also be subsumed under SSCM literature. Hence, this study intends to facilitate the knowledge about sustainable supply chains for a needed sustainability transition in and across integrated systems of production, supply and consumption. Taking into account dynamic capabilities (DCs) theory, critical supply chain actors, in particular LSPs, will be examined in the study at hand to realize a conceptual integration beyond the level of the focal company. In this context, the use of participatory systems mapping (PSM) (Sedlacko et al., 2014) opens new perspectives for system alternatives with enhanced sustainability performance and operational efficiency. Thereafter, implications can be derived concerning specific SSCM DCs to facilitate supply chain innovations in terms of infrastructure development as well as operations management practices. In detail, this research analyses the dynamic interactions of consumer behavior and sustainable logistics services and contributes to theory by improving the understanding of the LSPs' role in sustainable production and consumption systems. Accordingly, the following research question guided our study: How can LSPs contribute to creating sustainable production and consumption systems and, at the same time, support more sustainable consumption patterns? To answer this research question, several workshops with relevant stakeholders following the principle of triple helix stakeholdership (business practice, public management and policy as well as science) (Etzkowitz and Leydesdorff, 2000) were conducted, which included the use of participatory modeling and systems thinking brainstorming techniques. These research activities are embedded in the research project "ILoNa" (Innovative Logistics for SustaiNable lifestyles).[27] The general objective of this research project is to investigate the interlinkages between innovative logistics services and sustainable lifestyles. Here, the research project analyzes production and consumption systems and related supply chain configurations in a participatory way to construct alternative and sustainable business options for LSPs. In addition, the study at hand is grounded in some of the results reported by Melkonyan, Krumme, Gruchmann, and de la Torre (2017). Here, Melkonyan et al.'s (2017) relevant findings are interpreted and extended through the theoretical lens of DCs. Accordingly, the structure of the study is as follows: Sect. 2 describes the relevant literature streams regarding theory building in SSCM, while Sect. 3 gives an overview of the methodological approach of PSM. The related literature towards system dynamics (SD) modeling and causal loop diagrams (CLDs) is described in detail in Sect. 4. Next, Sect. 5 describes the results of the conducted PSM workshops, while Sect. 6 discusses the derived CLD against selected theoretical SSCM frameworks. The last section concludes the main findings of the study by providing an outlook on future research perspectives accordingly.

[27] "Innovative Logistik für Nachhaltige Lebensstile" in German.

4.2.2 Theory Building in SSCM

In the past two decades, social and environmental issues found their way into supply chain research, stressing the importance of co-operation among companies to maximize profitability while minimizing environmental impacts and maximizing social well-being at the same time (Carter and Rogers, 2008; Pagell and Wu, 2009; Seuring and Müller, 2008). In contrast to the traditional supply chain management (SCM), which is usually intended to focus on economic performance, SSCM is characterized by the explicit integration of environmental and social objectives which extend the focus of the economic dimension to the triple bottom line (TBL) as suggested by Carter and Rogers (2008). Starting from a rather holistic and broad analysis of SSCM literature at the beginning of research in this field, recent publications concerning SSCM tend to focus on sub-bodies of the discipline. Hence, the detected literature gaps and the expressed future research directions of general literature reviews led to an increased research interest in social aspects of SSCM. Answering the increasing demand for addressing social aspects in SSCM in recent years, Yawar and Seuring (2017) as well as Quarshie et al. (2016) provided literature reviews linking SSCM and CSR improvements. Even though there have already been answers to the calls for strengthening the robustness of developed frameworks and for promoting the building of more comprehensive theory in (S)SCM, the need for theoretical grounded research in SSCM is still not saturated (Matthews et al., 2016; Quarshie et al., 2016; Touboulic and Walker, 2015). Especially, the practical integration of concepts of sustainability and SCM is seen as the biggest challenge. Here, Hanke and Krumme (2012) criticized a missing reference of SSCM theory building to the conceptual achievements of Sustainability Science and advanced sustainability definitions and state a dominant orientation on (less helpful) weak sustainability models such as the TBL. In this vein, Matthews et al. (2016) even argue that the omnipresent assumption of achieving economic, environmental and social goals at the same time needs to be reassessed to build an alternative theory. Following Halldorsson et al. (2007), Carter and Easton (2011) as well as Touboulic and Walker (2015), most theoretical studies on (S)SCM use popular theories from other disciplines such as stakeholder theory (cf. Freeman, 1984), institutional theory (cf. DiMaggio and Powell, 1983), transaction cost theory (cf. Williamson, 1975) as well as the resource-based view (RBV) (cf. Barney, 1991) and natural resource-based view (NRBV) (cf. Hart, 1995; Hart and Dowell, 2011). Taking into account the underlying theories, their suitability for the proposed research question is discussed in the following. With regards to stakeholder theory and institutional theory, both theories stress the influence of stakeholders and other parties as drivers for (S)SCM (Quarshie et al., 2016; Touboulic and Walker, 2015). Although DiMaggio and Powell (1983) originally talk about organizational fields tending towards homogenization, most authors tend to use this theoretical lens to emphasize the role of large buyer firms in the supply chain. Due to their strong organizational and strategic view, stakeholder theory and institutional theory might not explain fully how LSPs can adopt further logistics and supply chain practices promoting more sustainable consumption patterns. Considering transaction cost theory, this theory stresses efficiency gains and cost reduction by entering interorganizational arrangements, in particular through co-operation with external partners (Halldorsson et al., 2007). Due to the high impact of logistics services on the economic firm performance, logistical activities have been mainly studied from a transaction cost perspective to achieve low-cost logistics services (Mentzer et al., 2001) and customer satisfaction through inventory availability, on-time deliveries and less product failure (Esper et al., 2007). Therefore, the transaction cost perspective with its emphasis on leveraging the efficiency of logistics services might even be obstructive in reaching holistic sustainability goals. Regarding RBV and NRBV, these theories focus on the competitive advantage that can be derived from managing resources as well as (sustainability-related) competencies (Touboulic and Walker, 2015). In particular, the NRBV perspective on the contingent nature of resources and capabilities allowed researchers to draw specific links between environmental and financial performance (Hart and Dowell, 2011). Although Hart's (1995) key strategic capabilities of pollution prevention, product stewardship and sustainable development foster the environmental pillar of the TBL, the LSPs' impact on the environmental performance of a company and supply chain is distinct. Based on these theories, the concept of DCs was derived from transferring the RBV and the NRBV into a dynamic environment (Beske, 2012). Dynamic capability theory aims to explain how companies can achieve a temporary or even long-term competitive advantage in dynamic markets (Eisenhardt and Martin, 2000; Teece, 2007; Teece et al., 1997). However, the research on DCs in sustainability management and particularly in SSCM is relatively young, although it has accelerated in the past few years because of its prevalence for purposefully changing business environments (Helfat et al., 2009). Recently, Amui et al. (2017) reviewed the literature on corporate sustainability and DCs stating that this research area needs to be further explored by using qualitative and quantitative methods. To build on DC theory, the empirical results presented in this chapter are analyzed abductively based on the conceptualization of SSCM practices and DCs proposed by Beske (2012) and Beske et al. (2014). Table 4.1 presents an overview of the SSCM-related DCs accordingly.

Table 4.1: SSCM-related DCs (Sources: Beske (2012) and Beske et al. (2014))

SSCM-related DC	Description
Knowledge management	Knowledge management includes the acquisition of new and the evaluation of current knowledge by the supply chain members (Defee and Fugate, 2010). From a LSPs' perspective, routines to generate, access and assess information about the sustainability impact of logistics services will contribute to improve the reliability of LSPs' sustainability performance (Yawar and Seuring, 2017). Moreover, the development and adaption of new technologies and practices may be eased.
Partner development	Partner development involves all activities to qualify supply chain partners to fulfill their (sustainability) responsibilities (Seuring and Müller, 2008). In this vein, the LSP business partners on the horizontal and vertical levels should be able to decide on the adaptation towards a more effective sustainability strategy of the supply chain.
Supply chain reconceptualization	Another set of routines deals with the reconceptualization describing the change of supply chain wide business models (Beske et al., 2014). Here, the transformation of the supply chain in line with a strategic reorientation of single members, particularly LSPs, might reduce the focal firm orientation and the competitive pressure (Gruchmann et al., 2016).
Co-evolution	Co-evolution is characterized by improved relationships of single supply chain members leading to more efficient collaboration and co-operation among the partners (Eisenhardt and Martin, 2000). In particular in dynamic and complex supply environments, co-evolution might lead to a certain equilibrium in the system (Choi et al., 2001). In the automotive industry for instance, when the original equipment manufacturer develops a supplier as a first-tier supplier, this action in turn creates a whole new set of second-tier suppliers who will deliver to this new system supplier.
Reflexive control	Reflexive control contains the comparison and evaluation of the supply chain functionality (Beske et al., 2014). Here, the setup of key performance indicators reliably measuring the social performance (Yawar and Seuring, 2017) of LSPs would support a transparent communication among SC members (Gruchmann et al., 2016).

4.2.3 Participatory Systems Mapping

To understand the connection between logistics services and sustainable production and consumption systems, a systems thinking approach for integrating complex issues of the TBL is required (Krumme, 2016). Therefore, the PSM method was adopted to facilitate knowledge transfer, based on participatory modeling and application (Sedlacko et al., 2014). PSM generally aims to develop and analyze CLDs to provide insights into a particular issue, while using a facilitated group process to connect the mental models of participants through structured discussions (Sedlacko et al., 2014). To answer the proposed questions with the help of PSM, participants work in groups and follow a predefined script over a certain period of time guided by a moderator. This is to enable participants to become familiar with the CLD syntax and the given problem itself, and gives them the opportunity to discuss the scope and delineation of the topic. In the next phase, participants are instructed to determine causal connections to establish cause-effect relationships between the variables, followed by an attempt to lead back these effects directly to the causes (creating feedback loops). The main task during this phase is accordingly the identification of relevant variables in the system. Thus, the mappings in the second phase are based on suggestions from the participants to incrementally add and connect new variables to the CLD. This often leads to group discussions about causal connections and the corresponding supporting evidence. During the process, the participants experience effects of combined feedback loops, identify cascade effects (if present) and take new standpoints on emergent systems behaviour. Through the inclusion of participants from different disciplines, the groups have the opportunity to obtain new input and are able to test the impact of the models and knowledge gaps. Therefore, knowledge sharing and breakthroughs usually take place in the discussions. These learning outcomes seem to originate mainly at the level of implicit knowledge (where mental models are normally located), and they leave only a few explicit traces in the memory of the participants in the evaluation of the usefulness of the exercise. During the third phase, still open knowledge gaps are identified in order to ascertain where further research is necessary to complete and specify the CLD. To summarize the integrated approach using the methods mentioned, Figure 4.1 graphically shows the described phases: While Sedlacko et al. (2014) use PSM in the field of sustainable consumption, the study at hand intends to contribute to theory by using PSM in the field of SSCM and sustainable logistics to facilitate more sustainable consumption patterns (including feedbacks as typical for mutual relationships). Accordingly, the exploratory method of PSM was carried out to develop (advanced) CLDs, based on the modeling language of qualitative SD modeling in conjunction with the concept of SSCM as a theoretical foundation of the study.

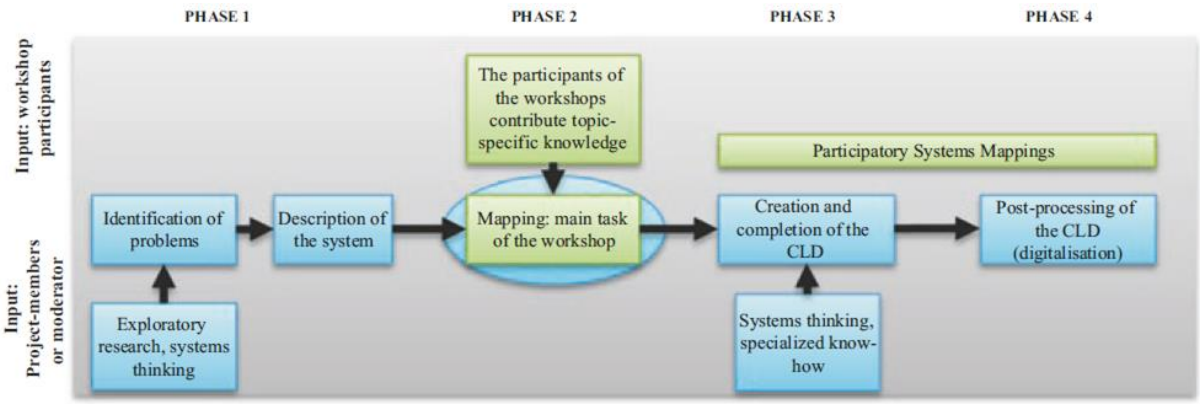


Figure 4.1: Applied methodology of causal diagrams and participatory system mapping

4.2.4 System Dynamics Modelling

To operationalize systems thinking methods such as PSM into SD modeling has a rich tradition not only in a sustainability context, but also for decades in traditional SCM (Tako and Robinson, 2012). Here, SD modeling is seen as a tested instrument to analyze problems of dynamic complexity in a wide range of settings (Sterman, 2000). Forrester (1968, 1977) was the first author who scientifically described SD modeling; namely as “the investigation of the information-feedback character of industrial systems and the use of models for the design of improved organizational form and guiding policies” (Forrester, 1977, p. 13). Moreover, Wolstenholme (1990), who incorporates the quantitative simulation concept, provides an extended definition. He defines SD as a “rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies, which facilitates quantitative simulation modelling and analysis for the design of system structure and control” (Wolstenholme, 1990, p. 3). Interpreting these definitions, SD modeling leads to a profound understanding of complex issues and systems as well as its circumstances. Sterman (2006) calls these issues “needle-in-a-haystack problems” when complexity arises from finding the right path between a high number of possibilities. Accordingly, SD modeling deals with the non-linear behavior of complex systems over time (Morecroft, 1992) aiming to describe systems with the help of qualitative and quantitative models, but also to understand how feedback structures determine systems’ behavior (Coyle, 1996). So far, SD modeling has established itself as a computer-aided simulation method. Here, feedback structures should be actively created and decision-making rules should be derived from the knowledge learned through simulation. Following Davis et al. (2007) SD simulation is also increasingly used as a methodology for theory development. Particularly for longitudinal and non-linear processes, simulation can help to build a more comprehensive and precise theory from so-called simple theory (Davis et al., 2007). Although CLDs are not part of the original process described by Forrester (1977), they are one of the most important qualitative modeling methods (Coyle, 1996; Sterman, 2000). Generally, CLDs comprise a set of nodes and edges, which consist of a set of variables connected by arrows denoting the causal in influences among them. Here, a feedback loop contains two or more related variables that relate back to themselves. These relationships can be either positive or negative. In this context, CLDs fill the knowledge gaps in SD models to gain a sense of non-linear systems behavior based on feedback structures, and identify assumptions and underlying mechanisms in mental models (Sedlacko et al., 2014). therefore, CLDs can be considered as the basis for simulation modeling. they fulfill additionally the central task of bringing people closer to the understanding of systems in the sense of “systemic thinking” (Coyle, 1996). However, CLDs are expressed in a formal language which needs practice to be understood properly (Forrester, 1968). Thus, it is recommended to translate the participants’ statements into the

CLD syntax in order to avoid misunderstandings. CLDs are excellent not only for the fast capturing of hypotheses to explain the dynamics of a model, but also for communicating relevant feedback responsible for, at first sight, “hidden” problems concerning the system (such as counterproductive rebounds or back-fire effects). They identify the most relevant feedback loops of a system, which are used to describe basic causal mechanisms hypothesized to generate a reference type of a system’s behaviour over time (Sedlacko et al., 2014). Although CLDs demand to capture a system in its whole complexity, they still simplify reality to provide the ability to focus on specific issues.

4.2.5 Workshop Results

For systematically creating results, a workshop platform integrating various perspectives of the experts in the field of sustainable logistics, production and consumption was established following the principle of triple helix innovation (Etzkowitz and Leydesdorff, 2000). Within this platform, the trends in logistics services and consumption affecting the sustainability of production and consumption systems were analyzed and discussed with representatives of LSPs, consumer advice agencies and academics within several conjoint workshops (Melkonyan et al., 2017). workshops were based on the key aspects linking logistics services and sustainable consumption patterns which have recently been explored by Gruchmann et al. (2016). These key aspects contain in particular Last Mile[28] (LM) configurations, sharing economy solutions and raising consumers’ awareness of logistics services. In this vein, the main task of the PSM workshops was to map the actors, success factors, challenges and strategies towards implementing sustainable logistics services in sustainable production and consumption systems in a joint manner in order to investigate relevant variables and their causal connections.

4.2.5.1 LM Configuration

Within the workshops considering the LM configuration, the participants differentiated between two types of consumer lifestyles (Melkonyan et al., 2017). The first lifestyle was defined as group of consumers who work full-time and have limited time for grocery shopping (for instance young and employed parents). Accordingly, these consumers need to plan their shopping activities carefully. In this context, the workshop participants saw online distribution channels such as “Click & Collect”[29] (C&C) as well as home delivery services as an attractive distribution channel for this group, mainly due to possible time savings. Operating within online retailing

[28] The LM serves as “meeting point” of retailers, LSPs and consumers. In the literature, the LM is seen as the most expensive part of the supply chain (Schliwa et al., 2015) and accountable for a large proportion of total CO_2 emissions (Edwards et al., 2011). Furthermore, the LM is one of the most complex parts of the supply chain, due to tight delivery time windows and a growing number of small orders (Kull et al., 2007; Punakivi et al., 2001).

[29] C&C integrates online and stationary distribution services into a hybrid channel. Here, the consumer may order online while pickup, return or exchange of goods stays in-store.

channels, LSPs have the best opportunity to interact directly with consumers, and vice versa consumers can place their demand for more sustainable LM configurations more easily (Gruchmann et al., 2016). The participants argued that the classical parcel delivery services are not sufficient to achieve a higher LM sustainability performance. Instead, a more personalized parcel delivery including value-adding services, such as the handling of complaints, should be offered to increase convenience. The participants also warned that parcel pickup concepts like C&C present a business model to bypass the challenges in the LM to the consumer. Hence, performance with regard to sustainability aspects depends strongly on the mobility preferences of consumers (Gruchmann et al., 2016). In contrast, the second lifestyle was defined as consumers who do not invest time in pre-consuming, but rather in the shopping activity itself, seeking to be inspired by the product offers on the market (e.g. elderly people). For this consumer group, conventional “brick and mortar” retailers still seem to be the most relevant distribution channel. Additionally, the participants argued that communication about sustainable mobility patterns is very important for this second group of consumers. Hence, the inclusion of consumers’ consumption and mobility preferences, also in the configuration of a conventional distribution channel, is crucial to achieve a better sustainability performance in the LM.

4.2.5.2 Sharing Economy Solutions

From the workshop participants’ perspective, the concepts of the sharing economy[30] have potential for a more sustainable configuration of supply chains in general and the LM in particular. Considering these solutions of a sharing economy, freight shipping services conducted by consumers themselves, especially in the LM when consumers indicate the location of goods available for pickup and delivery, are seen as an interesting trend from a sustainability point of view. In line with these crowd logistics concepts, it is possible to pick up or drop off goods on the way back from work for a small reward and at the same time achieve a positive effect on sustainability. These sharing concepts have been particularly highlighted by the workshop participants since the LM efforts can be reduced significantly. us, sharing economy solutions could weaken the price pressure due to more logistical advantageous configurations on a local level.

[30] Botsman and Rogers (2011) identified a growing consumer interest in shared consumption which is facilitated by innovations in information technologies. Here, shared consumption has the potential to raise awareness of ecological and social aspects related to distribution channels. Heinrichs and Grunenberg (2012) distinguish three types of shared consumption. These are professional product-service-systems (e.g. car-sharing), redistribution markets (e.g. platforms such as eBay) and collaborative lifestyles (e.g. sharing music files).

4.2.5.3 Raising Consumers' Awareness of Logistics Services

The participants also stated that a general consumer awareness not only for sustainable logistics issues, but also for logistics services in general as an integral part of a product should be raised as this is often barely noticeable for the consumer. In this context, an increased visibility and perceptibility of logistics services can lead to its higher recognition and esteem as well as a higher willingness to pay (Gruchmann et al., 2016). Therefore, the willingness to pay for sustainable products and services was defined as an important success factor, but simultaneously as a challenge (Melkonyan et al., 2017). In this vein, the workshop participants argued that consumers who are willing to pay more for sustainable products, might be willing to pay more for sustainable logistics services as well. On the other hand, willingness to pay was considered as a challenge by workshop participants, since a consumer has limited financial resources and once paying for the sustainable products, less income will be available to afford sustainable logistics services. In addition, the participants stated that communication and clear information about sustainability aspects concerning logistics services is considered to be a necessary condition for sustainable consumption behavior. Although it was mentioned that too much information could be a challenge as it might overburden the consumer, providing sufficient information about logistics services and its sustainability impact was considered to be predominantly positive (Melkonyan et al., 2017).

4.2.5.4 Causal Loop Diagram

Summarizing the results of all workshops, Figure 4.2 presents the CLD using all parameters highlighted by the participants together with their logical feedback mechanisms. As shown in Figure 4.2, there are six feed-back mechanisms which influence the dynamics of the system (Melkonyan et al., 2017). The "Willingness to pay" feedback loop describes the stabilizing interconnection among the willingness to pay for the performance and the price of sustainable logistics services in dependence on the consumer income. The feedback loop "Investment in infrastructure" shows the positive impact of the demand for sustainable logistics services on investments in logistics infrastructure dependent on available resources. e option between the use of the private car and using logistics services representing the mobility preferences of consumers is clarified with the feedback mechanism "Choice of the distribution channel". "Sustainability image" shows that the image of the firm and its communication efforts positively influence the supply of sustainable products. All feedback mechanisms are summarized in the main feedback loop called "ILoNa" (according to the research project's name), which connects the awareness of sustainability aspects in logistics services (thus also the willingness to pay for them) with the image and reputation of the firm and, at the same time, supports sustainable consumption patterns.

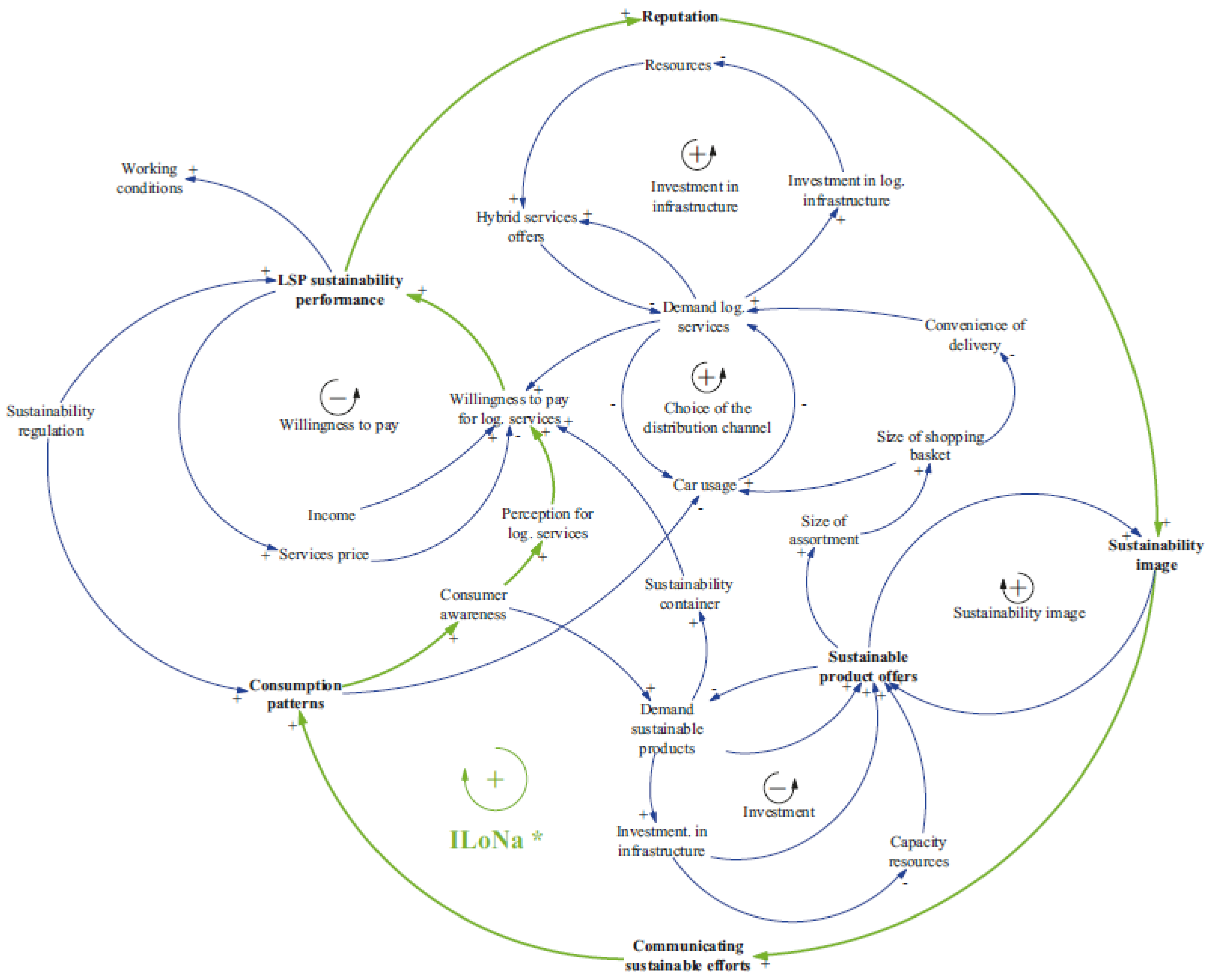


Figure 4.2: Causal loop diagram (Melkonyan et al., 2017)

4.2.6 Theoretical Lens

In the following, the classification scheme of SSCM functions proposed by Hassini et al. (2012) is used to discuss the identified relevant causal relations in a broader SSCM context. The SSCM functions of transformation, delivery and value proposition were chosen as they imply linkages between logistic services and consumer decisions. The purpose of this section is to structure the findings of the PSM systematically and, at the same time, extend the SSCM functions pointed out by Hassini et al. (2012) by adding the LSP's causal relations and feedback mechanisms to the dynamic system. In this vein, the LSP's potential for building more sustainable production and consumption systems as well as necessary LSP's DCs in sustainable supply chains can be stressed. At the same time, insights into unfolding existing sustainability potentials through new business practices are derived.

4.2.6.1 Transformation

Following Hassini et al. (2012), the focal company in the supply chain may trigger an adaptation towards technologies and practices that result in engaging labor practices that are considered as fair and result in a lower impact on the environment. To achieve such a transformation, the members of a supply chain need to co-ordinate their cross-company activities in a network to share risks and rewards in a fair manner (Skjøett-Larsen, 2000). Relevant SSCM practices for achieving supply chain collaboration are the joint development of new technologies, processes and products (Vachon and Klassen, 2006), technical and logistical integration as well as an enhanced communication (Beske et al., 2014). When it comes to more sustainable product and service offers, the necessary infrastructure and resources have to be provided by the actors in the supply chain. Accordingly, the co-ordination of such resources which are distributed and shared across the supply chain (Halldorsson et al., 2007) must solve or avoid conflicts in the interests of all members to realize a supply chain reconceptualization. Here, technological innovations provide the opportunity to strengthen the position of LSPs and, at the same time, enable the creation of more sustainable and integrative production and supply systems. As technological innovations require knowledge management capabilities, routines for knowledge sharing as well as knowledge acquisition and evaluation need to be developed (Beske et al., 2014). In this context, Chapman et al. (2003) see particularly high transformation potentials by investing in advanced information technologies such as web-based ordering, electronic data interchange, barcoding, vehicle routing and scheduling, inventory replenishments and automated storage. Moreover, the development of new partnerships, also with partners who are not necessarily directly involved with the business, can ease the reconceptualization of the supply chain (Beske et al., 2014).

4.2.6.2 Delivery

Hassini et al. (2012) see the delivery process as a broad term to encompass multiple operational processes (like the choice of location, mode of transportation, etc.). Particularly with regard to sustainable logistics services and the possibilities of designing distribution channel options (stationary retailing, online retailing and hybrid configurations such as parcel stations or C&C), consumers' mobility preferences, especially their car usage, have to be considered to achieve more sustainable production and consumption systems. For instance, in regional settings with less stationary retailers, online retailing can be useful by bundling the ow of goods if additional private shopping trips can be avoided. Moreover, the convenience of the delivery is crucial for the consumers' choice of the distribution channel on the one hand and the sustainability performance of the system on the other hand. Thus, the offer of a large size of assortment has a negative impact on the convenience of the delivery, but, at the same time, is necessary to achieve less private shop-ping trips and demands for more sophisticated logistics services. Accordingly, distribution channels which simply bypass the LM responsibility to the consumer, such as C&C, need to be accompanied by additional activities to achieve more sustainable consumption patterns. Therefore, a co-evolution of supply chain partners, in a first step between LSPs and retailers, would lead to more sustainable distribution channel options. In a second step, a co-volution actively involving the consumer, for instance by organizing the LM with the help of sharing economy solutions, might tap further sustainability synergies.

4.2.6.3 Value Proposition

As consumer satisfaction is usually the primary goal of manufacturing or provided services, it is important that the product or the service is accepted by the consumer. Therefore, the performance measurement is not only defined and limited to financial and income-related indicators, but is also driven by performance indicators based on consumer wishes and judgements (Eisenhardt and Martin, 2000). Accordingly, willingness to pay is balanced by price and performance. However, consumer perception of logistics services as integral part of a product and its impact on sustainability (the so-called sustainability container) is still rather low (Gruchmann et al., 2016). Thus, costs related to environmentally friendly or sustainable products and services cannot be easily passed onto consumers. Consequently, the benefits of more sustainable products and services should be stressed to justify higher logistics service prices. Following Hassini et al. (2012), the key value proposition needs to be well communicated and understood by consumers in order to translate into alternative consumption patterns. Therefore, those consumers who are open-minded to social-ecological issues should be addressed first as they are more sensitive to a better sustainability performance (in the sense of “first movers” or “early innovators”). In this vein, establishing a reflexive control with regards to measuring the impact on sustainability increases the awareness directly among supply chain members and indirectly, through transparent and reliable communication, among certain consumer target groups. In addition, communication of a higher LSPs’ sustainability performance has a positive impact on the reputation and sustainability image of the company. Nonetheless, the setup of key performance indicators reliably measuring social performance in particular is still a challenge in supply chains (Yawar and Seuring, 2017).

4.2.7 Conclusion and Outlook

On the way to identifying more sustainable alternatives with respect to environmental and social externalities of production and consumption systems, this study has shown the application of PSM that considers systems thinking (1) in terms of understanding a systems behavior and (2) the integration of available systems knowledge of experts in the field through a participatory process. This combined approach led to a system map based on perceptions and implicit knowledge stocks of the participating actors blending responsible consumership and SSCM into an integrated production and consumption system. The PSM approach explicitly incorporated the key issues for sustainable alternatives in the system, in particular the LM configuration, sharing economy solutions and consumer awareness of logistics services. Thereby, the interplay of logistics services from the sphere of SSCM and consumer behavior from the sphere of lifestyles was represented on an empirical basis. The derived CLD, which describes the relevant parameters and their logical feedback mechanisms, provides a reliable representation which serves as a starting point for several next steps of future research such as SD simulation. To theoretically concretize DCs within sustainable supply chains and LSPs as supply chain facilitators, the initial anchor points of the PSM workshop series (LM configuration, sharing economy and awareness of logistics services) have been interpreted with the help of the theoretical frameworks proposed by Hassini et al. (2012), Beske (2012) and Beske et al. (2014). The SSCM functions of transformation, delivery and value proposition served to identify and structure DCs from an LSP's perspective with significant meaning for supply chain transitions towards sustainability. The findings indicate valuable elements for sustainable added-value services and respective business models in sustainable production and consumption systems. From a consumer's perspective, for instance, it is necessary to include ecological and social sustainability parameters into the price-performance ratio. Increased sustainability performance can only achieve a positive impetus if supply chain integrity is well communicated to the consumer and if the relevant effects and impacts of the system are made transparent. To conclude and highlight logistical DCs, the study reveals a high relevance of collaborative management skills in line with a coherent implementation of integrated supply chain information and communication technologies to achieve reflexive control. From the viewpoint of LSPs, supply chain reconceptualization with regard to shared financial and operational risks as well as interest conflict avoidance among supply chain members is seemingly a connected critical capability. A pre-requisite for the identification of such risks and conflicts, but also to spot opportunities, is appropriate knowledge management for sharing, acquisition, evaluation, enrichment and preservation of knowledge) about interfaces between sub-systems in the vertical supply chain structure and in a horizontal order of main material and information flows with co- flows representing sustainability-related issues such as energy, water, waste, or emissions. These issues – such as enhanced consumer driven communication schemes in upstream information flows (sustainability demands) addressing vertical as much as horizontal structures and the internalization of external information through developing new partnerships, for example with mediate stakeholders (e.g. GOs, NGOs, independent expert groups) – represent promising potential for more sustainable operations and are important for companies to actively consider. In addition, the capability of LSPs to also channel rich product assortments, especially on the basis of decentralized production sites, is attractive to win competitive advantages against the backdrop of regional supply systems, while this combination is able to fulfill dominant consumer convenience aspects through the co-ordination and consolidating role of LSPs. This asks for a stronger co-evolution between LSPs and retailers, LSPs and producers, as well as LSPs and consumers. In this light, LSP/retailers' and LSP/consumers' co-evolution in particular shows sustainability potential through the integration of sharing economy solutions and collaborative consumption modes respectively. Nonetheless, the specific LSPs' characteristics could not be fully addressed by the used frameworks due to the LSPs' fixed role within the supply chain as providers of services (Mentzer et al., 2001). In line with Beske et al. (2014), the majority of DCs are relationship-specific and aim to improve the relations among the different SC members in order to enable further transformation towards a more sustainable supply chain configuration. Considering the LSPs challenge to gain from developing new business practices stressing anti-competitive and performance enhancement purposes (Gruchmann et al., 2016), future research activities need to deduce LSP-specific DCs from the existing SSCM-related DCs. In particular, future research might conceptualize logistics social responsibility practices from a DC's perspective to enhance understanding of the logistics service providers' capability to shape alternative supply chain configurations and, therefore, to promote sustainability in supply chains. In this context, further research can also build on a stronger investigation of the resilience design based on the target levels of a sustainability transition. The theory of system resilience is not only offering concrete orientation for a sustainable economy discourse (Krumme, 2016), but, even more interesting in the context of this study, is naturally correlated to DCs (Christopher and Peck, 2004). Current literature on DCs for resilient supply chains shows a high concentration on the inherent dynamics of the supply chain structures, functions and actors with an emphasis still against an economically dominated background, but much less reflects on the wider system boundaries to explore the urgent relevance of sustainability-related factors of SSCM.

4.3 Logistics Business Transformation for Sustainability: Assessing the Role of the Lead Sustainability Service Provider (Gruchmann, Melkonyan, Krumme, 2018)

The following chapter presents a peer-reviewed article by the author with Tim Gruchmann (Westcoast University of Applied Sciences) and Ani Melkonyan (University of Duisburg-Essen), accepted for publication in the MDPI Journal *Logistics*, 2018.[31]

The presented research refers to the project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015).

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Abstract

Societal, economic and ecological prosperity will be highly affected in the next decades due to socio-demographic developments and climate change. The design of more sustainable logistics business types can address such challenges to build more resilient supply chains. Therefore, the discussion with regard to transformational potentials of logistics businesses provides valuable information to shape business strategies according to future sustainability requirements. Within the framework of this paper, a mixed-methods approach has been applied to explore and analyze drivers and barriers for sustainability transformations of logistics service providers (LSPs) and to evaluate related business strategies with optimization and simulation methods in a concrete regional context. So far, LSPs' main obstacles are competitive pressure, focal firm orientation, and dependence on other supply chain members, while supply chain collaboration and integration, as well as the integration of sharing economy solutions and new digital technologies, have been identified as promising for sustainability transitions. Accordingly, this paper suggests a roadmap for the logistics sector while defining retention strategies such as growth, replication, mimicry, and mergence to meet future societal and environmental requirements. By doing so, this study contributes to theory by constructing

[31] Klaus Krumme introduced the basic conception of the "Lead Sustainability Service Provider" (6PL). This publication represents the first description of this business archetype in a peer-rev journal. He was also responsible for the revision of the article.

the Lead Sustainability Service Provider (6PL) business model (arche)type and its role in societal transitions.

Keywords

sustainable logistics; sustainable supply chain management; strategy development; business transformation; business model classification

4.3.1 Introduction

Several supply chains are likely to drastically change due to regional impacts of climate change, rapid urbanization, demographic developments, and a dynamic shift in demand patterns. Concrete climate protection strategies designed, for example, to prevent CO_2 emissions, are therefore being actively pursued by industrial companies (Tozanli et al., 2017). For the logistics industry as such, which is strongly affected by rising fuel prices, more sustainable business activities mean not only a reduction of CO_2 emissions and cost savings in economic terms, but also opportunities to highlight the value creation logic of logistics businesses and to allow for new governance forms in the supply chain (Schaltegger et al., 2016a). In this context, transformational management along the entire supply chain requires integrated solutions considering the main characteristics of business strategies to discuss promising avenues for sustainability transformations (Schaltegger et al., 2016b). Hence, a better understanding of transformation potentials in the logistics industry will promote the development of innovative, integrative business models based on a strategic roadmap.

Even though sustainability strategies and business practices in logistics have been intensively discussed in the literature, they have been focused on the economic (optimization of single logistical functions) and environmental dimension (e.g., environmental impacts, such as emissions of transportation activities), underrepresenting the social dimension of sustainability (Brandenburg and Rebs, 2015). Also, most research work being done concentrates on the (re-active) adaptation potentials of logistics businesses against the before mentioned challenges rather than discussing pro-active and design-oriented capabilities of logistics to contribute to a sustainability transformation within the frame of alternative sustainable supply chains of a green economy. However, the improvement of social performance within the logistics industry and their societal implications are crucial nowadays since concrete sustainability transformations on the operational levels of economic alternatives are urgently needed as well as scandals and resulting public debates increased the logistical awareness of consumers. Accordingly, the present study intends to contribute by facilitating the understanding of transformation potentials leading to pathways for sustainable logistics business models. Such a perspective of sustainability transformations is essential to understand and overcome existing business model limitations and develop strategies for socio-technical regime changes. Accordingly, the following research questions guided our study:

RQ 1. What are the driving factors and challenges for sustainable logistics business model transformation?

RQ 2. What are transformational pathways for the logistics sector to respond to the requirements of sustainable supply chains?

To answer these questions, the present study combines qualitative methods with optimization and simulation techniques to enhance strategic decision-making. Here, the use of specialized techniques for the sustainable optimization of logistical structures enables decision makers to carry out evaluations of different logistical strategies. As various objectives are explored with qualitative interviews and embedded in an optimization model, the purpose of this study is “exploring” the landscape of plausible outcomes and their relationships with certain decisions. Through applying a representative sample of the search space, the available information for strategic decision-making is evaluated with regard to a concrete regional setting.

The present study is structured as follows. In Section 2, the research is positioned in the existing literature. Section 3 informs about related exploratory modeling and analysis (EMA) approaches. Section 4 describes the research design while the findings are presented in Section 5. Section 6 maps the results with regards to potential pathways for sustainability within the 1PL to 5PL logistics business classification scheme. A discussion of logistics business models in societal transformation processes is provided in Section 7. Concluding remarks and an outlook are presented in Section 8.

4.3.2 Literature Background

Companies use strategic planning to integrate sustainability within the vision of the company and enhance its innovation potential (Judge and Douglas, 1998). In general, sustainability strategies can be linked to environmental marketing management (Peattie, 1995), green supply chain management (Sarkis, 2003), sustainable supply chain management (Seuring and Müller, 2008), purchasing (Carter and Jennings, 2004), reverse logistics (Nikolaou et al., 2013); and Life Cycle Assessment (LCA) (Tan and Khoo, 2005). In addition, all these practices and strategies can be related to socially responsible and green logistics management including the processes of transportation, packaging, and warehousing (Carter and Jennings, 2002). For instance, technical innovations and a shift towards transport modes that create the least pollution and strategies promoting multi-modality contribute to more sustainable transport and mobility systems (Gruchmann, 2019). Here, planning approaches use a variety of static and dynamic models as well as mathematical approximation methods and heuristics to support strategic planning. These approaches focus on different sub-areas such as route planning, location planning, network design, or warehouse planning. With regard to transportation issues, the main goal of most models is to minimize the distance travelled. This can be achieved either directly through intelligent routing (route planning), or indirectly through denser transport capacity utilization (loading space optimization). For this study, routing problems are explicitly incorporated into the explorative modelling because of its importance for the sustainability performance in supply chains.

4.3.2.1 *Sustainable Logistics Business Models*

Extending conventional business frameworks in accordance with sustainability requirements, Boons and Lüdeke-Freund (2013) define the key parameters in sustainable business models as follows:

(1) value proposition of products and services focusing on ecological, social, and economic value; (2) overall infrastructure and logistics of the business guided by the principles of sustainable supply chain management; (3) interface with customers enabling close relationships between customers and other stakeholders to improve co-responsibility in production and consumption; and (4) equal distribution of economic costs and benefits among all actors involved. Broadening this systems' scope further, Neumeyer and Santos (2018) position business models as part of the whole entrepreneurial ecosystem, particularly dependent on the stakeholder's social network. In addition, Lüdeke-Freund et al. (2016) see research in the field of sustainable business models as still limited, particularly with regard to empirical analyses.

In this line, the logistics service providers' (LSPs) potential to facilitate sustainable practices in the supply chains is coming to the fore such that the alignment of logistical actions between actors in the supply chain defines more sustainable and innovative logistics business models (Boschian and Paganelli, 2016). Such industry- and branch-specific sustainable businesses can be analyzed to access business model elements and (arche)types that support the management of voluntary social and environmental activities in certain environments (Bocken et al., 2014). For the logistics industry as such, the business models of shippers and LSPs are categorized by means of their service range and structure. A popular classification scheme is the 1PL to 5PL scheme (Köylüoglu and Krumme, 2014). Table 4.2 gives an overview of this classification scheme and related sustainable logistics practices.

Table 4.2: 1PL to 5PL scheme and related sustainable logistics practices (Gruchmann, 2019)

Classification	Description
1PL (Single Service Provider)	Single service providers execute single logistics services, such as freight carrier (transportation) or stock keeper (warehousing). Accordingly, single service providers should concentrate on methods to decrease the environmental and social impact of their logistical assets (e.g., using cleaner drive technology).
2PL (2nd Party Logistics Provider)	The 2nd party logistics provider executes all classical logistics functions of transportation, handling and warehousing; typical business model for freight forwarders, ocean carriers and parcel services. As they operate different transport modes, the selection of the best modal split becomes an important instrument to increase the environmental performance of their logistical activities.
3PL (3rd Party Logistics Provider)	The 3rd party logistics provider extends the classical logistics function with neighboring logistics services such as cross docking, inventory management and packaging design. In this line, 3rd party logistics providers are often globally acting companies who contract with their customers “at eye level” (Wolf and Seuring, 2010). Hence, they have the opportunity to implement more advanced, sustainable strategies such as decision support systems to optimize transport mode, route and capacity usage.
4PL (4th Party Logistics Provider) and 5PL (so-called Lead Logistics Provider)	The 4th party logistics provider provides comprehensive solutions to coordinate and integrate all supply chain members using information and communication technologies (ICT). 4th party logistics providers are often specialized consulting companies not carrying out any operations (so-called non-asset-owning service providers). In contrast, lead logistics providers carry out certain operations by owning or buying physical logistics infrastructure. Accordingly, coordination mechanisms and joint decision-making are relevant to achieve more sustainable supply chain configurations.

4.3.2.2 *Logistics Business Transformation for Sustainability*

Market innovations that drive sustainable change are often triggered by individuals and companies incorporating sustainability aspects into their core business (Schaltegger and Wagner, 2011). Companies can either provide effective solutions to environmental or social problems or sell sustainably produced products in the mass market (Hockerts and Wüstenhagen, 2010). Taking an evolutionary economics perspective (Nelson and Winter, 2002), the processes of varying, selecting, and retaining business models induce market transformation (Schaltegger et al., 2016b). Most of the factors combined into the scenarios lie outside the control of the organization itself, and describe the current trends not only from an economic or technological point of view, but also cover social aspects, e.g., consumer awareness or new sharing models. Taking into account these factors, the present study focuses on potential pathways for the diffusion of sustainable logistics businesses. Here, retention is most important in increasing market share. Retention, in general, describes diffusion processes through innovation promoting growth in the market share of more sustainable businesses. Growth, replication, mimicry, and mergence are seen as retention processes and strategies (Schaltegger et al., 2016b).

Growth: While business growth is often viewed in contrast to sustainable development, the growth of a sustainable business model has to take place at the cost of unsustainable business models. Thus, sustainable growth in consolidated markets acquires a structural market change. To do so, high-growth niche players have to foster radical sustainability innovations in combination with professional management techniques (Schaltegger et al., 2016b). For the logistics sector, sustainable growth potentials lie within the replacement of conventional transport and warehousing technologies favoring LNG (Liquified Natural Gas), electricity, or hydrogen as energy sources (Gruchmann, 2019). Here, advanced decision support systems (e.g., for vehicle routing) supported by advanced information technologies, such as big data analytics or artificial intelligence are coming to the fore (Tozanli et al., 2017). Growth potential also lies within the implementation of sustainable reverse logistics practices that guarantee the use and reuse of products. Recently, authors have started to incorporate social aspects in reverse logistics systems, such as equity, diversity, health and safety practices, education, and stakeholder engagement (Nikolaou et al., 2013; Agrawal et al., 2016).

Replication and mimicry: Replication is an alternative form of diffusion. Here, niche pioneers set up a sustainability-oriented business model solely applying sustainable ways of production and were followed by other niche players. Mimicry describes the strategy of copying business model elements of niche businesses and incorporating them in a modified way into a mass market player's business models. For the logistics industry, start-up businesses with a city logistics focus provide the potential for replication and mimicry as they allow for alternative transportation modes such as cargo bikes, private or public transportation. In crowd logistics businesses, for instance, the offered services are mostly fulfilled by consumers and not by the staff of a company (Frehe et al., 2017). Accordingly, these allow for an inclusion of private persons to conduct logistics activities. Here, replication and mimicry strategies are promising the field of sharing economy businesses as shared consumption has the potential to raise the awareness for ecological and social aspects related to distribution channels (Botsman and Rogers, 2011). In addition, circular economy business models provide the potential to leverage LSP's sustainability potential (Batista et al., 2019).

Mergence: Mergence has been studied mainly from the perspective of mass market players through the acquisition of promising niche players. If companies do not compete directly, they can also build strategic alliances such as strategic partnerships. Thus, a balance between a customer orientation and operating cost-effectively can be also achieved through supply chain coordination. In this context, supply chain coordination is defined as coordinating cross-company activities on a vertical and horizontal supply chain level to share risks and rewards in a fair manner (Vachon and Klassen, 2006). Accordingly, logistical infrastructure has to be shared and combined effectively to achieve better sustainability.

4.3.3 Exploratory Modeling and Analysis (EMA)

EMA aims to utilize the advantages of computer-aided simulations and experiments when it comes to decision-making where a significant amount of uncertainty is present (Bankes, 1993). Within EMA, exploration procedures are conducted via computer-aided experiments. One single run of the computer aided experiment (calculation run) is performed with a model that has a given structure and a given parameterization. Here, a calculation run based on the input of fixed data represents a single estimate of the future. Conducting a large number of calculation runs (performed with one or several models), a structure for likely actions and sequences of events can be derived. These possible outcomes arise by making alternative decisions assuming different, unknown future events. Accordingly, different possible scenarios can be explored. Therefore, EMA is not about optimizing the outcome of possible solution through the evaluation. Rather, the possible "what-if" questions are supposed to be clarified (Kwakkel and Pruyt, 2013; Walker et al., 2013). Hence, the most important goal of EMA is to find the most robust decision paths to cover a variety of future scenarios (Walker et al., 2013; Lempert et al., 2003). Accordingly, strategic pathways are robust in the face of uncertainty when its actions perform satisfactorily over a wide range of future situations.

So far, there have been few studies that use exploratory modeling for supply chain or logistics issues. For instance, Kwakkel et al. (2012) developed an Adaptive Airport Strategic Planning (AASP) approach based on the more common Airport Master Planning (AMP) for the development and expansion of airports. They used exploratory modeling to test the efficacy of their AASP for a variety of future scenarios concerning Amsterdam Airport Schiphol. Moreover, Halim et al. (2016) dealt with EMA and scenario discovery regarding the impact of deep uncertainty on global container transport in European ports. These authors combined the concept of scenario discovery with an additional worst-case discovery technique. In addition, Corvers (2016) conducted a scenario discovery in the context of Supply Chain Risk Management. Factors that were tested are warehousing decisions and various common risks coming from business and customer demand. Just recently, Moallemi et al. (2018) used a scenario discovery approach based on a hypothetical air fleet. It deals with the trade-off between maintenance services and aircraft investments with the aim of maximizing flight hours and keeping investment and service costs to a minimum. In contrast to the previous studies, the present study focuses on the application of EMA-based techniques (optimization and simulation) for analyzing potential pathways for LSPs in a specific regional setting based on a more general, qualitative exploration. To the best of our knowledge, none of the previous studies tackled the proposed research questions so far.

4.3.4 Research Design

In general, a mixed-methods approach was applied to explore relevant driving factors and barriers for sustainability transitions of LSPs (see Section 4.1), as well as to analyze and evaluate related transformational strategies within a concrete region, in particular the Linz region in Upper Austria (Section 4.2).

4.3.4.1 *Qualitative Exploration*

In order to study transformational potentials of logistics business models, drivers and barriers influencing the sustainability performance of the supply chain were identified through qualitative expert interviews and discussed within a participatory workshop. Since the research interest particularly addresses logistics services, the qualitative interviews were held with experts in the field of supply chain and logistics services, as well as in consumer lifestyle. All the specialists had at least five years of experience in their field. Regarding the expert interviewee selection, six interviewees were chosen from a group of scientists (professors) holding a chair in logistics and SC management at European universities, while the other six interviews were conducted with scientists whose research is focused on sustainable consumption and production. From the practitioners' side, three interviewees were selected from sustainability managers who work with Western European LSPs, while three interviewees worked with Western European non-governmental consumer organizations (see Table 4.3). In sum, 18 qualitative expert interviews were conducted based on an interview topic guide. The interviews lasted up to 60 min and were tape-recorded or transcribed with important quotes summarized. The transcripts, summaries and important quotes were analyzed with the qualitative content analysis approach in a structured, inductive manner (Mayring and Fenzl, 2014) and linked to the literature, whenever possible.

Table 4.3: Interviewee settings and expertise

Index	Setting and expertise
Practitioners	
P1	German third-party food logistics provider
P2	German third-party fashion logistics provider
P3	Austrian third-party food and FMCG logistics provider
P4	German consumer advice agency
P5	Irish consumer engagement and information center
P6	Finnish sharing economy expert
Scientists in the field of (sustainable) logistics and SC management	
S1	Professor in transport and logistics management
S2	Professor in retail logistics
S3	Professor in SC management
S4	Professor in logistics and service management
S5	Professor in SC management
S6	Scientist working in a research institute concerned with mobility research
Scientists in the field of (sustainable) consumption	
S7	Professor of consumer and household economics
S8	Scientist in research group concerned with sustainable consumption and production
S9	Scientist in research institute concerned with responsibility research
S10	Scientist in research institute concerned with social innovation
S11	Scientist in research center concerned with environmental economics
S12	Scientist in research concerned with environmental economics

Due to the complexity of qualitative interviews, careful interpretations of the interview results are necessary to analyze the extent to which the findings serve the research purpose (Alvesson, 2003). According to Yin (2003), quality procedures with regards to internal validity, external validity, construct validity, and inter-rater reliability need to be in place when analyzing qualitative data and documents to ensure methodological rigor. Regarding internal validity, the transcript coding was performed by two researchers, also ensuring inter-rater reliability. To further strengthen internal validity, the insights from the expert interviews were triangulated with the data from the consumer interviews. In terms of external validity, comparisons with literature were conducted, as suggested by Riege (2003). To further strengthen external validity, an expert workshop was performed with scientific participants from various German universities (none of whom was an interviewee) discussing the approach to evaluate the inductive coding scheme as well as the strategic categories derived from the qualitative content analysis approach. Construct validity was built by collecting data from multiple sources, while reliability was achieved by exposing relevant parallels across multiple sources.

4.3.4.2 *Strategy Evaluation*

To evaluate the observed business strategies in a concrete setting, synthetic data were generated to simulate the peri-urban and socioeconomic characteristics of the Linz region in Upper Austria. Generally, generating a synthetic population is useful when real data are not (yet) available, in particular when testing future strategic scenarios (Bradfield et al., 2005). In this line, agent-based models such as traffic models require explicit assumptions about individuals or households. Therefore, synthetic data about households require datasets that preserve the statistical characteristics of the entire population. To generate the synthetic data, in a first step, all buildings in the concrete region of Linz were retrieved from OpenStreetMap (OSM). These buildings were filtered to include only private housing. Each house was randomly given socioeconomic parameters such as income, number of adults and children in the household as well as car ownership. The probability of owning a car is based on the income in the household. In a second step, the logistics network is constructed to apply for certain sustainable logistics strategies. Such a logistics network consists of specific facilities, in particular plants, warehouses, distribution centers (DCs), and customers. Assuming that plants and consumers are fixed locations, strategic decision-making on certain retention strategies is concentrated on DCs in terms of the optimal number and location (Jayaraman, 1998). Accordingly, the locations of DCs were calculated using k-means clustering algorithm (Jain, 2010). The k-means clustering algorithm produces different results, with each calculation run given a fixed input. Therefore, the calculation with k-means was run 100 times and the results were averaged. An example of 10 DCs is illustrated in Figure 4.3.

Figure 4.3: Facility location

Once DCs were defined by k-means, route optimization and the underlying Traveling Salesman Problem (TSP) with starting point and end point being the same DC was carried out (Laporte, 1992). Figure 4.4 illustrates an example of the shortest route visiting eight DCs. The TSP was solved by using closest neighbor heuristics and by applying a two-opt algorithm to improve the initial solution.

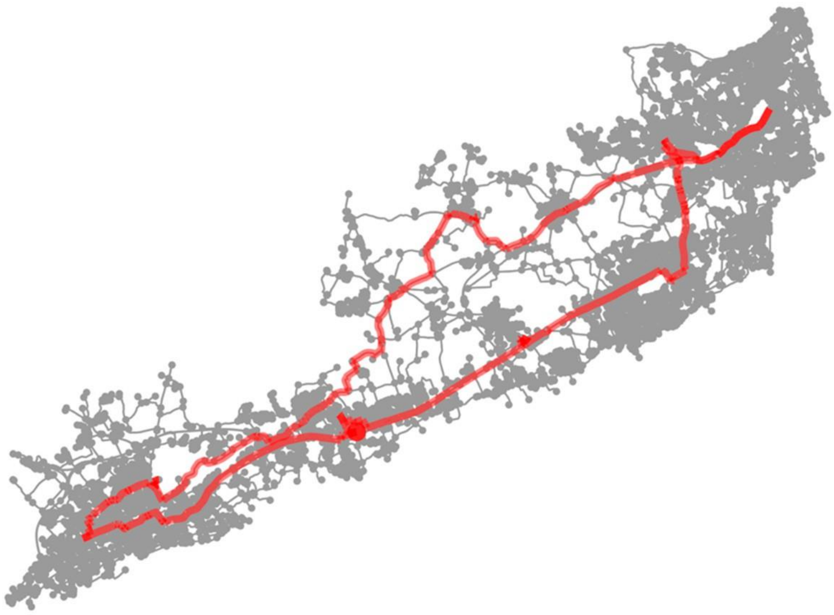


Figure 4.4: Route optimization

To model individual agents (households) with numerous decision possibilities, parameters were included that control the behavior of households. Each of these parameters represent a conditional, discrete probability distribution, which defines, for instance, the degree of contributing to an action of interest based on belonging to a socioeconomic class. These probability distributions were subject to Monte Carlo simulation experiments in a third step. These results of the Monte Carlo simulation were further coupled with certain transformational pathways to derive insights for business decision-making (Moallemi et al., 2018).

4.3.5 Findings

By analyzing the interview data, structural dimensions describing current challenges (Section 5.1), driving factors and emerging trends (Section 5.2) were derived. These findings were linked to the literature in order to refine business transformation strategies for sustainability (Section 5.3). In a last step, related last-mile strategies were evaluated for the Linz region in Upper Austria (Section 5.4).

4.3.5.1 *Transformation Challenges*

“If a logistics service provider, for instance, would run an online supermarket and, at the same time, offering transportation services to retailers, this would cause a clear conflict of interest. The logistics service provider would be a competitor to its own customer. This is not our self-comprehension.” (P1)

In the experts’ opinion, the focal company in the supply chain is still the main trigger for adopting technologies and practices that result in labor practices considered to be fair, and that result in a lower impact on the environment (P1; P2; S1). Despite external pressures on focal companies to act sustainably, a strong focal firm orientation might also prevent LSPs from implementing further sustainable practices considering the empirical results. With regard to communication of sustainable aspects, for instance, retailers need to strengthen the value of their brand to differentiate themselves from competitors as cross-company retailing slackens the consumers’ brand loyalty to a single trading firm (P1; P3). Although LSPs and retailers need to cooperate to achieve a clear and consistent communication about sustainable logistics aspects, retailers have little interest in doing so, fearing the dilution of their own brand identity (P1; P3).

Moreover, there is a need for LSPs to guarantee minimum social standards due to the increasing internationalization of the logistics industry (in line with the engagement of foreign employees, often employed through sub-contractors) (S1; S5). Therefore, the experts highlighted the importance for compliance with social and legal standards when operating logistics across borders (P1; P2; P3; S2). In contrast, the retailers’ high price sensitivity concerning logistics services (e.g., as a consequence of not charging shipping costs to the consumer) supports a low consumer willingness to pay for logistics services (P2; P3; S1; S2; S4). However, some of the interviewees did not exclude consumers who are willing to pay more for better sustainability performance, particularly those target groups that are open-minded toward social and ecological issues (P1, P2, P3, S2, S4). To meet this goal, it would be mandatory to coordinate pricing activities across the whole supply chain to assure social logistics standards (S2). Currently, the experts see rather small chances to realize such a transformation due to the high competition within the logistics industry (P1; P2; P3; S2; S4; S5). Nonetheless, logistics- oriented retailers, such as Amazon, are already changing consumers’ attitudes toward new business practices, creating new competitive pressures for “traditional” business practices that may lead to structural changes within supply chains.

4.3.5.2 *Transformation Drivers*

"I think, the problem is, the industry is changing, the social structure is changing, and the technology is changing. Logistic service providers have to either follow or lead these changes. Certainly, one logistic service provider, one company does not have enough room, […] skills and the resources to make this change happen. So, in that case, collaboration, establishing joint trading programs, defining what will be required in the next five to ten years, being proactive is the key in my opinion." (S4)

The interviewees stressed the importance of coordinating activities among the supply chain actors (S1; S2; S3; S4; S5). During the interviews, the question of how to configure supply chains under such conditions was discussed. With regard to trends like leasing or renting vehicles and warehouses, the interviewees focused on the shared use of resources and infrastructure among LSPs (P1; P6; S3; S4; S6; S10; S11). Here, several 3PLs providers no longer operate their own truck fleet in favor of coordinating material and information flows (P1; P2; P3). On the one hand, this was seen as a chance for sustainable logistics services since, for instance, the cross-company use of vehicles might also support conversion to alternative technologies (like e-mobility), which are currently too expensive for one single company to operate (P1; P6; S6). On the other hand, these practices were controversial when discussed by the interviewees. They argued that a paradigm shift is required to achieve stronger horizontal collaboration (P1; P2; P3; S3; S4). For instance, truck drivers would have to share their vehicles and retailers would need to lower their competitive foreclosure thinking in consolidating commodity flows (P1). Currently, the experts see better chances to gain efficiency potentials for the supply chain by the joint development of advanced technologies (S2; S3; S4; S6).

In addition, possibilities to expand logistics service offerings on a vertical supply chain level in regard to manufacturing (e.g., by using 3D printing) and to online retailing were discussed in the interviews (P1; S2; S4; S8). With 3D printing, a more sustainable supply chain configuration is achievable in terms of decentralized production (S2; S4). 3D prints can be produced in LSPs' warehouses, or the printing raw material can be supplied for production directly at the consumers' site (S4). This change would simplify the supply chain configuration and reduce efforts (e.g., less traffic). Although technological innovations, such as 3D printing on a vertical level or e-mobility on a horizontal level, would provide the opportunity to strengthen the position of LSPs and, at the same time, enforce a more sustainable supply chain configuration, many interviewees recognized that such an implementation might be difficult (P1; S2; S4; S8). Due to the role of LSPs as a link between manufacturer, retailer, and consumers, a strategic reorientation that extends the LSPs' portfolio might conflict with the interests of other supply chain actors (P1). In the opinion of the interviewees, the highest potential for sustainability currently lies in professionalizing online retailing in terms of last- mile logistics: for example, by bundling cross-company commodity flows (P2; S2).

From the interviewees' point of view, the trend of the sharing and circular economy businesses has the potential for more sustainable configurations of business-to-customer relationships in general, and last-mile logistics in particular (P2; S2; S4; S8; S10; S11). In this line, shared consumption considerably affects last-mile logistics since products must be transported by consumers to consumers (S11). During the interviews, the question of how to configure last-mile logistics was discussed, with a focus on crowd logistics business models (S2; S4). The interviewees mentioned storage services, freight shipping, local delivery services and freight forwarding as the most promising trends in the sharing economy with regard to logistics professionalism and sustainability impact (P2; W2; S4; S8; S10; S11). However, in the opinion of the interviewees, the sharing economy business practices still require further logistical professionalism to cope with system and technological complexity (S8; S10; S11). Moreover, the interviewees considered logistics practices carried out by private parties to be controversial, also to close cycles. The current social performance of sharing services is the main argument against this form of last-mile configuration, since an official registration, compulsory insurances, and load protection are missing (P2; S2; S4). Accordingly, logistical sharing and circular economy practices should assure at least the social minimum standards including fair wages, compulsory insurances, and accident prevention regulations.

"New logistic service providers are coming, trying to develop peer-to-peer services in order to facilitate the exchange of logistics services on a platform. […] In the sharing economy, you need some logistics that can be done by the consumers themselves." (W11)

4.3.5.3 *Synthesized Empirical Results*

During the interviews, LSPs' main obstacles and drivers in enhancing their sustainability activities were investigated. These obstacles are competitive pressure, focal firm orientation, and dependence on other supply chain members. Secondly, the expert's implications are presented regarding the factors and trends that drive the application of sustainable logistics practices beyond current activities. In particular, supply chain collaboration and integration, as well as the integration of sharing economy solutions and new digital technologies, have been identified through the qualitative content analysis approach. Mapping logistics businesses in a wider entrepreneurial ecosystem, classical and future sustainable logistics business models can be derived and clustered in accordance to retention processes and strategies. In this line, the empirical results suggest at least three transformation pathways for sustainability with regard to the single retention strategies of growth, replication/mimicry and mergence, which are evaluated and discussed in the next sections.

So far, the empirical data indicate that growth and in particular mergence strategies are most promising for the logistics industry while replication/mimicry rather have the potential to complement the other pathways. Table 4.4 synthesizes the empirical results with regard to the 1PL to 5PL logistics businesses classification scheme and related retention strategies.

Table 4.4: Observed sustainable logistical strategies from the expert interviews

<table>
<tr><th>Classification</th><th>Growth</th><th>Replication/Mimicry</th><th>Mergence</th></tr>
<tr><td>1PL (Single Service Provider)</td><td>Increasing use of cleaner technologies</td><td>New (digital) technologies</td><td>Shared use of infrastructure</td></tr>
<tr><td>2PL (2nd Party Logistics Provider)</td><td rowspan="2">Advanced decision support systems</td><td rowspan="2">Crowd logistics solutions</td><td rowspan="2">Multi-modal transportation</td></tr>
<tr><td>3PL (3rd Party Logistics Provider)</td></tr>
<tr><td>4PL (4th Party Logistics Provider) and 5PL (so-called Lead Logistics Provider)</td><td>Last-mile and reverse logistics integration</td><td>Sharing and circular economy businesses</td><td>Supply chain coordination</td></tr>
</table>

4.3.5.4 *Strategy Evaluation*

To evaluate the derived transformation pathways, the required logistics infrastructure is a most crucial. Therefore, an important decision variable in the modeling is the number of DCs determining the realization of last-mile and reverse logistics integrated supply chains as well as logistically coordinated sharing and circular economy businesses. In this line, the number and density of DCs defines strategic potential, such as potential growth through additionally generated demand and mergence potentials to increase efficiency. While a solely economic perspective primarily fosters the expansion of market shares and the reduction of operation costs, a holistic perspective fosters also alternative transportation modes, such as cargo bikes, private car use, or even walking distance as well as logistically enabled sharing and circular economy businesses. The evaluation of the required infrastructure in the concrete setting fostered the analysis of how different numbers of DCs affect the average distances to enable alternative transportation modes and consumer-centered logistics services such as delivery services (see Figure 4.5).

Such an analysis gives insights where thresholds exist that allow certain business practices in a peri-urban area such as the Linz region. For instance, if 3 km is a threshold for using a cargo bike, then there is little motivation to establish more than 10 DCs. The total length of transporting goods (milk-run based on TSP) and consumer trips (from private households to the closest DC) is shown in Figure 4.6. Here, an increasing number of DCs decreases the total travel length. While this analysis can be useful for deciding on the number of DCs, however, it does not take into consideration the consumers' mobility behavior. Therefore, the analysis was extended by a simulation approach to construct certain scenarios. Figure 4.7 illustrates the customers' distance to the nearest DC while Figures 4.8-4.10 illustrates a single run of a Monte Carlo simulation for a given parameterization and five DCs. These results are based on individual purchasing choices that are determined by income, number of people living in a household, and whether a consumer owns a car or not. Accordingly, the mode of transportation (bike, car or walk) is also determined by these factors.

Evaluation of growth strategies: Generally, the use of decision support systems for location planning and vehicle routing allows for a more efficient and sustainable growth to achieve last-mile and reverse logistics integration. In particular, Figure 4.7 illustrates that the median distance to the closest DC can be reduced far below 2000 m if a sufficient infrastructure is in place. Nonetheless, the related investments in additional DCs need to be economically justified when it comes to balancing the single sustainability dimensions. So far, the existing barriers such as the high competition in a specific region rather frustrate sustainable growth strategies lead by LSPs. However, logistics- oriented retailing companies such as Amazon are currently favoring power shifts in the supply chain. In addition, white-label logistics solutions fostered by municipalities might also have a positive influence in achieving the required infrastructure density.

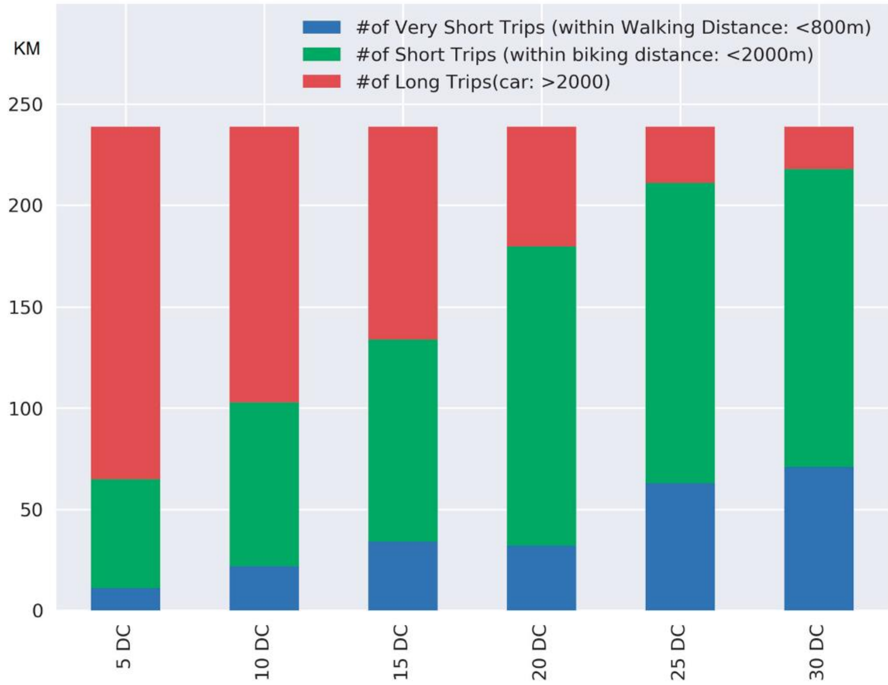


Figure 4.5: Analysis on an aggregate level

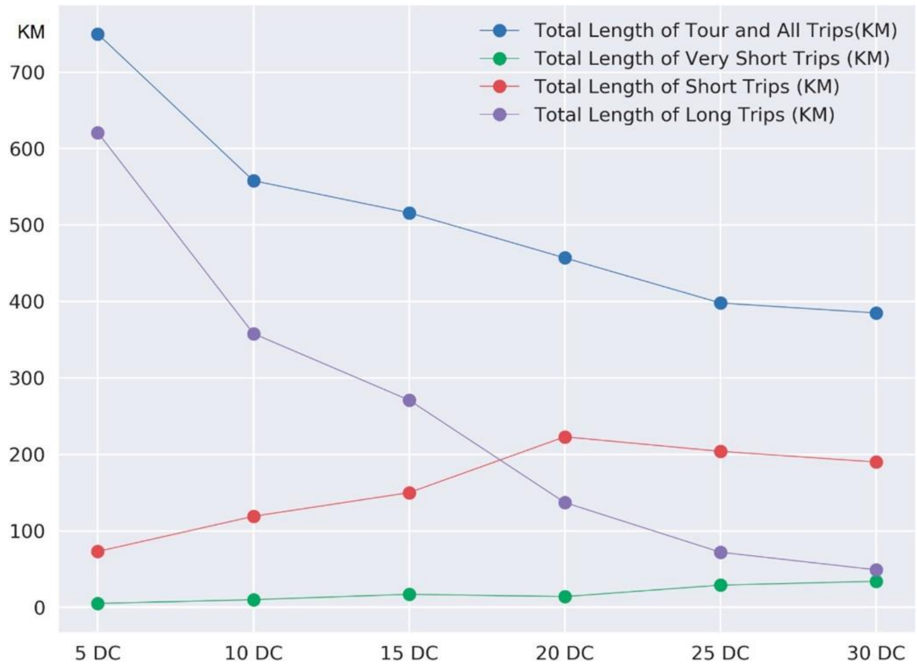


Figure 4.6: Total length of trips

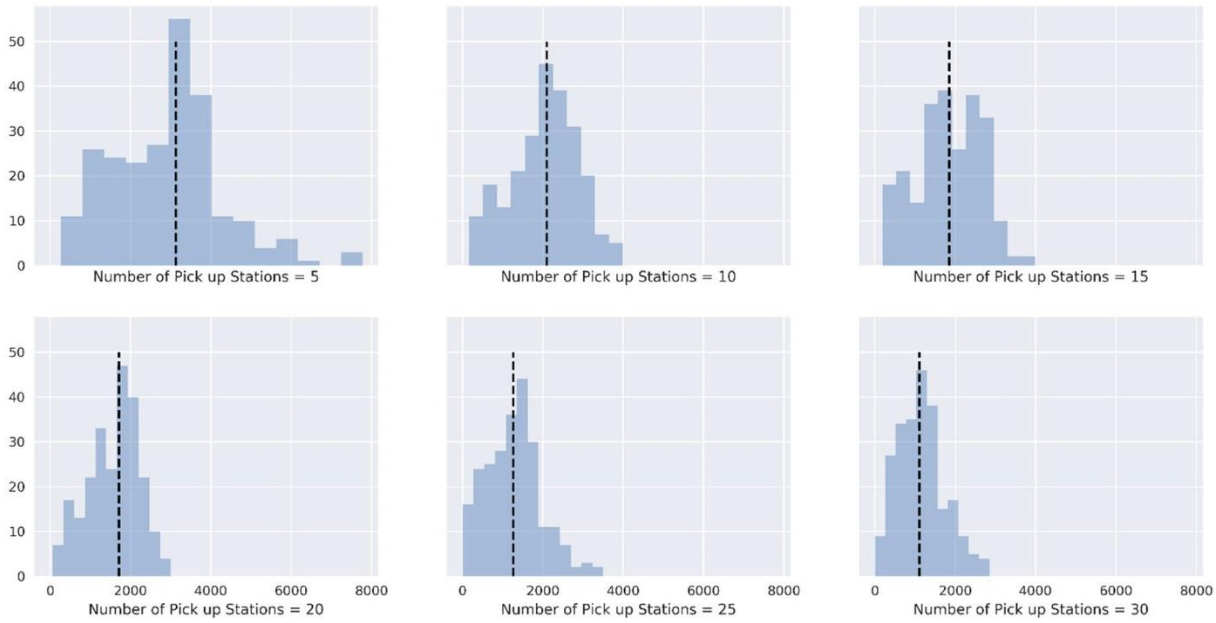


Figure 4.7: Customer distance to the nearest DC in meters (dashed line represents median value)

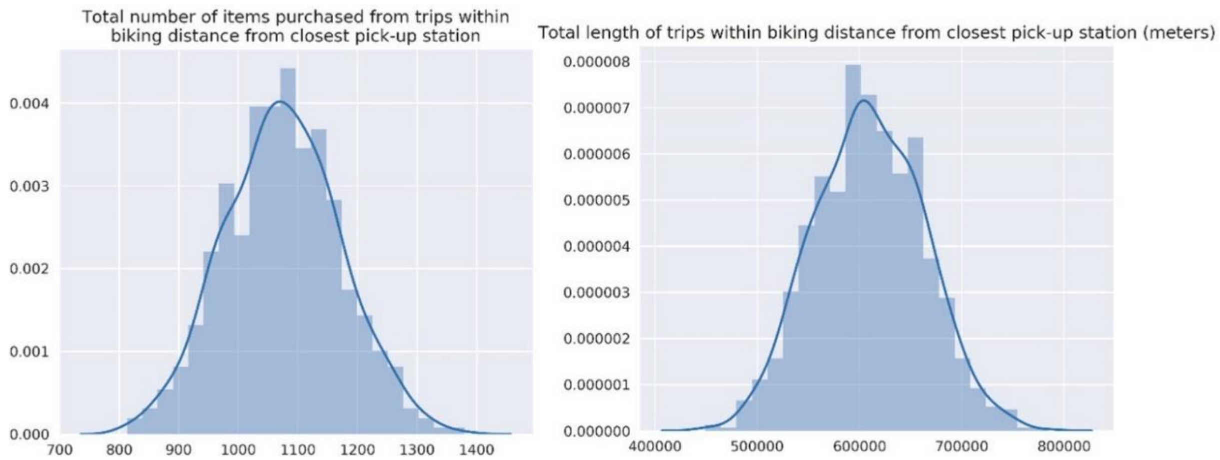


Figure 4.8: Total number of purchases from trips within biking distance

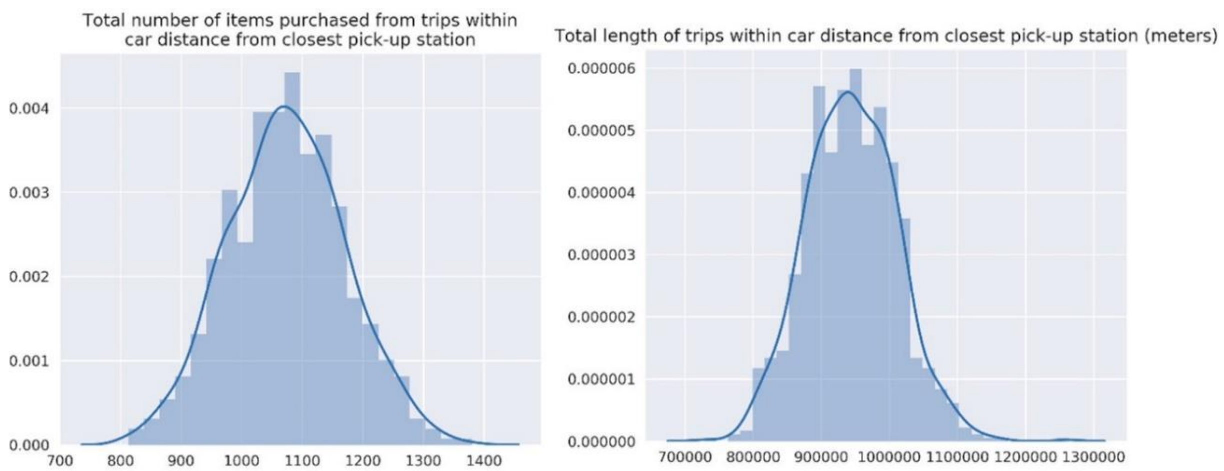


Figure 4.9: Total number of purchases from trips within car distance

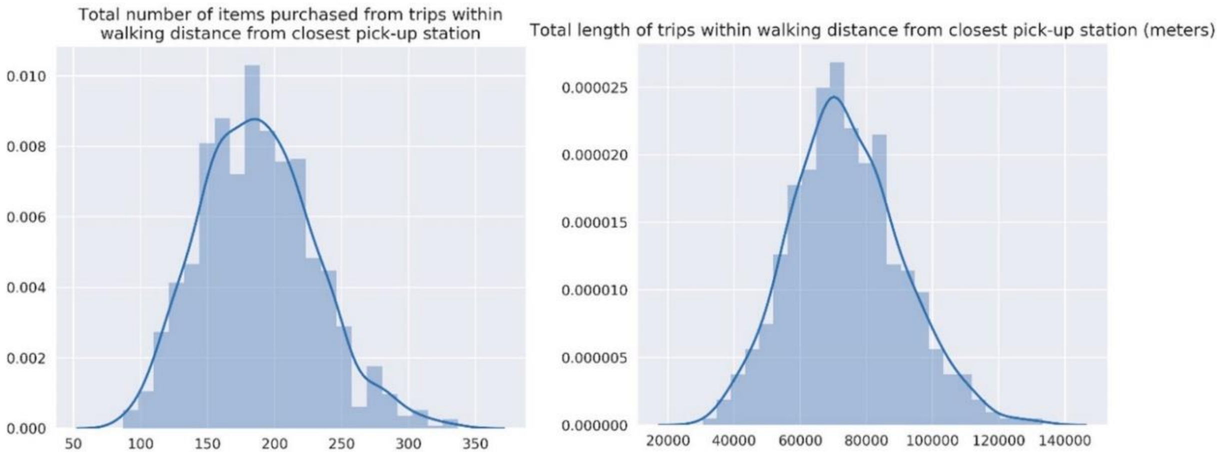


Figure 4.10: Total number of purchases from trips within walking distance

Evaluation of replication and mimicry strategies: While the emphasis was put on the essential network elements of facilities and transportation modes to evaluate more green and sustainable network designs, relevant insights with regard to promoting alternative transportation modes in walking or biking distance could be derived. Assuming a threshold of 2000 m as biking distance, for instance, 20 DCs guarantee the maximum total length of short trips in the region of Linz (see Figure 4.6). Accordingly, the inclusion of private persons to conduct logistics activities is possible and promising for a future sharing economy and circular economy businesses to further leverage LSP's sustainability potentials. However, the required logistical infrastructure is a necessary prerequisite for replication and mimicry strategies and, therefore, their realization continues growth and mergence strategies.

Evaluation of mergence strategies: To achieve a high coverage also in peri-urban areas, such as the Linz region, existing opportunities should be activated through a shared use of infrastructure, e.g., through collaborating with other retail stores or restaurants. In order to realize a higher sustainability performance, warehousing infrastructure can be shared and combined more effectively constructing a network of micro hubs and depots to also allow for alternative transport modes. Accordingly, the evaluation of the derived transformation pathways confirms the qualitative, empirical results and points to the growth and mergence strategies as the most promising in the near future.

4.3.6 Road Mapping to Include LSP Pathways for Sustainability

To allow for a structured discussion of potential transformation pathways for sustainability, the existing 1PL to 5PL business model (arche-)types are incorporated into a transformation roadmap (see Figure 4.11). In the following, the 1PL to 5PL classification scheme is discussed taking into account current business developments and challenges, in particular the observed challenges coming from e- commerce and multi-/omni-channel retailing. These business challenges have been changing in the past from subcontracting (1PL) and globalization (2PL) towards E-commerce and omni-channel growth (3PL to 5PL). Solutions for these challenges have also been strongly driven by transformations in the past, starting from the planning of locations and vehicle routing (1PL) towards advanced ICT (2PL), cross-docking (3PL), and advanced pooling (4PL to 5PL). Combining these challenges with possible solutions allows for the inclusion of a new business model (arche)type to the 1PL to 5PL scheme, the so-called Lead Sustainability Service Provider (6PL). The 6PL not only extends the existing 1PL to 5PL scheme, but also represents the target course of the transformation roadmap. As a developmental option, 6PL was part of the ILoNa research designs that led to this paper's underlying research activities (see Acknowledgments).

Single Service Provider: With regard to multi-channel grocery retailing, 1PLs either run distribution centers to store products or carry out transports between suppliers, distribution centers and retail stores (Hübner et al., 2013). In addition, picking processes can be carried out as contract logistics services by 1PLs. Within those conventional business models, transformation potentials lie not just in the application of cleaner technologies but also in the inclusion of new (digital) technologies. However, subcontracting as practice to achieve a high regional coverage will remain such that 1PLs are an important part of growth and mergence strategies of 4PL–5PL companies. Therefore, 4PL–5PL companies have to assure social standards when outsourcing single logistics activities.

2nd Party Logistics Provider: With regard to online retailing, last-mile delivery services of groceries are becoming more relevant for 2PLs in the near future, in particular for parcel service providers. Due to nature of food products, requirements considering hygiene, perishability as well as packaging and labelling (Spence and Bourlakis, 2009) are also tackling service providers in the last mile. Hence, specific packaging (isolated boxes) or transport processes (in different temperature zones) might have negative impacts on the sustainability performance (Wollenburg et al., 2018). As 2PLs already coordinate limited parts of the supply chain such as the last mile, advanced decision support systems are coming to the fore to decrease the travel distance and increase the drop-off rate. In addition, 2PLs have the replication and mimicry opportunities to include consumer in crowd logistics businesses. However, such business need, once again, assure social standards as well as the necessary procedures to assure quality procedures.

3rd Party Logistics Provider: 3PLs are generally capable to run omni-channel distribution channels and, therefore, can include mergence strategies such as multi-modal transportation. However, decentralized organizations like cooperatives have more and higher hurdles when implementing centralized online solutions and distrust logistics service providers when it comes to a safe handling of food products (Wollenburg et al., 2018). This is why omni-channel retailers often deliver their products by themselves rather than using a 3PL. Accordingly, 3PLs might have to include retailing activities in their business portfolio in line with a sustainability growth strategy. Although new players in the market, such as Amazon, are following such a strategy, established LSPs might fear to lose retail customers by pursuing such a way.

4th Party Logistics Provider and Lead Logistics Provider: 4PLs and 5PLs have the opportunity to realize more alternative business models through the concrete integration of consumer-centered businesses such as circular and sharing economy solutions in their service portfolio to achieve further positive sustainability effects. A prerequisite for such alterative businesses is that coordinated, and logistically integrated supply chains are in place. Accordingly, growth and mergence strategies lie the basis for a strategy development towards the development into a 6PL. Such a development allows for new solutions that include advanced sustainability performance goals into conventional logistics businesses as well as empower consumers for logistics prosumption activities (Schmidt, 2016).

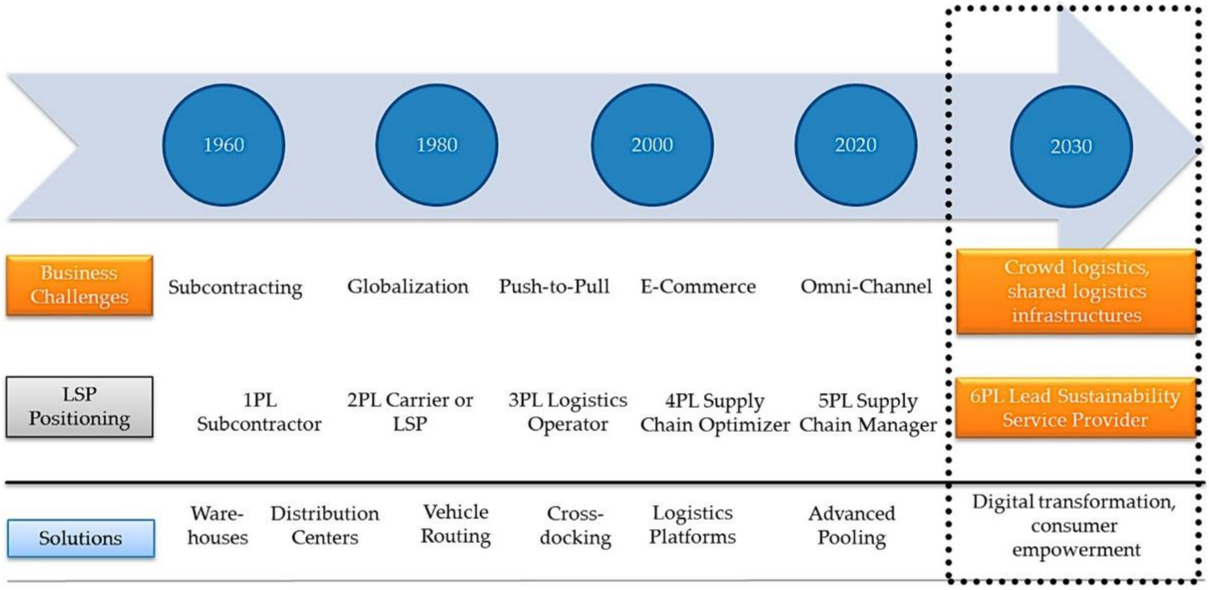


Figure 4.11: LSP's sustainability roadmap

Lead Sustainability Service Provider (6PL): Constructing a 6PL business (arche)type, a consumer-choice-centered perspective is important to resolve existing barriers such as the willingness to pay for logistics services or the realization of a higher social and societal performance. Hence, LSPs need to include consumers directly into their business strategies and communicate related activities. In this line, a closing of business cycles has to bridge the last mile as a crucial point to achieve supply chain and reverse logistics integration. Possible practices in this direction are the sharing of existing infrastructure and the building of alternative (transportation) systems such as the use of cargo bikes. However, dependence on other supply chain members as well as fierce competition is still seen as a major challenge for LSPs to implement such sustainable practices. Accordingly, LSPs would gain from potential pathways that stress anti-competitive and performance enhancement purposes. In this line, new (digital) technologies as well as consumer empowerment play an important role to also pursue replication and mimicry strategies.

4.3.7 Discussion of Societal Transitions and Related Logistics Strategies from a Business Model Perspective

So far, competition within the logistics industry is preventing a transformation in direction to a more sustainable supply chain configuration. Therefore, the existing logistics business model (1PL to 3PL) hampers transitions by reinforcing the current system's stability (Bidmon and Knab, 2018). As these business models are part of the current socio-technical regime and apply the dominant regime logic (Bidmon and Knab, 2018), LSPs mainly adapt to environmental "stand-alone" practices in transportation and packaging and assure the minimum social standards required by external stakeholders so far (Gruchmann and Seuring, 2018). Accordingly, many interviewees recognized that due to the role of LSPs as link between manufacturing, retailing, and consumer, a strategic extension of the LSPs' portfolio might conflict with the interests of other supply chain members. However, the findings provide evidence that growth and mergence strategies allow further sustainability improvements of the existing system, at least to a certain extend. Here, also 4PL and 5PL companies have the opportunity to increase the sustainability performance by governing fast parts of the supply. Nonetheless, there are currently just a limited number of 4PL and 5PL companies in the market able to pursue such strategies. However, technological innovations provide the opportunity to strengthen the position of 3PLs in the supply chain and, at the same time, grow in the direction of a 5PL with the required logistical infrastructure.

A second option for a transition of the existing system lies in the potential of LSP's business models to act as an intermediary between technological niche players and the socio-technical regime (Bidmon and Knab, 2018). Here, replication and mimicry strategies allow LSPs to implement sustainability-oriented business practices from niche pioneers in their own business portfolio such as crowd logistics, sharing or circular economy business practices. Currently, these business practices might not be profitable but allow for achieving consumer-choice-centered logistical services. In particular, those businesses that incorporate the last mile have the opportunity to implement a 6PL business model. In this line, alternative transportation modes could weaken the pricing pressure on logistics services. However, the current findings indicate that such a pathway is unlikely in the near future and rather provides the potential to continue future, transformational processes since the required logistics network do not exist yet and current systems thinking limits the sharing of existing logistics infrastructure.

Looking closer at sustainable business models for LSPs itself, the 1PL to 6PL classification scheme does not fit the existing business model ontologies and archetypes. While authors have started to consolidate the literature on sustainable business models by introducing sustainable business model ontologies and archetypes in recent years (Neumeyer and Santos, 2018), they neglected the nature of LSPs as service provider for sustainable niche players and globally acting companies alike. For instance, Bocken et al. (2014) distinguish between eight different sustainable business model archetypes: (1) promoting maximization of material and energy efficiency; (2) creation of value from waste; (3) substitution with renewable and natural processes; (4) delivery of functionality rather than ownership; (5) adoption of a stewardship role; (6) encouraging sufficiency; (7) repurposing products and services for society and environment; and (8) the development of scale-up solutions. In this line, the 6PL business model can adopt all of these business model archetypes. Accordingly, future research should foster transformative business model innovation approaches for certain business model (arche-)types in other industries (Gorissen et al., 2016).

4.3.8 Conclusions and Outlook

Purpose of this explorative study was to provide a structured analysis of sustainability pathways for logistics business transformation. In this line, the authors conducted a two-stage approach by (a) knowledge production with expert interviews and (b) systematically evaluating the results with the help of quantitative approaches. By doing so, the present study defines LSP’s retention strategies to meet future societal and environmental requirements. In addition, the study contributes to theory by constructing the Lead Sustainability Service Provider (6PL) business model (arche)type and its role in societal transitions.

However, applying qualitative and quantitative research methods is not free of limitations that can be addressed in future research activities. Therefore, future work can further address the people dimension in logistics and supply chain management, for instance by testing the empirical results with a survey. Moreover, the logistics industry comprises the primary focus of this study. Hence, the findings are not generalizable for other industry contexts and, accordingly, provide opportunities for future research.

4.4 Scenario and Strategy Planning for Transformative Supply Chains within a Sustainable Economy (Melkonyan, Krumme, Gruchmann, Spinler, Schumacher, Bleischwitz, 2019)

The following chapter presents a peer-reviewed article by the author together with Ani Melkonyan (University of Duisburg-Essen), Tim Gruchmann (Westcoast University of Applied Sciences), Stefan Spinler (WHU Otto Beisheim School of Management), Terry Schmacher (Rose Hulman Institute of Technology, USA) and Raimund Bleischwitz (University College London, UK), accepted for publication in the *Journal of Cleaner Production*, 2019.[32]

The presented research refers to the project "Innovative Logistics for Sustainable Lifestyles – IloNa", funded by the German Ministry of Education and Research (BMBF) from 2015 to 2018, for which the author was both main applicant and project director (see Krumme et al., 2015).

Any reference to this chapter should be cited as:

Melkonyan, A., Krumme, K., Gruchmann, T., Spinler, S., Schumacher, T., & Bleischwitz, R. (2019). Scenario and Strategy Planning for Transformative Supply Chains within a Sustainable Economy. *Journal of Cleaner Production*, *231*, 144–160

Abstract

Supply chain effectiveness and general societal prosperity, as well as economic and ecological productivity will be highly affected in the next decades, entailing challenges for the supply chain and logistics sector. Thereby this sector plays a significant role within the transformation process of economic systems, yet the capacities of it remain up till now underestimated. This paper suggests a holistic approach to assess transformation potential of the supply chain and logistics sector towards more sustainable economic systems while defining innovative business strategies to meet future macroeconomic developments. This is achieved through an integrated assessment of production and consumption systems, considering the interests of the key stakeholders. Moreover, the paper combines advanced methods to develop future macroeconomic scenarios and to assess the strategic business opportunities of the supply chain and logistics sector addressing societal developments, e.g. new consumption patterns. The analysis relies on modern theories of Environmental and Ecological Economics, contributing to transformation theories. Moreover, the innovative role of supply chain and

[32] Klaus Krumme, together with Ani Melkonyan, provided the strategic orientation, structure of the paper and the basic interpretation of the research results. He also contributed to the theoretical foundations, the integration into the justification context of the research and wrote parts of the discussion. He also brought up the concept of the Lead Sustainability Service Provider and wrote the relevant text parts.

logistics management in achieving sustainable macroeconomic goals at regional and international levels is addressed.

The results of the scenario analysis show that the innovation potential is the highest if the consumers exert pressure on the industry and the global governance policy sets favorable conditions for the supply chain/logistics sector to implement innovative and sustainable strategies. To address this scenario, the logistics service providers should extend their business portfolios, becoming a "lead sustainability service provider" (6 PL). If both governmental regulations and consumer requirements for sustainability are at a low level, the innovation rate in the sector can slightly increase, if the logistics service providers focus solely on economic performance indicators, such as cost and time efficiency, by applying new technologies or management methods. This scenario represents a realistic case, since the logistics providers are forced to innovate their business models to a certain extent, due to high competition in the sector. Based on the findings, a strategy roadmap of the supply chains and logistics sector is developed in the sense of a transformative force to address future potential macroeconomic changes, providing managerial implications and policy recommendations.

Keywords

sustainable macroeconomics, sustainable supply chains, scenario-strategy development, sustainable consumer, transformation roadmap

4.4.1 Introduction

Supply chains are likely to drastically change due to interdependent regional impacts of climate change (Challinor et al., 2017), rapid urbanization (Satterthwaite et al., 2010), demographic developments (Rolfe, 2013), resource overconsumption (Hoekstra and Wiedmann, 2014) and related shifts in demand patterns. According to the "Turn Down the Heat series" 3rd report, "warming of about 1.5°C above pre-industrial times is already locked into the Earth's atmospheric system by past and predicted greenhouse gas emissions", having significant regional effects on climate change (World Bank Group, 2014). These effects are expressed in more frequent severe droughts, increased risks in food and water security, and represent a high likelihood of global supply bottlenecks or even deadlocks in the life supporting systems of the societies (IPCC, 2014a). The risk of supply insecurity will be even more intensified in the course of global demographic developments, if not very profound changes in raw material extraction, production, management of value and supply chains, as well as qualitative transformations at the consumer side take place. The increased risk of supply insecurity is highly influenced by the unsustainable global resource consumption within the value creation process of modern products (from material extraction, design and production, supply chains to consumption and use) (Bleischwitz et al., 2018). Despite the progress achieved in material efficiency and substitution in various sectors, the past decades have seen a steady rise in the material intensity. The regeneration capabilities of the basic ecological systems have already been exceeded (Rockström et al., 2009; Rockström and Klum, 2015). Moreover, it is projected that under existing trends, resource extraction will increase 119% from 2015 to 2050 (from 84 to 184 billion tons per annum), while greenhouse gas emissions will increase by 41% (Hatfield-Dodds et al., 2017). These changes are driven by doubling of the value of global economic activity (Geng et al., 2019).

This background highlights the need to develop economic rationale for designing and operating global supply chains in a sustainable manner. Within the last one and a half decade, a growing body of literature have contributed to the sustainable supply chain management (SSCM) with a stronger integration of various sustainability issues (Carter and Rogers, 2008; Seuring and Müller, 2008). Notwithstanding, the “proactive” role of supply chains within transformative macroeconomic system has so far been under-exposed. Thus, fulfilling this gap, the given study aims at bringing together business priorities of global supply chains and the macroeconomic parameters with highest impact on reshaping the business models from logistics perspective (Research Objective – RO 1). Furthermore, we aim at designing transformation pathways towards a sustainable economy (RO 2). For this, we analyze the global supply chains from nature to consumers for each resource, their interaction (resource nexus) and connection with the Sustainability Development Goals (SDGs) at regional and international levels. Thereby the socioeconomic supply systems and their distribution, recycling and re-use functions in the sense of circular economy, as well as development of innovative business models are addressed. Not only sharing economy models, but also extension of business portfolios are considered once discussing innovation in the business models.

To unlock transformation potential for an increased sustainability performance, different driving factors and challenges for the future scenarios by the year 2030 are investigated on the example of Germany as a highly industrialized country. The scenarios were built taking into consideration dynamical changes in the macro factors with highest impact on business environment, e.g. climate change, policy decisions, societal and consumer trends/lifestyles, meanwhile relying on the modern theories of ecological and environmental economics. Within the frames of the given paper, the following research questions are addressed:

1. What are the driving macro (external) factors for possible future scenarios?

2. What kind of strategies should the supply chain and logistics sector employ, in order to address probable future macroeconomic scenarios in a sustainable way?
3. What are promising transformation pathways towards a sustainable economy?

The answers to these questions will help countries and communities worldwide to establish inclusive and sustainable development agendas, to hold global warming below 2° C, preferably under 1.5 °C, according to Paris Agreement (Rogeli et al., 2016). While parties to the Paris Agreement act nationally, production and consumption systems are global. Thus, improving global supply chain and logistics management is a contribution to strengthening sustainable transformation processes, meanwhile empowering both producers and consumers within the process of the climate action. This will enable the policymakers and supply chain members to facilitate integrated logistics strategies, balancing the sustainable development fueled by globalization, consumption patterns, market competition and exploration of new markets.

Figure 4.12 below provides an overview on the paper structure.

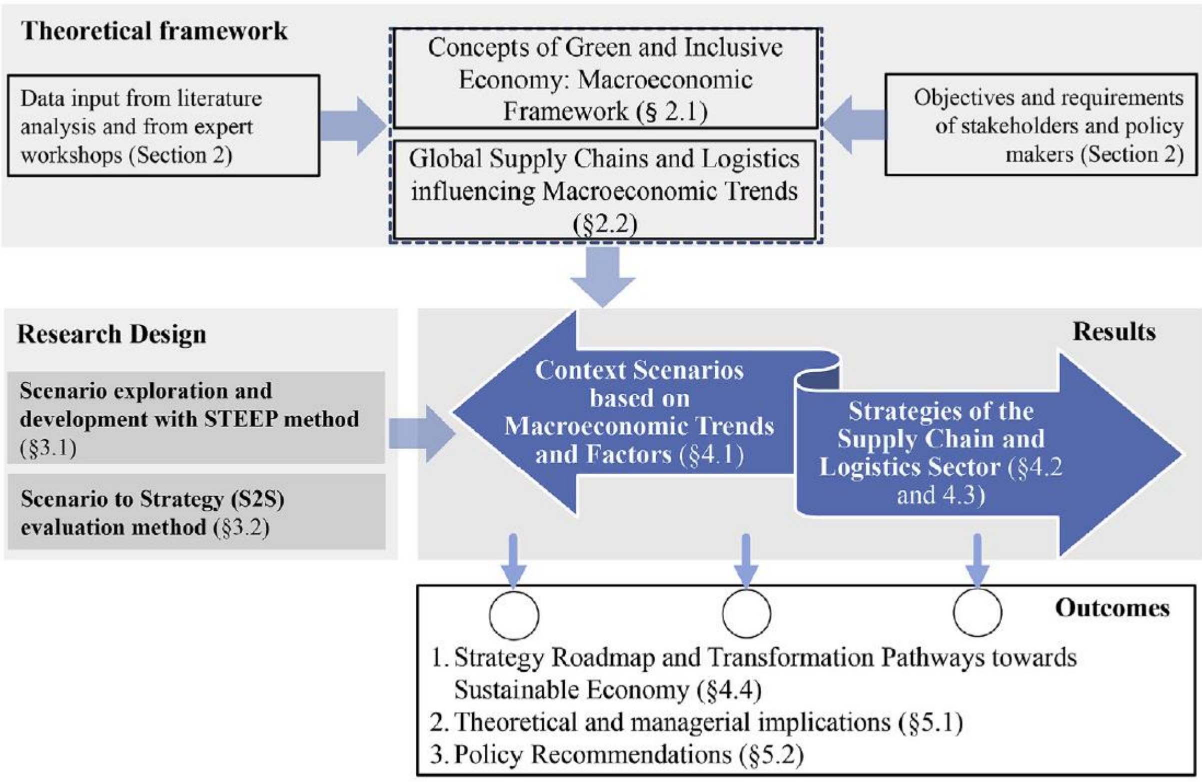


Figure 4.12: Structure of the paper

Section 2 summarizes the literature on the concepts of sustainable economy linking those to supply chains and their transformation strategies. Section 3 explains the research design, describing the methods of scenario and strategy development. Macroeconomic trends and key factors influencing scenario development within supply chain and logistics sector are presented in Section 4.1. Strategies and their evaluation for the future scenarios are discussed in section 4.2 and 4.3. A roadmap of transformative strategies is presented in section 4.4. Section 5 discusses the key findings and provides concluding remarks along with the outlook.

4.4.2 Literature review

Current global socioeconomic and political trends highlight the need for a better understanding of future developments within global economic systems from the sustainability perspective. Because of high complexity of transformation processes towards sustainable economic systems, long-term challenges characterized by uncertainty and complexity have to be addressed. An adequate approach for doing so is development and assessment of future scenarios utilizing both quantitative and qualitative approaches. The future scenarios should not only address uncertainty and risks of long-term changes, but also help exploring different alternative pathways (Fauré et al., 2017). Quantitative methods rely on both simple and complex models. Simple or equilibrium models consider time series extrapolations of trends assuming a move from a present state towards a more balanced future state. Since some states/systems cannot be extrapolated from past values, exploratory methods or computer-aided simulations are used (Moallemi et al., 2017). In contrary to the quantitative tools, qualitative assessment methods might better fit the purpose of developing long-term transformative scenarios. The combination of quantitative and qualitative methods arguably entails a solid framework to include a comprehensive set of sustainability aspects within global and complex economic systems and supply chains. Clearly, this kind of integrated scenarios cover many aspects, such as climate futures, different possible and internally consistent socioeconomic developments. One good example of this kind of complex scenario framework is a Scenario Matrix Architecture, which is based on coupling of so-called Shared Socioeconomic Pathways (SSPs). The SSPs deal with population, economic growth, education, urbanization and the rate of technological development, considering the Representative Concentration Pathways (RCPs), which represent greenhouse gas concentration trajectories. (IPCC, 2014a; Hausfather, 2018).

Supply Chain Management (SCM) can be used for defining transformation process of sustainable and innovative production – consumption systems (Seuring and Müller, 2008), since SCM is considered as a driver of and driven by the complexity of the respective value creating networks (Agrawal et al., 2015; Lan et al., 2018). Therefore, our study contributes to the development of theoretical concepts linking sustainable economic theories (Ecological Economics, Environmental Economics, Recourse-based View theories) to SCM literature, meanwhile combining qualitative and quantitative analysis of scenario and strategy development. The rationale of these complex interactions is that only proactive strategies to innovate business models may lead to achievement of sustainable economy goals defined by regional and international governments, while considering dynamic changes in production-consumption patterns. In order to precisely understand the interaction among these macroeconomic factors and to estimate their future mutual influence on supply chains, a holistic analysis of the key factors driving the transformation towards a sustainable economy is necessary, where this paper also contributes to. Thus, we carry out a literature analysis on macroeconomic concepts in respect to sustainability at the first stage to set the frame of our study.

4.4.2.1 Macroeconomic Framework: Sustainable Economy Concepts

A sustainable economy can be defined as being low-carbon, resource efficient and socially inclusive (UNEP, 2016; Loiseau et al., 2016). It entails improved human well-being and reduced inequalities to protect future generations from environmental risks and ecological scarcities (Jackson and Victor, 2011). The macroeconomic landscape has a tremendous impact on the decisions made by economic agents, associated with optimized production, distribution and consumption of the products and services. To understand this impact, the interaction and the feedback mechanisms among macroeconomic parameters, e.g. employment, economic growth and inflation, demand and prices of natural resources, as well as the environmental damages have to be analyzed in detail. This kind of analysis results in the definition of effective environmental policies to ensure smooth transformation processes of economic systems.

Environmental and ecological economics serves as a good basis to explore causal feedbacks among environmental and macroeconomic parameters for a sustainable economy. Although being conceptually connected, ecological and environmental economics show different emphasis in their conceptual baselines. Providing insights for sustainability transitions, environmental economics is closely related to cleaner production and resource efficiency, whereas ecological economics relies merely on the concepts of Industrial Ecology or Circular Economy (Daly and Townsend, 1993; Hueting, 2010; Loiseau et al., 2016). Generally, ecological economists reject the growth models based on interactions between environment and economy (IPCC, 2014b), questioning the assumption that rational, utility- or profit-maximizing behavior by firms and consumers will favor an optimal, equilibrium growth path (Taylor et al., 2016). In contrast, environmental economists claim that “sustainable economy”, which deals with decreased pressure on resources, climate change and emissions, can at the same time ensure economic growth and employment. In addition to these main concepts, some other approaches, such as the bio-economy (more related to environmental economics) and Product-Service Systems (PSS, linked to ecological economics), have been identified as promising concepts to reach sustainable development goals. Besides these more macroeconomic concepts, Resource-based view (RBV) or the Natural Resource-based view (NRBV) theories could serve as good instruments for companies to implement sustainable economy strategies. The rationale behind this is that advantage by a company can be gained, if it develops distinct capabilities and can leverage resources that are rare, valuable, inimitable/substitution-resistant, organizationally specific, and heterogeneously distributed (Tate and Bals, 2018). Here, the NRBV perspective on the contingent nature of resources and capabilities allowed researchers to draw specific links between environmental and financial performance (Hart and Dowell, 2011). Although Hart's (1995) key strategic capabilities of pollution prevention, product stewardship and sustainable development foster green logistics practices, the logistics service providers' impact on the (socially) sustainability performance of a company or supply chain is contingent.

Despite some conceptual differences, all these theoretical macroeconomic approaches are seeking to develop better analytical frameworks to understand economy-environment interactions at a macro scale, meanwhile providing tools to manage the transition towards a sustainable economy (Fontana and Sawyer, 2016). These frameworks and approaches mainly consider global material resources and their efficient use, discuss green technology and technological decoupling from economic growth. Furthermore, they consider balancing mechanisms between global consumption and production systems through international trade, recycling and circular economy, as well as policy options and levers to control pollution. Meanwhile these concepts refer to the environmental, economic, technological and political risks associated with economic growth (WEF Global Risks, 2019; UNEP, 2016), making the transformation towards sustainable economy extremely complex.

Summarizing the literature analysis on existing concepts of sustainable economy, the interrelated key drivers of transformation process have been identified, which sets the framework of this paper: (1) Global demand and consumption systems; (2) Financial systems: Taxes and financial incentives; (3) Societal changes: Demographics and Employment rates; (4) Resource efficiency and Global Climate Change. The describing factors of these systems and their trends are used to develop the macro scenarios, which give precious information for the strategy and decision making within supply chains.

4.4.2.2 Global Supply Chains influencing trends

To achieve sustainable transformation of global supply chains and, conversely, to unleash their transformative power with effect on the economic system, a coordinated development between strategic and basic/operational perspectives should take place within the boundaries of macroeconomic developments. From the strategic and commercial perspective, the most important issue is the balancing among environmental and economic factors at a macro level (Neto et al., 2009). The main challenges for balancing are managerial complexity, network imbalance, customer priorities and technological and legislative uncertainties (Abbasi and Nilsson, 2016). Representing physical flows, international trade heavily relies on transport chains, which represent a series of efficiently organized logistical operations ensuring the continuity along supply chains. Hence, the improvements in logistics performance indicator (LPI) generally favor increase in the trade volumes, along with trade openness, urbanization, and industrialization (Liu et al., 2018). Yet, being focused on LPIs, planning of logistics operations may not necessarily be based on taking the most direct path, but the path of least cost. Therefore, the quality and quantity of trade and transport-related infrastructure may have significantly negative impact on the environment, which is reflected in increased resource consumption or release of emissions (Khan et al., 2018). The increase in upstream resource requirement for trade are explained by increasing share of higher-processed goods in total trade and by more intermediate goods being traded between countries, before satisfying final demand. For EU-27, Zaman and Shamsuddin (2017) showed that industrialization and trade liberalization policies increase carbon-fossil emissions, thus claiming that supply chain and logistics activities should be closely linked to the country's national sustainability agenda. Although transport related activities represent just one part of modern supply chain and logistics services, it is still core to the service portfolios. According to the European Commission report, transport related industries contribute almost 4.6% to GDP and employ around 10 million people, which is approximately 4.5% of the total employment in the EU-28. The transport industry heavily relies on oil, consuming approximately 96% of its energy needs. Therefore, its contribution to GHG (greenhouse gas) emissions was calculated to be around 20 % during the year 2017 (European Commission, 2018). Through evaluating Environmental Kuznets Curve (EKC), Nassani et al. (2017) confirmed the inverted U-shaped relationship between financial development and nitrous oxide emissions, and U-shaped relationship between economic growth and GHG emissions.

In the macro-scale context of shifts in global sources and sinks linked by supply chains, urbanization is of particular importance. The growing proportion of urban populations and downstream resource agglomerations is fundamentally shifting global source-sink relationships and generating macro-scale teleconnections (Seto et al., 2012; Liu et al., 2013). Cities are seen as “places of spatially extended socioeconomic relations” in the context of their governance role of globalized value creation, and resource, energy, goods and information flows (Amin and Thrift, 2002). Urban ecological footprints are disproportionately high per person and often exceed the area of the territory to be served by more than 200 times per city (Rees and Wackernagel, 1996). This exponential hunger for resources in relation to urban growth curves and resulting emissions can be explained by the theory of “non-biological scaling behavior” (Bettencourt and West, 2010). Basically, the theory explains the positively increasing network effects of cities and metropolitan regions, which, among other things, increase demand.

These negative environmental impacts associated with global supply chains, and with increased international trade may completely cancel out a potentially better allocation of extraction and production processes through world trade. Therefore, with increased globalization, strategic planning of sustainable supply chain management (SSCM) practices (Carter and Easton, 2011; Min and Kim, 2012) under different logistics activities is crucial, in order to achieve sustainable development goals. The strategic planning of SSCM and logistics management positively influences operational performances of the sector through reduction of externalities (Lai and Wong, 2012). Reviews done on SSCM at operational level show that sustainability practices are mostly focused at the firm level and are linked to e.g. Corporate Social Responsibility (CSR) (Bhardwaj, 2016); sustainable supply network management (Eskandarpour et al., 2015); environmental purchasing (Chin et al., 2015); environmental marketing and management (Ansari and Qureshi, 2015); reverse logistics (Beh et al., 2016); sustainability labeling schemes (van Dam and van Trijp, 2016); LCA (Young, 2018): waste management (Ahmad, 2016); energy usage (Shi et al., 2015).

Both strategic and operational planning levels of supply chains are supported by the digitization of the sector nowadays. Digital transformation opens far-reaching advantages for companies in SCM, such as increased transparency and reliability, improved delivery capability, new service models and higher flexibility. The impact of digitization is very high at the strategic planning level, helping the decision-makers to better align the supply chain according to factors such as costs, time, quality, risk mitigation and environmental friendliness. With the help of digital technologies, the dynamic behavior of supply chains can be illustrated and analyzed, thus reducing the costs of a sudden fluctuation in demand enormously. The effects of digitization at operational level may even be higher. The operational processes are changing steadily through the integration of machines and robots for tour and route planning (Bräysy and Hasle, 2014), supply chain planning (Zijm and Klumpp, 2016), returns management (Choi et al., 2018), layout planning (Lien and Cheng, 2012), dimensioning of production capacities or the design of the material flow system (Bierer et al., 2015). In general, it is expected that increase in efficiency, delivery reliability, supply chain transparency, predictability and flexibility will be achieved through implementation of new digital technologies. These optimistic expectations do not take into consideration that counterproductive rebounds can occur, particularly through digitization, if complex system feedbacks stay unconsidered (Galvin, 2015). With respect to specifications in logistics and supply chains in and for a sustainable economy, this issue still needs more attention to be paid on.

Summing up the literature review, the framework for developing resource-efficient and effective strategies for global supply chains related to sustainable macroeconomic system is set. The framework considers continued economic globalization as the driving force of trade and investments, the growing demand for just-in-time delivery concepts, the adoption of agile manufacturing and business practices enabled by digitization. Agile and innovative corporations with international supply chains depend heavily on modern logistics services. Their continuous efforts to offer innovative services to consumers, such as same-day delivery or last mile delivery through new digital or connected approaches, are influenced by and at the same time shape consumers' lifestyles for example in the shopping context by retailers or at the community level through social marketing (Joerss et al., 2016). Therefore, behavioral insights, which include Psychology, marketing and behavioral economics should be used in the design, implementation and evaluation of corporate or governmental policies (Lehner et al., 2015). If these strategies promote beneficial behavior for individuals or society as a whole, meanwhile promoting policy effectiveness, "nudging" applies (Mont et al., 2014). Many companies are already building robust nudge tools to efficiently deal with various organizational and strategic challenges (Güntner and Sperling, 2017). Simplification and framing of information, changes to the physical environment, or the use of social norms are examples of applied nudging tools. These tools increase organization's reactivity to rapid changes in consumer behavior, hence fostering its agility and performance (Michalek et al., 2016). This is increasingly crucial for competitiveness especially in the supply chain and logistics, considering the rapid growth of on-line retail. Thus, consumer expectations, their environmental awareness and willingness to pay for sustainable logistics services plays a decisive role in creating the fundamental framework of this paper.

4.4.3 Research Design

To develop reliable scenarios, we combine the results from the literature analysis and from expert workshops into exploratory scenarios, which can generally be both qualitative (storytelling) and quantitative (van Vliet and Kok, 2015). The advantage of the exploratory scenarios is their capability to describe different developments of social, economic and environmental factors, firstly applying participatory techniques, and afterwards quantifying those (RO 1). Furthermore, the advantage of combining quantitative and qualitative scenarios is the identification of robust actions, which are effective in the different socio-environmental contexts (Amer et al., 2013). Based on this action roadmap, recommendations for smooth transformation towards sustainable economy can be formulated, which corresponds to the RO 2 of this paper.

During the expert workshops the factors with the highest impact on supply and consumption patterns were explored and evaluated through applying a mixed-method approach of STEEP (Social, Technological, Environmental, Economic and Political). This method was applied in order to combine external factors into scenarios and to map them (Section 3.1). Moreover, we have used the results from 500 queries reflecting consumer preferences and sustainability awareness, as well as their perception of logistics processes, in order to provide the workshop participants with sufficient information from the consumer side. These results implied a higher impact of sustainability-related attributes, such as environmental impact and working conditions on the willingness of the consumers to include consider sustainable logistics services into their decision-making process (Stöckigt et al., 2018).

For developing transformational strategies and evaluating the most appropriate ones Scenarios to Strategies (S2S) method was used (Section 3.2), which also relies on quantitative approaches.

Data were collected from several sources, in particular

- scenario development workshops with experts (4 days, 45 participants, aim: identification of external and internal factors, combination of them into scenarios and strategies),
- an evaluation workshop (2 days, 40 participants, aim: evaluation of the best scenario-strategy match).

4.4.3.1 Scenario exploration and development workshops with STEEP method

The scenario development workshop series lasted four days aiming at identification of external and internal factors and their combination into scenarios and strategies to achieve RO 1. Consistent with theoretical sampling, participant selection of the workshops was conducted based on the participants' ability to generate new insights that would support theory development. The choice of the workshop participants (in total 45) followed the principle of triple helix stakeholdership (business practice, public management and policy as well as science) (Etzkowitz and Leydesdorff, 2000). Representatives of the business practice were medium-sized and multi-national logistics service providers active in B2C (business-to-consumer) market of western European countries, covering both fashion and food domains (35 participants). All of them had an experience in implementation of sustainability practices into their businesses. Public management was represented by the departments of logistics and traffic as well as digitization of the city halls of Duisburg and Essen (three participants). To cover consumer perspective, seven participants were invited from the Consumer Organization North Rhine-Westphalia, the Research Institute of Sustainable Nutrition, Collaborative Center for Sustainable Production and Consumption, and Center for Media and Health (the Netherlands).

STEEP method is usually applied in marketing or business-related fields, with the aim to identify external factors that could have impact on the operation of a certain organization or system and lay out of the control of the organization itself. Besides qualitative techniques, such as participatory and brainstorming techniques, STEEP combines also several statistical tools, like CIB (Cross-Impact Balance Analysis) and multidimensional scaling (Lorenz and Veenhoff, 2013). CIB is used to analyze both the qualitative and quantitative impact networks (Weimer-Jehle et al., 2016). The aim of CIB is to construct consistent images of the network behavior by providing values into the relations between the factors of an impact network. Moreover, multidimensional scaling (MDS) technique was applied to analyze the similarities of data on a set of objects used in several fields, including inter-correlations, ratings or indices of any kind. The main reason to use the MDS is to obtain a graphical visualization of the data structure, display the essential information, smoothing the noise of the data statistics. The graphical representation or mapping the scenarios helps to deal with the high complexity of a system with numerous elements.

The STEEP analysis was applied according to the schematic proposal of Figure 4.13 (Lorenz and Veenhoff, 2013). During the STEEP analysis a dedicated list of macroeconomic factors influencing the supply chains was created by the workshop participants. Accordingly, the collected factors were specified by the spheres of the STEEP model.

The other stages of the scenario creating process will be explained in the section "Results", simultaneously explaining the central findings of the analysis.

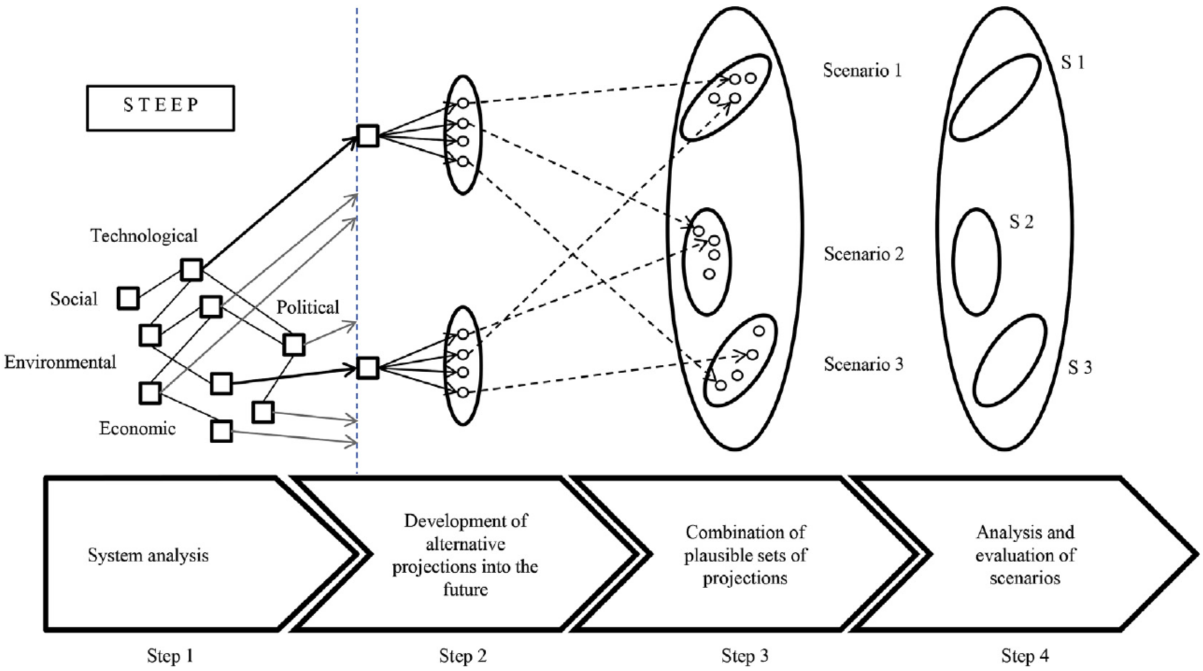


Figure 4.13: Schematic model of building STEEP analysis (Lorenz and Veenhoff, 2013)

4.4.3.2 Scenarios to Strategies (S2S) evaluation

In this section we show how to design strategy maps in order to bring predictive qualities to key performance indicators by linking them to perceived cause-and-effect relationships. Strategy maps seem more often to extrapolate past performances and are seldom sufficiently linked to possible future dynamics (Buytendijk et al., 2010). We argue that scenario analysis plays an important role in the design of strategy maps, providing opportunities to the companies in preparing themselves for multiple plausible futures, not only the one they expect to happen. Therefore, scenario-based strategy method has the advantage for organizations to face strategic uncertainty in a more effective way and make them more sustainable in the longer term (Bodwell and Chermack, 2010). For this, three approaches are used: a) problems with predictions (studying what happened in the past), b) system thinking (interlinkages among the parameters relevant for the decision-making), and c) strategy as 'fit' (organization's ability to fit into the environment it operates in) (van der Merve, 2008). All three approaches have been considered in this paper, while applying S2S method.

The S2S used here is a method, which was initially developed as an alternate strategic planning method in the electric utility industry. The S2S is a process to guide a group of participants in defining a set of scenarios, which are later used to test strategies the group develops. The process begins by distinguishing factors, and choices/actions that the planning entity could undertake. A list of factors and choices is developed which is discussed to define a shared understanding among the participants. Strategies are developed by including all choice dimensions and selecting combinations of points on each choice range. A common starting point is to define 'Business as Usual', which is the current choice pattern. A key strength of scenario methods is the exploration of 'What if?' possible futures. After the list of choices has been defined, alternate strategies can be generated. The group often begins with combinations of choices they wish to understand better and these guide the combinations of choices included in strategies to be tested. Criteria for evaluating the performance of a strategy are developed. For this, the balanced scorecard approach of considering several dimensions is recommended. When the group has defined a set of scenarios and a set of strategies, each strategy is considered in each scenario and a score is determined using performance criteria (Figure 4.14). Within the scope of this paper, we focused only on the set of strategies, like Scenario-based Strategy, System Thinking, Strategy and Alignment. Some aspects of Change Management and Organizational Culture have also been included, while designing the strategies in details. The others are beyond the scope of the given paper.

Given the fact that sustainability performance of the strategies is crucial, three sustainability criteria have been selected – Price for logistics service (PS); environmental protection (ENV) and social standards (SS). The evaluation of a strategy in a scenario, using these criteria, produces an 'Outcome' in the S2S, which was carried out with the same forty-five participants during a two-day workshop.

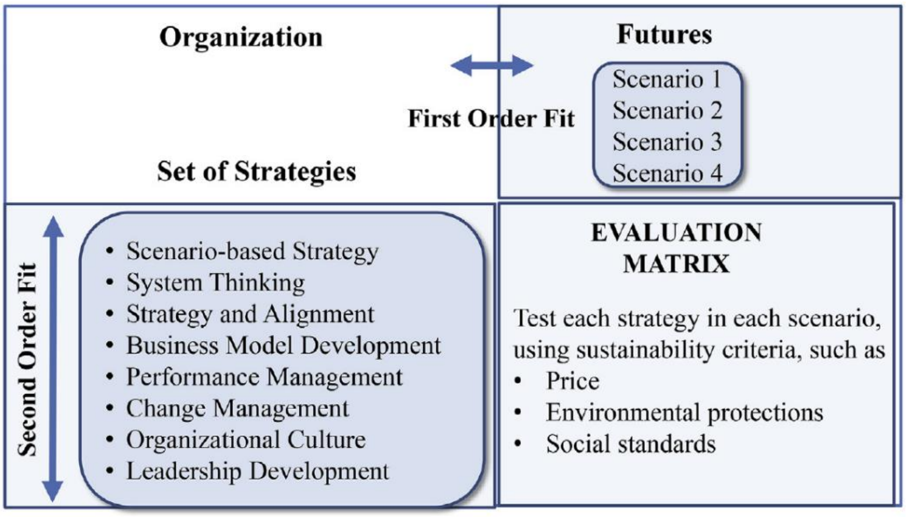


Figure 4.14: Evaluation matrix for merging scenarios and strategies (adopted from van der Merwe, 2008)

4.4.4 Results: Scenario and strategy building

4.4.4.1 Scenario Development

Macroeconomic trends influencing future developments of the supply chains and logistics sector and, conversely, considering their transformative power with effect on the economic system have been summarized from the literature analysis (§ 2.1) and presented during a series of scenario and strategy development workshops with the key actors. These eight trends referred to Globalization, Digitization, Policy regulation, Resource availability, Climate change and air pollution, Open innovation (development of new business models), Societal and consumption trends. In order to create joint understanding of the trends' impact on the sector, these have been described by choosing two factors (attributes) each, resulting in sixteen key factors. To keep the process of scenario building structured, the selected key factors were classified into different content-related spheres of society, technology, environment, economy and policy (STEEP) (Table 4.5).

Table 4.5: List of the selected sixteen key factors

Social	Technological	Environmental	Economic	Political
Urbanization	Big data analytics and optimization models	Share of renewable energy	International trade	Environmental regulations
Demographics	Technology use to promote transparency along the value chains	Land use changes	Price pressure (volatility enhancement)	Policies to adopt internalization of externalities
Environmental awareness of consumers		Release of GHG and air pollutants	Raw material prices	
Growth of sharing economy models			Population income	
Established associations /partnerships				

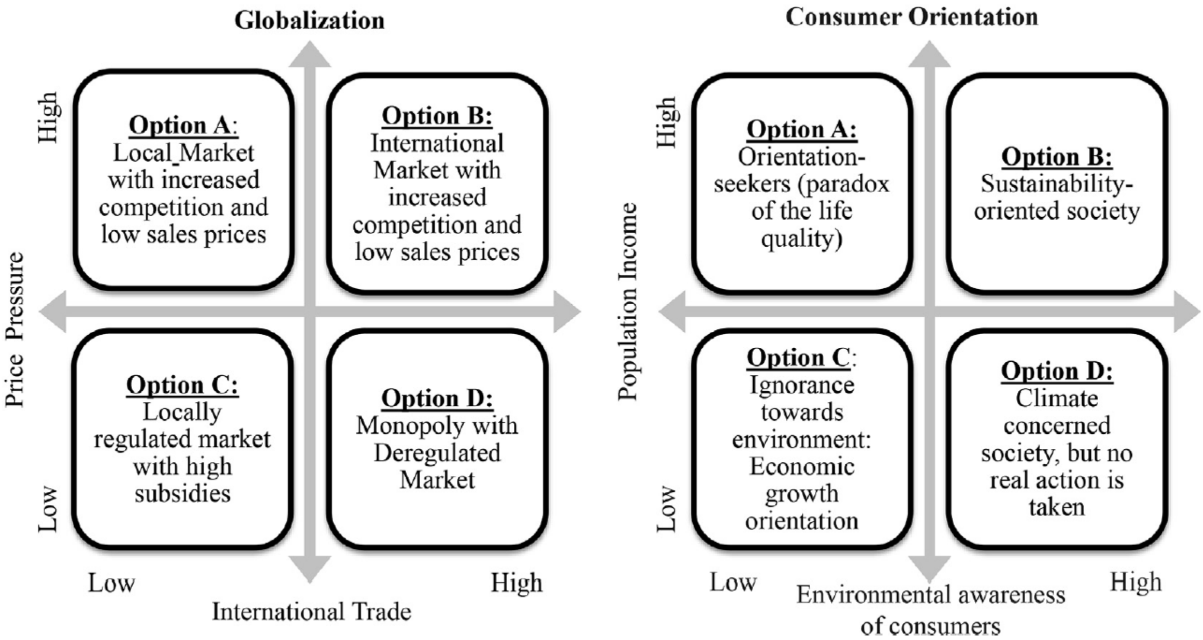
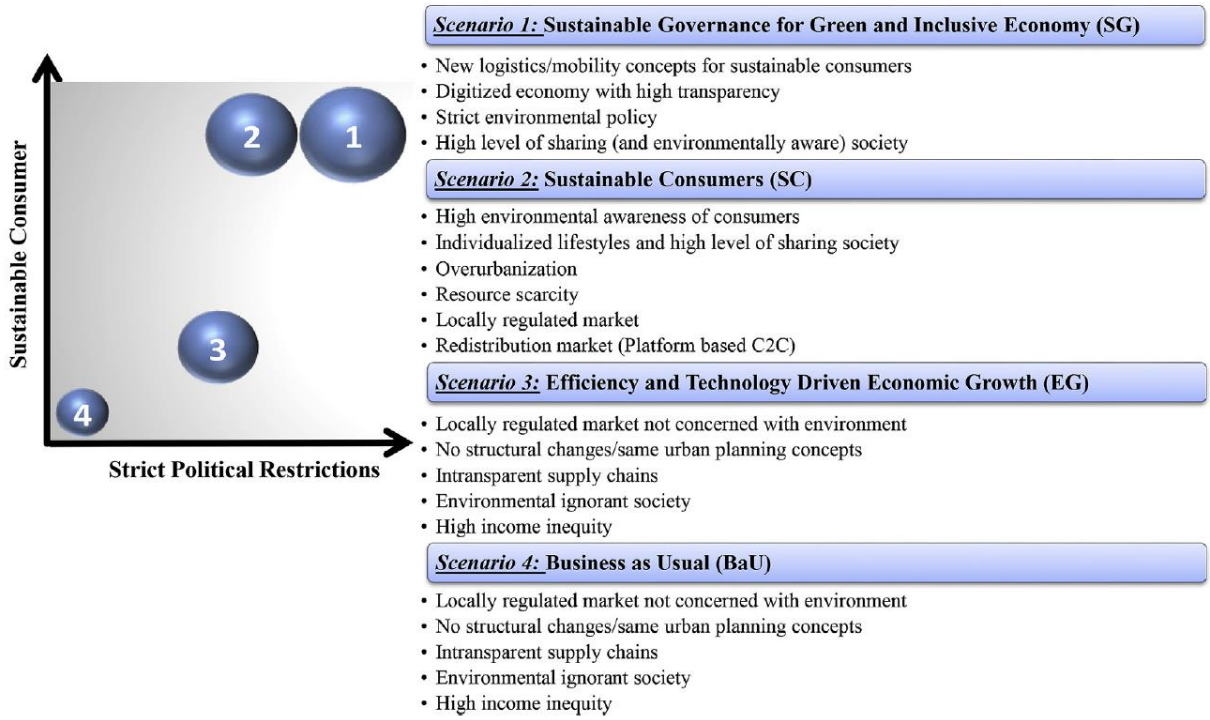


Figure 4.15: Four portfolio options on the example of two trends: Globalization (left-hand side) and Change in Consumer Orientation Patterns (right-hand side)



The X-axis represents the policy regulations, Y-axis environmental awareness and lifestyles of the consumers and Z-axis is the innovation rate within the economies, expressed in the bubbles size

Figure 4.16: Four final scenarios and their main descriptors

In the next step, possible developments of the key factors were combined into a matrix, creating a portfolio with four possible options for each factor. Firstly, detailed information on scoping the scenario field, possible impacts of macroeconomic trends on global supply chains, as well as system boundaries has been provided to the participants. Each option was discussed with the participants during the scenario development workshop. An example is shown in Figure 4.15 for two trends – “Globalization” and “Consumer Orientation Patterns”. The factors international trade and price pressure describe the trend of “Globalization”, while environmental awareness (expressed in willingness to pay for sustainable logistics) and population income are the descriptive factors for the change in “Consumer Orientation Patterns”. Portfolios for the remaining six trends with their factors are presented in Figure 4.17 a-f.

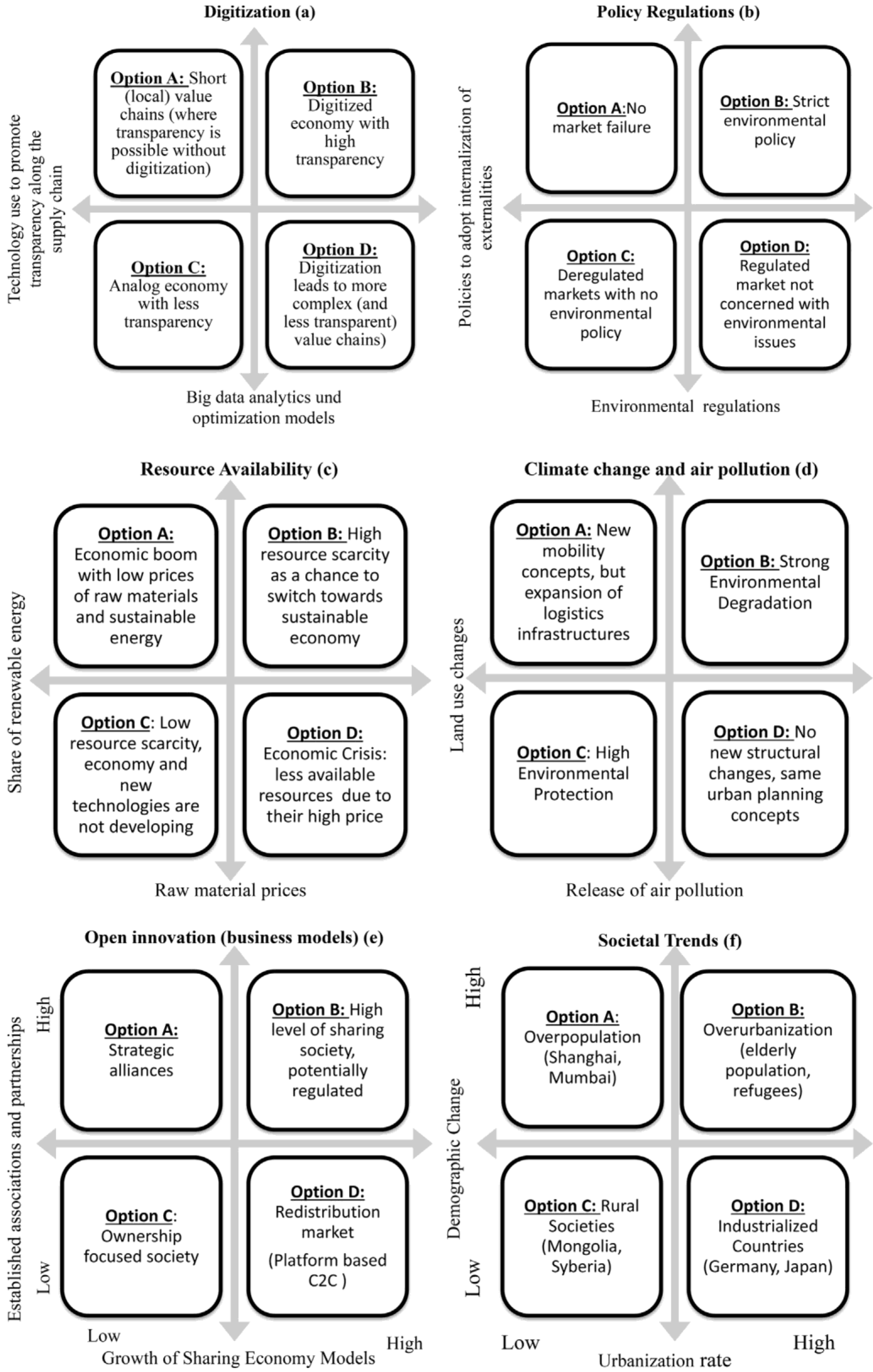


Figure 4.17: Four portfolio options for the factors: Digitization (a); Policy Regulations (b); Resource Availability (c); Climate Change and Air Pollution (d); Open Innovation (e); Social Trends (f)

The four options for the trend "Globalization" are shortly described in the following.

<u>Trend 1: Globalization (Figure 4.15, left-hand side)</u>

Option A: The level of international trade is low, but price pressure is high. This option represents a local market with high competition and low sales prices.

Option B: Both the international trade level and the price pressure are high. This situation is typical for an international market with increased competition and low sales prices.

Option C: Both the international trade level and the price pressure are quite low. This option is common for a locally regulated market with high subsidies.

Option D: The combination of high level of international trade and low price pressure characterizes monopolistic economy within a deregulated market.

After creating all possible portfolios for eight trends, the next stage was devoted to the scenario development itself. Optional future states of each key parameter defined in the last stage were checked pair-wise with the future states of all the others, through applying am evaluation range of -2 to +2. Here, -2 means that it is deemed impossible for the given two states to coexist, and +2 indicates mutual occurrence between two portfolios of randomly chosen factors. This analysis caused a development of a 32 x 32 matrix (eight trends with four options each). The options being estimated as mutually exclusive combinations (-2 and -1) have been eliminated to create consistent scenarios. In order to combine the remaining options into clusters, which represent than the final scenarios, the multidimensional scaling analysis was carried out, showing the graphical representation (common space) of the options classified after STEEP method.

As a result, four clusters of the future options have been identified, describing the scenarios of the future supply chains considering macroeconomic trends. Even though the resulting common space obtained from the multidimensional scaling displays the interrelationships between the future options, it neglects the type of dimension in which they are displayed. Thus, a further analysis to define the dimensions of the scenarios is required. Having the future options organized by type and arranged in a cardinal representation, the dimensions or axes of the graphic were determined based on the similarities and differences among all the options. After finding a common pattern, the dimensions were defined and discussed with the experts during the workshops. The X-axis describes the policy regulations, Y-axis environmental awareness and lifestyles of the consumers and Z-axis is the innovation rate within the economies, expressed in the size of the bubbles (Figure 4.16, left-hand side). The characteristics of each scenario is shown in the right-hand side of Figure 4.16.

Scenario 1: "Sustainable Governance for a Green and Inclusive Economy" (SG)

Scenario 1 considers sustainable economic development with high share of public and private investments in new supply chain concepts. This enhances innovation, enabled by application of innovative digital technologies, which may increase transparency within the system. Moreover, this may help consumers to make environmentally friendly decisions, while improving sustainability awareness of the society. The government plays also a decisive role within this scenario by developing new urban development concepts, utilizing e.g. "Smart City" approaches. This would promote renewable energy production, strengthen the public transport network, shorten commute distance and prevent land use changes. Moreover, the government would make strict environmental restrictions on emission release, resource exploitation, carbon and water footprint of the sector, by making constraints on e.g. driving hours, speed, and vehicle ownership. Except environmental restrictions, innovation rate could be enhanced by public incentives to create favorable conditions for logistics service providers (LSP) to make their services more sustainable. These conditions might include e.g. longer time-span to access low emission areas, access to areas restricted for conventional fuel vehicles, free parking during a short time/better parking slots and conditions.

Scenario 2: "Sustainable Consumers" (SC)

Individualized lifestyles and high rates of urbanization are the main descriptors of this scenario. Individualized lifestyles are expressed in inventing, designing and producing own products by consumers themselves (prosumers), which is partially facilitated by 3-D printers and so called "fab lab" structures. This trend leads to an increase in regional trade flows. Only data and raw material travel over the world, causing a drastic decrease in long-distance transport of finished products. Hence, local and regional logistics becomes increasingly important in this scenario.

Presence of new digital technologies and increasing environmental awareness of the consumers also favors development of sharing/collaborative economy models (in Customer-to-customer: C2C). Sharing and circular economy solutions enable quick and easy responses to consumer needs by matching supply and demand in an efficient way. Such business models mainly rely on:

- Use of IT systems, typically available via web-based platforms, such as mobile "apps" or internet-enabled devices, to facilitate peer-to-peer transactions.

- Reliance on user-based rating systems for quality control, ensuring a level of trust between consumers and service providers who have not met previously.
- Flexibility of the workers who provide services via digital matching platforms in deciding their typical working hours.
- Digital matching firms rely on their own tools and assets to provide a service.

<u>Scenario 3: "Efficiency and Technology Driven Economic Growth" (EC)</u>

This scenario assumes digitization to revolutionize business with the growing influx of technological innovation. Besides hardware-oriented trends like robotics, the software-based digital technologies create fundamental change in processes, operations, functions, and even within entire business models. With respect to individual technologies, a series of technological solutions play a central role within the ongoing digitization trend in the supply chain and logistics sector. Among others, miscellaneous sensors, video cameras, cyber-physical systems, augmented and virtual reality, as well as the internet of things and services were mentioned by the key actors.

Apart from the introduction of the individual technologies to different application areas of global supply chains, which is solely efficiency driven, this scenario assumes that global governance lacks at a clear strategy of a holistic digital transformation towards sustainable economy, being expressed in deregulated economic growth. Resources are extracted in a harmful way causing strong environmental degradation. The consumers are also environmentally ignorant and ownership focused. Moreover, technological progress here is described by digital divide. Thus, digital transformation means more than the sheer move to digital business. It is a fundamental and accelerating transformation of business activities to make full use of the promising digital technologies and their impact across the industry and society in a strategic manner. Therefore, in order digitization serves to the efficient transformation of the sustainable economy, policy interventions are absolutely necessary, like in the Scenario 1.

<u>Scenario 4: "Business as Usual" (BaU)</u>

Scenario 4 "Business as Usual" is the least case scenario. Supply chains firstly benefit from economic growth and continuous increase in consumption, until resources get scarcer, natural disasters pile up and supply disruptions become more frequent. A lack of political regulations for environmental reverse globalization prohibits the importance of short value chains. Technological development will become recessive. With no structural changes, the same urban development and logistics concepts cause expansion of built-up areas and high rate of land use change. Within this scenario the society is focused solely on economic growth. Some participants believed that countries being focused on economic growth would become the world's principal engine of new demand growth and spending power. However, it is important to highlight that numerous factors and trends block the exponential growth of these economies. High level of urbanization will lead to more polluted environment and natural resource scarcity, limiting the further economic growth.

4.4.4.2 Strategy Development

When deciding on the right business transformation strategy for a LSP, discussing all the operational factors, which the company has an influence on, is the first step. Thus, after combining the external factors into scenarios, at the next stage the internal/operational factors were discussed with the participants in the evaluation workshop. The combination of these factors resulted in development of the firms' strategies to face possible future scenarios in a sustainable way.

Strategies / Action Fields	Str. 1: Lead Sustainability Service Provider (6-PL)	Str. 2: Efficient Logistics (4-5 PL)	Str. 3: Business as Usual (3-PL)
Design of the supply chain	• Production-consumption integration • Vertical integration of information flows • Circular economy concepts	• Multi-channel concepts • Crowd-logistics • On-demand solution	Home- delivery
Transport and Location Planning	• Hybrid services, multi-user platform • City hubs, micro depots • On-demand delivery forms	• Modal shift • Central warehousing • Distribution centers	Central warehousing
Transport Technology	• Electro-, autonomous, alternative fuel (cell- and carbon-based) vehicles • Drones, bicycles	• Electro- autonomous, vehicles • Bicycles	Conventional trucks
Technology	• New digital technologies • New cooling systems • Shared logistics	• Zero-emissions buildings • New cooling systems • New digital technologies	No new technologies
Packaging	• Digital packaging (smart) • Innovative packaging materials	• New packaging materials • Digital and reduced packaging	Reduction of the packaging
Communication (Internet of things)	• Automation of information systems • Networking	• Certification • High quality product/service description	Communication strategies via traditional marketing
Customer-Orientation	• Life-style oriented delivery • Customer empowerment	• New price models • Customer empowerment	Life-style oriented delivery

Figure 4.18: Choices grouped in relevant action fields and clustered into strategies

For this, firstly action fields relevant for decision making processes and the choices which can be made within each action field were identified during the workshop. These action fields are: design of the supply chains; transport and location planning; investment in new technologies (in transport, packaging, warehousing); communication strategies and consumer-orientation (Figure 4.18). The choices in each action field were later combined into three main strategies. Note, that there were initially four strategies: in addition to the three strategies listed below, there was another one, named ‘Old-School Logistics’. Since the descriptors of this strategy were very similar to those in BaU with the only difference in the field of communication, the participants decided to merge these two strategies into BaU in the last stage of the workshop, which was the evaluation of scenarios and strategies.

The current trends relevant both for strategic and operational levels within the sector cause significant changes in the business models of logistics. The performance-determining share of logistics in the value-adding interplay between production and consumption has thus steadily increased. The typical logistics domains of transport, delivery and storage have expanded to a variety of cross-sectional tasks in rendering comprehensive industrial services for the entirety of production and supply systems. In 1960, the companies acted as only a subcontractor (1 PL). In the 1990s, the strategies of Carrier (2 PL) and Logistics operator (3 PL) and by the mid-2000s the strategies of Supply Chain Optimizer (4-5 PL) were developed (Selviaridis and Spring, 2007; Dhayanidhi et al., 2011, Gruchmann et al., 2018). Using this popular classification scheme of 1PL to 5PL business model, each derived strategy was aligned with certain business model types. Combining these scenarios with possible strategies allows for the inclusion of a new business type to the 1PL to 5PL scheme, the so-called Lead Sustainability Service Provider (6PL) (Gruchmann et al., 2018).

Strategy 1: “Lead Sustainability Service Provider” (LSSP) (6 PL)

In this strategy the integration of production, supply and consumption systems into an umbrella of strong sustainability is enforced (Pelenc and Ballet, 2015). Against this, physical and digital supply network structures and functions play the central role as merged and holistically managed, planned and controlled physical distribution, stakeholder, data/ information and collaboration networks. Consumer empowerment through communication strategies, collaborative PSS/ prosumer integration into decision making as well as advanced vertical supply chain information management (co-flows with respect to environment –water, carbon, etc.- as well as social impacts) represent powerful innovation for the LSSP. The flow of goods and products including related sustainability assets are completely transparent and traceable to all supply chain members, particularly to the end-customer. Advanced use of information technologies, such as big data/ prescriptive data analytics, artificial intelligence or blockchain concepts, often in combined technology platforms is implemented. All possible transport modes and structurally related logistics services are considered and the most sustainable are preferred since externalities of transport, storage and transshipment have been internalized into service prize building mechanisms as well as regulatory framework conditions (e.g. environmental tax policy). Supply network optimization leads to maximum environmental friendly and economically profitable solutions, under changed framework conditions with respect to (pulling) society, mindsets and (pushing) regulations. Transport reduction/ avoidance is a central parameter for sustainable supply chain planning and LSSP create alternative value added services with respect to information logistics to customers (both B2B and B2C). Through networking, parts of data and information management as well as physical flows of goods can be outsourced to society (the “crowd”) if needed. The storage and transshipment, particularly on the critical urban last mile, is carried out in city hubs, micro depots, meanwhile providing innovative on-demand solutions and new business models as well as specialized last mile service providers. Means of transport for single deliveries generally cover all available options (including autonomous and electric/ fuel cell or other alternative “high tech” vehicles, as well as drones, robots, or cargo-bikes) depending on their in situ sustainability related performances. This leads to radical shifts of the mass transport modal split towards more sustainable transport forms (including higher shares of modern waterborne and railway transport) as well as new structures of transport chains with respect to integrated production and consumption systems (regional and urban supply as well as temporal shifts in supply induced by shifting consumption modes).

Closed Loop SCM is standardized in many industrial commodity chains and enables value creation through re-manufacturing or refurbishment strategies. The co-flows of packaging are largely digitized and adapted to the logistical and recycling/ re-use requirements.

Strategy 2: “Efficient Logistics” (EL) (4-5 PL)

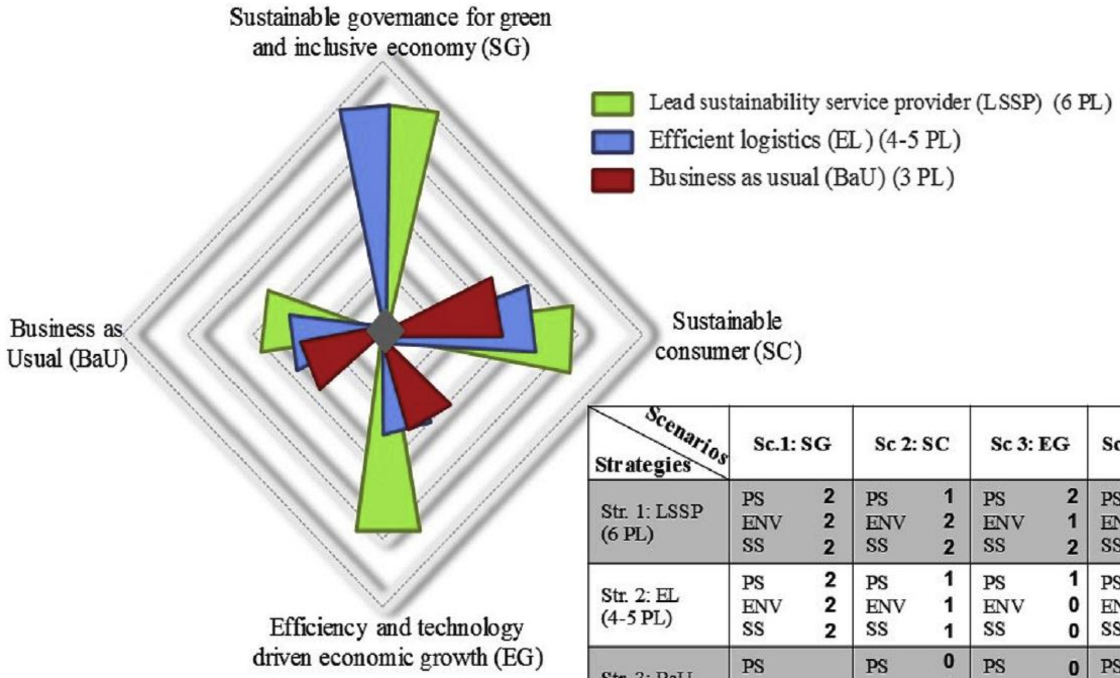
Fourth party logistics (4 PL) is an integrator that assembles the resources, capabilities, and technology of its own organization and other organizations to design, build and run comprehensive supply chain solutions using information and communication technologies (ICT). As digital technologies enable supply chains to become more global, the international logistics industry has been researching the development of 4 PL services, i.e. the realization of full-scale operation of e-procurement. A key function of the 5 PL is to aggregate the demands of the 3 PL into a bulky volume in order to be able to negotiate more favorable rates with airlines and shipping companies. To increase cost efficiency in the focal company, 5 PL logistics assumes value added services (network planning, assembly, part production steps, take back systems, etc.). This strategy focuses on efficiency improvements both in an ecological and an economic sense. Nevertheless, no integrative sustainability approach is used. Multi-channel and crowd-logistics concepts bundling as many streams as possible are used to deliver to the end customers. Delivery to the end customers is carried out using electric vehicles and cargo-bikes. Picking and storage of the goods takes place mainly in a central warehouse. Some investments might be done in zero-emission buildings and new cooling systems. Digitization enables new forms of packaging, utilizing new materials in reduced quantities. Overall, this strategy can be described as strongly efficiency- and technology-driven. Organizations that have successfully implemented a 4 -5 PL model have benefited from improved service levels, reduced logistics costs, and greater flexibility to deal with changing business needs. Key for the success of this strategy is the willingness of the customers to pay. Increased trust between firms and their SCM providers is enhanced by economic imperatives, technological innovations, integration of information flows at horizontal and vertical levels, as well as market competition and managerial ability to provide advanced logistics services.

Strategy 3: “Business as Usual” (BaU) (1-3 PL)

“Business as Usual” follows the more traditional business strategy of a third-party logistics provider (3 PL), targeting a single function. 3 PL provides logistics services for companies for a part or sometimes all of their supply chain management. The delivery takes place exclusively to the end-consumers’ home mainly via the modality of the road. Important instruments are bundling and the use of central warehouses. Conventional technologies are used: conventional trucks with combustion engines transport the goods. This strategy is strongly driven by the growth and cost efficiency and relies heavily on fossil fuels.

4.4.4.3 Scenario-to-Strategy

Applying the S2S method in the final stage, four scenarios and the three strategies were evaluated within a matrix using criteria of sustainability, such as price for logistics services (PS), environmental protection (ENV), and social standards (SS). The intersecting field was given the note 0 if the future situation is worse than the current one, 1 – no changes are expected and 2, if the situation is expected to improve (Table, right-hand side of the Figure 4.19). The values given to each criterion were aggregated at the end, in order to estimate the best strategy addressing future scenarios (Figure 4.19, left-hand side).



Strategies \ Scenarios	Sc.1: SG	Sc 2: SC	Sc 3: EG	Sc 4: BaU
Str. 1: LSSP (6 PL)	PS 2 ENV 2 SS 2	PS 1 ENV 2 SS 2	PS 2 ENV 1 SS 2	PS 1 ENV 1 SS 0
Str. 2: EL (4-5 PL)	PS 2 ENV 2 SS 2	PS 1 ENV 1 SS 1	PS 1 ENV 0 SS 0	PS 1 ENV 0 SS 0
Str. 3: BaU (3 PL)	PS ENV SS	PS 0 ENV 1 SS 1	PS 0 ENV 0 SS 1	PS 1 ENV 1 SS 0

Price for logistics service (PS); environmental protection (ENV) and social standards (SS) were used as criteria: 0 stands for a future deterioration of the situation; 1 stands for no change to be expected, and 2 supposes improvement of the current situation. These values were aggregated in the Figure on the left-hand side to estimate the entire efficiency of the strategies. *Note, the field crossing Scenario 1 and Strategy 3 was not filled in, since the participants didn't consider this crossing to be realistic.

Figure 4.19: Evaluation matrix of scenarios and strategies

As shown in Figure 4.19, following Strategy 1 – “Lead Sustainability Service Provider – LSSP”, a logistics firm would be clearly better off for all the scenarios. If the logistics company follows Strategy 2 – “Efficient Logistics – EL”, the situation would be improved if future Scenario 1 is to apply. In any other case, it performs worse, except Scenario 2, where no actual change is considered. The Business as Usual (BaU) strategy performs better if consumers become more environmentally aware and if they are willing to pay for sustainable logistics services, as well as if the Scenario 4 takes place. In any other situation, it is clearly the strategy with the worst performance, thus identifying the urgent need to innovate the business models.

4.4.4.4 Transformation pathways towards sustainable economy

Possible pathways of economic transformation are shown in Figure 4.20, where the four main scenarios and three strategies are mapped. For creating the transformation pathways, estimation of the scenarios’ similarity to today’s situation, desirability and probability of the best scenario to occur in the future has been discussed in the last workshop with the same stakeholders who created the scenarios. To guide the process of mapping the transformative pathways from today's situation towards more desired scenario, the following questions have been discussed:

- Which of the scenarios is the "most similar to today"?
- Which of the scenarios are the ones we would like to see?
- Which scenario do we expect to actually happen?

With this visualization it is possible to highlight today's situation of the supply chains with the corresponding possible divergences as expected scenarios. It is based on the majority of the circumstances apparent today which can be described mainly by traditional economic systems with less environmentally oriented consumers and integrated political decisions.

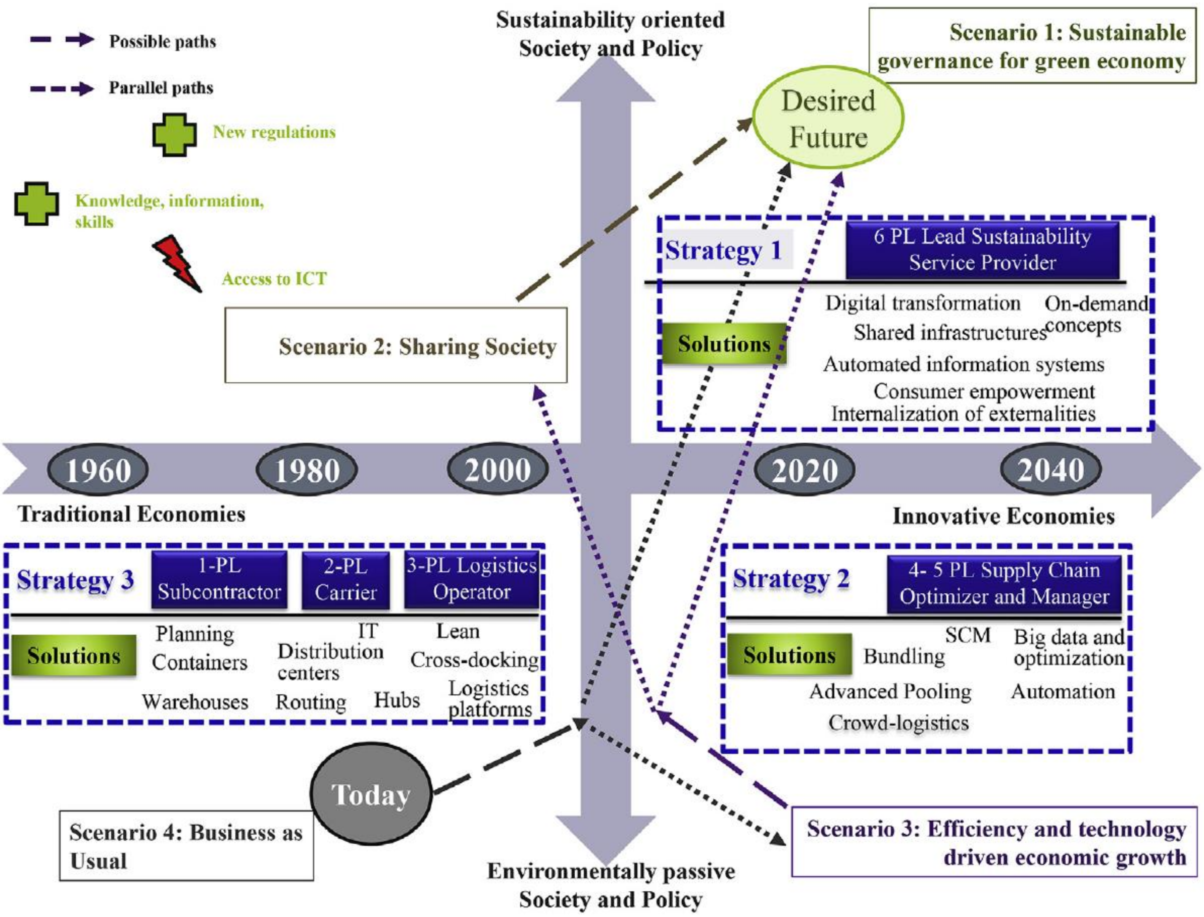


Figure 4.20: Scenario and strategy mapping, showing the transformation pathways of the future economic systems and how the supply chain and logistics sector can adopt to this process

Scenario development showed that the innovation potential in the sector of supply chain and logistics is the highest if there is a pressure coming from both the government and consumers to become sustainable. Considering no substantial changes in governmental restrictions and consumer requirements for sustainability staying at a low level, the Scenario 4 – 'Business as

Usual: BaU' might continue to be the possible future pathway. In that case, the innovation rate in the sector is slightly higher, if the logistics providers focus on Key Performance Indicators (KPI) of efficiency, such as economic (cost savings) and time (fast delivery) efficiency, while applying new digital technologies. In this current situation, the logistics providers are forced to innovate their business models to a certain extent, due to high competition and disruptions in the sector. From today's situation on, “Business as Usual” scenario can develop into two main directions: either it can continue to be fostered without significant change in economic structure or policies will leading to stagnation (1). The alternative might be that due to resource scarcity and climate change induced vulnerability a switch towards sustainable future and innovative economic models will emerge to balance the market (2). In the first case, the winners will be big companies (mergers and alliances), which are the major players in the market. This, in its turn, will lead to unequal competition and market failure, resulting in higher prices and environmental ignorance by the big players. In the second case, there is a chance to switch to innovative sharing economy models, as it is the best solution for SMEs to cooperate and increase their power. This chance will case the development pathway from Scenario 4 to Scenario 2 – Sustainable Consumer (SC). Slight changes in the consumption behavior will lead to a rapid development of sharing economy models at least for B2C and C2C business, which might be accompanied by certain regulations on a local level, as well as gained additional knowledge skills. In that case, Scenario 4 (BaU) might develop into the same direction, as Scenarios 1 (SG) and Scenario 3 – ‘Efficiency driven economic growth: EG’. In the case of increase in sustainable consumption patterns and integrative/ sustainability oriented policy regulations, Scenario 3 might develop towards Scenario 2 and Scenario 1 – ‘Sustainable governance for green and inclusive economy: SG’. The latter represents the desired future, where societies manage to combat climate change, leading to high environmental protection and development of new forward oriented supply chain concepts. These would favor the sector to become sustainable, fast, flexible, stable and locally adapted. These favorable conditions to innovate the company strategies are further mapped in Figure 4.20, while the discussion of the roadmap is carried out in the next section.

4.4.5 Discussion

4.4.5.1 Strategy roadmap addressing macroeconomic trends

Theoretical implications

Current macroeconomic trends, accompanied with unsustainable resource use and environmental degradation highlight the urgent need for the transformation of economic systems. Transformation means reducing the negative emissions and environmental impacts of economic activities, decreasing resources use to get back into the range of natural sustainability, meanwhile creating new opportunities for the societies to consume in a sustainable way (Bontoux and Bengtsson, 2015).

Transformation potential of economy towards more sustainable systems has been assessed by using various model approaches of ecological economics (Safarzyńska and van den Bergh, 2010), complex systems (Zeppini et al., 2014), socioeconomic systems, behaviour and dynamics (System Dynamics (SD) models: Papachristos, 2017). However, these model approaches are still weak in representing qualitative changes of different normative aspects, such as new fields of social activity, new ways of consuming (Köhler et al., 2018). This gap is filled by the present paper, where integrated, qualitative and quantitative methods have been applied to evaluate the transformation potential of the economic system. This was achieved by developing future macroeconomic scenarios influencing the supply chain and logistics sector, which is the driver of economic system, meanwhile causing unsustainability within the system. A strategy roadmap for this sector was created in the sense of a transformative or 'pro-active' force to address the future potential changes. Sustainable Governance scenario represents a combination of several potential changes and is evaluated to be the desired future for sustainable macroeconomic systems. Moreover, literature analysis shows that it might also be realistic and achievable one, since it is characterized by e.g.

- strict environmental policy on emissions (55 % of CO_2 reduction by 2030; Ministry of Environment, Nature Protection of Germany, 2019: national target)
- large investments in logistics infrastructures (BMVI, 2019: national investment strategy)
- a highly digitized economy with supply chain transparency (Kagermann, 2015: global estimation)
- increase in number of business models within sharing and circular economy (Carra and Magdani, 2016; Puschmann and Alt, 2016: global estimation)

Managerial implications

These macroeconomic trends relevant both for strategic and operational levels within the logistics sector will cause significant changes in the business models. These changes are driven by a strong integration of information and communication technology (ICT) based services towards a direction of a more integral control and enrichment of value-added services in terms of contract or system logistics (Zijm and Klumpp, 2016). The performance-determining share of innovative logistics in the value-adding interplay between production and consumption has thus steadily increased.

In this line, our *first finding* states that the logistics sector should develop innovative and sustainable concepts through broadening the portfolio of sustainable added-value services in order to meet the desired future of Scenario 1 – Sustainable Governance. The development of sustainable added-value services by the logistics companies corresponds to the Strategy 1 – 6 PL Lead Sustainability Service Provider, which enables SSCM practices. Positive effects of SSCM practices on sustainable supply chain performance have already been empirically proven (Ahi and Searcy, 2013; Kashmanian, 2015). This highlights the fact that the firms need to collaborate globally in advocating SSCM practices to ensure firm's success. In evaluating SSCM practices, basically quantitative analysis dominates, such as equilibrium models, multi-criteria decision analysis or analytical hierarchy process, without really taking into account qualitative approaches (Seuring, 2013). Combining qualitative and quantitative approaches, we argue that 6 PL should be operationalized in the sense of Ecological Economics as "shared responsibility in the supply chain" and with respect to "critical capitals for supply and value chain management" (Krumme, 2019). Thereby we define key principles of a strong supply chain sustainability as:

- Stewardship of critical capitals (CC): particularly with respect to natural capital stocks and flows, CC may not fall below certain values of qualities/quantities.
- Supply Chain Responsibility (SCR) is a shared task and should be measurable, transparent and understandable within value creating supply chain networks for all stakeholders.
- Equity of (critical) capitals must be well distributed among producers, traders, service providers and consumers.

This brings us to our *second statement* is that only the companies, which are proactively driving the transformation of the macroeconomic systems towards more sustainable patterns, will be successful in the long-run. A survey-based analysis of Harms et al., 2012 reveals that large German companies mainly implement risk-oriented SSCM strategies, which means that instead of applying innovative supply chain concepts (or business-opportunity-oriented approach) they prefer 'only' adoption of supplier evaluation and selection. Moreover, until now external pressure to implement SSCM practices clearly outweighs the pro-active role in the transformation process (Mohanty and Prakash, 2014).

Our *third statement* argues that development of the successful strategies should follow a system thinking approach, addressing the most relevant macroeconomic aspects. System thinking approach in strategy development relies on prediction thinking and management thinking foresights, thus arising the need to combine qualitative and quantitative approaches

(Rebs et al., 2018). System thinking advances SSCM and sustainable logistics practices especially when focusing on innovation, learning and sense-making (Nilsson and Gammelgaard, 2012). One aspect of system thinking is that n-order supply chains should be considered in business practices from the point of origin in the first-order supply chains in order to enhance corporate efforts of SSCM (Svensson, 2007). The other aspect is that supply chains go beyond the traditional point of consumption, considering the consumer as driving force of the supply system. General SCM underestimates the demand and consumption dimensions and neglects natural limits of demand. Even Demand Chain Management (DCM) is linking SCM to marketing in a one-directional way aiming at maximization of sales by optimizing SCM and marketing measures. In contrast, 6 PL strongly enhances sustainable consumption patterns. Altmann (2015) supports our statement to include consumption perspective into the sustainable strategy development by creating a Mixed Integer Linear Programming Supply Chain Model based on a German production company that incorporates a demand function influenced by sustainability requirements.

4.4.5.2 Policy recommendations

The trigger to drive these transformative changes is willingness of the global policies to develop integrative and inclusive governmental patterns. Yet, application of sustainable (green and inclusive) economy concepts, which consider dematerialization, servicing and investments into environment and natural capital, are complex, requiring systemic changes in economies and societies. Even though the investments are mainly done by the private sector, governments play a central role in guiding these investments towards greening the economy. Thus, policy regulations are urgently required in order to promote sustainable economies, in particularly transforming supply chain and logistics sector. The sector fuels the global economy, by continuously expanding the system, becoming more complex and having higher impact on environment. In addition, regulations and frameworks, incentives and reward systems in the interest of society can strongly promote necessary innovations and practices while stopping opposing dynamics. In the case of the dominant role of the modern logistics and supply chain sector for production, trade and consumption, this can be a lever which, in the spirit of the paper, makes transformative supply chain structures and services for a sustainable economy possible.

Governmental policy recommendations for transformation towards sustainable economy are summarized below. These rely on macroeconomic parameters with high impact on SSCM and logistics practices. The governmental levers on these macroeconomic parameters are in line with international literature.

1. The governments themselves should implement sustainability practices into their decision-making processes, such as governmental expenditures and accounting (Loiseau et al., 2016).
2. Integration of the economy into ecosystem, considering the environmental limits and various aspects of well-being and working patterns is necessary. This can be done by inclusion of different income groups into economic systems (through taxing levels), meanwhile understanding the consumer behavior for shifting consumption patterns (nudging) (Hardt and O'Neill, 2017).
3. Production systems of disaggregated industries should also be strongly reflected into concepts of environmental economics, including different business models with different behaviors.
4. Policy regulation practices as governmental subsidies, tax exemptions or low interest rates for using renewable energy within logistics operational process (e.g. eco-design vehicles), penalties on polluted systems, fostering cooperation between logistics sector and governmental authorities should be implemented. This can be done through adoption of certification schemes (Khan et al., 2018).
5. Better understanding of logistics performance indicators at a country level, facilitating evaluation of supply chains efficiency, service and infrastructure development. For this, macrologistics costs are one of the most suitable indicators, being measured by the percentage of sales or turnover, absolute costs and percentage of GDP (Akoudad and Jawab, 2018). With the costs being low at a national level, competitiveness among industries is enhanced, trade and sales are increased, providing opportunities for new markets entrance. This indicated medium-term policy through trade liberalization.
6. Long-term policies to strengthen the supply chain processes at national and international levels should be implemented, considering international standardization of products, services and operations according sustainability requirements, which would attract global markets. Moreover, the importance of human (social) factors involvement within the process of logistics and supply chain development must also be highlighted (Aldakhil et al., 2018).
7. The proposed policies should be evaluated for their efficiency over time and across countries, through better understanding of logistics performance at country level, meanwhile considering dynamic interactions at local, national and regional scales.

4.4.6 Conclusion and Outlook

Applying a holistic approach, this paper addressed socioeconomic, environmental, technological and political aspects in order to develop macroeconomic scenarios and sustainable strategies for supply chain and logistics sector, defining the transformational pathways towards a sustainable and inclusive economy. This was achieved through a combined assessment of economic systems, meanwhile considering the interests of the key stakeholders. Four possible scenarios were developed, among which Scenario 1 – Sustainable Governance for Green and Inclusive Economy was evaluated to be the most desired and more realistic one. It considers the current macroeconomic trends on e.g. strict environmental regulation, a highly digitized economy with supply chain transparency, increasing cooperation among the supply chain members (in the form of sharing economy), being enabled by emerging new digital technologies.

Based on these scenarios, logistics service providers may adjust their business models with regard to their strategic positioning in the market and regulatory system, particularly by pro-actively developing and implementing innovative and sustainable concepts through broadening their portfolio of sustainable added-value services. These concepts will extend to the overall planning of supply chain networks (Strategy 1: Lead Sustainability Service Provider) in terms of configuration and coordination of supply chain partners, partial production steps, assemblies, and shaping of retailing businesses. Newer logistics value-added services configure high quality after sales services as well as the re-integration of products into lifecycles, as re-use, recycling, refurbishment or remanufacturing, in frames of circular economy. To do so, the 6PL "Lead Sustainability Service Provider" model includes modern logistics/ SSCM a responsible instance for the design, coordination, management and control of sustainable operational networks in integrated production, supply and consumption systems. To be able to move these transformation levers, however, changes in the management paradigms in classical SCM to fulfill the 6PL role are indispensable. Future management implications must be understood here as the central aspects of strong supply chain sustainability and systems thinking.

From the policy perspective, inclusive governmental patterns need to penetrate policy maker's actions. To support these actions, the present study provides basic guidance, focusing primarily on the logistics and supply chain sector as enabler of the comprehensive transformation towards a sustainable economy. Future scenario research in this field can focus on other sectors, such as the energy and housing sector, to develop cross-sectoral guidelines and policies. However, innovations so far are limited to the lack of considering important support, demand and reward aspects to change basic conditions. Here, particularly qualitative case studies can help to make best practices more visible and are necessary for further progress. For example, it is possible to investigate to what extent in the status quo innovation strategies of the Lead Sustainability Service Provider can have economic success in the market and generate environmental and wider societal benefits. Future work could also include the sustainability assessment of the proposed strategies in a case study and take into account the expansion of the logistics companies' business portfolio. Another issue could be the scalability of these kind of business models, where supply chains integrate regional, national or international production and consumption systems into strong sustainability services. Changed framework conditions can be mirrored in computer-based simulations and be blended with data obtained from case studies. This would have high orientation value for business actors, but also political / social decision-makers.

5 Discussion

5.1 Systematizing the Research Findings

In the following, 6 conclusive theses are put forward as condensed nuclei that serve to improve the systematics and clarity of the broad, addressed research spectrum of the cumulative contributions made in the previous parts of this research. Overlaps between the addressed subject areas are an inherent principle and refer to complex initial backgrounds, but also networked solutions for the future. The theses shape research outcomes and establish important contextualization in-between the research findings, but also between research findings, further contexts of directly related research questions and an emerging overarching sustainability-oriented research agenda.

Thesis 1: *Based on contexts of worldwide urbanization and increasingly urbanized economic networks, the Supply Chains, and the Services within are triggers for the Transformation Processes toward a Sustainable Socioeconomic Ecosystem.*

The central role of urban systems within economic and societal development has significantly increased demands for urban-industrial supply. Since a reduction in the urban ecological footprint depends principally on the levels of resource consumption in the forms of imported material and energy, turn-over, and the quality and quantity of outflows (including all waste deposits), supply chain competences are addressed to alter the composition, as well as the spatial and temporal patterns of a broad variety of systemically interrelated flows.

From the SCM perspective, and to organize a better-managed “space of flows” into, for and between urban, respectively industrial systems, a wider and more open understanding of supply chain services would depict logistics as a “co-designer” of a sustainable urban-industrial PSC Ecosystem in terms of particularly materials, energy and information flows toward, from or within a sustainable urban-industrial metabolism.

Logistics and SCM allow holistic system-oriented perspectives on the future urban-industrial supply system, bringing together conceptual, social, technological, and economic innovations such as logistics services and technologies in modern supply chain concepts, including, finally, the levels of consumption and lifestyles.

From the perspective of sustainable urban development, these advances in the interplay between the urban-industrial systems (in all its infrastructural, social, and economic facets) and logistics must find their way into new concepts and the testing of a sustainable “metabolic concept", which from the city-perspective can be summarized as "smart urban metabolism" (Shahrokni et al., 2015). From the perspective of superordinate urban-industrial global networks and their (then subsequent) regional and local implications, this was up to now not considered, but represents highly significant research needs.

Thesis 2: *Proactive Innovation for Transformative Supply Chains of a Sustainable Economy generates Opportunities for an alternative urban-industrial PSC Ecosystem Design, its Patterns and Services.*

Reflecting challenges of sustainability, value-added services increasingly determine higher performances of holistically understood alternative socioeconomic settings, especially within a sharing and circular economy (Manzini et al., 2001; Lahti et al., 2018). From this, new designs for structural innovation of production processes in the sense of remanufacturing/ refurbishment can be derived, which place new demands on the structure of the products themselves and their use, as well as the quality of the production and manufacturing areas and their spatial patterns.

Making sustainable PSC Ecosystems possible, requires a fundamental restructuring of material sourcing, production processes, as well as the establishment of supportive business services along innovative value creation structures in supply chains. In this context, proactive abilities of SCM and logistics to contribute to the required transformation of spatial and organizational structures as well as for effective operational changes of and within the socioeconomic system remained until recently largely unconsidered. A detailed understanding of exactly how SCM could serve in this respect and of more concrete preliminary profiling of logistics capabilities to fulfil these expectations is still lacking, although the cumulative parts of this dissertation and further related research of the involved academic network provide first new insights.

Ultimately, the modularity of supply chains in the entire product life cycle represents a paradigm to attain sustainability gains toward a circular and sharing economy, which has been recognized by several authors (Blevis, 2007; Seliger et al., 2008; Ülkü and Hsuan, 2017) as having high potential for transformation in terms of materials, products, and production processes for sustainable product use forms. As Niinimäki and Hassi (2011) point out, modularity plays a unifying role for production, supply and consumption systems and represents individualized solutions of user adaptation, enable decentralized production patterns, or improve the sustainability of products by increasing longevity through their ability to be repaired, upgraded, and transformed.

From the consumer's point of view, more adaptable and renewable ways of using and reusing products will effectively reduce the spatial, but also economic distance between production and consumption. This sustainability gain through modularization is dependent on the upstream and increasingly downstream (after-sales) structures, mechanisms, used technologies and services of the supply chain and its organization. Particularly the new services, as well as the associated strengthening of the consumer role (see thesis 4), correspond significantly to the inclusion of information and communications technology (ICT) (Fuchs, 2008). Generally, new technological options – above all, broad digital networking of economic system structures (data exchange, data collection, and information analysis under "big data") – offer considerable opportunities to optimize the networked processes needed in newly adapted supply systems.

Thesis 3: *Against the Backdrop of Climate Change, the WEF nexus emerges as a main challenge with respect to sustainable supply. Digitization helps designing Sustainable Food Supply Systems when it is integrated into a holistic WEF guided perspective.*

For fulfilling basic needs of food supply, sources of supply and agriculture as a major economic factor are being put into question through climate change. Besides this, food systems are particularly vulnerable to regional and local impacts of climate change and are intensively correlated with water and energy issues. Through food supply chains, the WEF nexus possibly cascades into supply bottlenecks of urban agglomerations worldwide. Cities, especially megacities are particularly vulnerable because of their population density, sealed areas, and dependence on external sources of supply (see thesis 1). Thus, issues of the WEF nexus represent high destabilization potential within the dynamics of primary production, supply chains, and consumption/lifestyle systems as discussed within this dissertation.

Previous solution attempts have usually ignored the systemic coherence of production, supply, and consumption, presented here in this dissertation as an elaborated PSC Ecosystem approach. Currently, food systems and all their substructures of production, distribution, commerce, consumption, and shopping habits are undergoing a major transformation triggered by sustainability requirements and by technological (mainly digital) and social developments (lifestyle trends). For an integrated approach, the components of an urban-industrial supply system must be combined and thus system boundaries must be re-examined as shown in this dissertation. This includes new relationships between local and regional/ urban and rural producers, traders, service providers and consumers, as well as alternative production, supply, and consumption patterns. Some authors have reconstructed and unified urban-rural relationships in terms of a regionalized urban metabolism (Zasada, 2011; Torreggiani et al., 2012). Against this background, strengthening of the potential for integrating the system components in a regional setting due to the interaction between cities and their regional surroundings for mutual benefit is particularly important. Attractivity and market diffusion depend to a great extent on the performances of logistics services, particularly in food systems as it could be shown by included research of this dissertation. To create synergistic services as counterparts of the land management in the region and to generate new sustainable supply scenarios in a practical way, a spatial-conceptual expansion of the concept of SSCM is necessary.

Internet-based procurement of fresh and local/ regional food by use of flexible end devices offers interesting synergies, indicated by research included into this dissertation. Early effects of digitization on the food supply chain are obviously possible, such as time saving, output increases, cost reductions, and greater environmental protection. Also, for consumer needs, digital technologies can bring many benefits “from farm to fork”. Digitising regional food supply chains can help to make further assets of a sustainable supply system transparent, comprehensible, and manageable.

This above all applies to the “ecological value-added” (Kratena, 2004) in the area of water- and energy-sensitive systems under climate change. However, what is technologically feasible has not yet been backed up by business models and suitable regulatory framework conditions.

Even though technological development is fast, the lack of a multistakeholder-based holistic approach represents an obstacle for effective implementation and further iterative developments. A multistakeholder approach brings together policy-level and private sector players (such as producers, logistics, insurances, technology developers, and mobile network operators) with early innovators and civil groups. Thus, the core question that arises here, is how digital technologies will help to overcome societal challenges such as food security, functioning of markets, sustainable value creation, employment, and quality of life.

Thesis 4: *Addressing Consumer Behaviour and Lifestyles plays a fundamental role on the way to urban-industrial PSC Ecosystems.*

The conducted consumer surveys as well as the system maps of the selected research within this dissertation have shown that the impact of the delivery of services and goods related to sustainability performances continues to gain importance as a decision-making criterion for products and services demands by consumers and as a driving force for sustainability-related socioeconomic transformations.

Consumer pressure can make services within the upstream supply system become more transparent and sustainable and prevents non-sustainable business activities from occurring. Nevertheless, these sustainable options must be much easier to use and to be co-designed.

A strong focus for further improvements must be in the communication between companies and their customers, especially between supply chain service providers and private end customers. The research on which this is based has tested several communication scenarios as examples. It can be stated that communication channels that are particularly rich in interaction offer considerable design perspectives here. This can and should result in Open Communication and Innovation Ecosystems between producers, service providers and customers, which could build on the structures and concepts of the PSC Ecosystems presented in the context of the dissertation. In this way, living design and change forces could be meaningfully integrated into PSC Ecosystems.

Furthermore, social network structures for resource and product sharing, collaboration in consumption, and upcycling and reuse of specific products have high sustainability potential and can fertilize new service models to support and effectivise those collaborative forms of product service systems.

Thesis 5: *Understanding and actively designing Urban-Industrial Metabolisms is essential for a sustainability success. The expansion of economic system boundaries of the city to include regional organisational frameworks and international telecouplings into a multilevel functional hierarchy opens perspectives for new coherent transformation designs.*

It could be shown that the operationalization of extended urban and regional metabolic processes (e.g., in the area of food supply) can represent essential, still open capacities and levers for sustainable development. Regarding the sustainable management of telecouplings, however, new, scale-independent service models are required (see thesis 6), which could be developed within the scope of the dissertation, but not tested.

A key factor is ICT as an “integrator”, “enabler” and “visualizer” of the holistic transformation of material, data and energy flows of varying quality. The intended change is therefore a development that will not be feasible without the solutions from the engineering disciplines. Basically, the concept of an extended metabolism sharpens the possibilities of concrete cooperation with scientific expertise from the social, economic and Environmental Sciences, but also from Psychology, the Humanities and Cultural Sciences.

The role of Geography could be particularly central here, as a basic multiscale governance and implementation organization must be well understood and developed. The complementarity, synergy and interactivity between coherently structured levels of scale can refer to the “Geography of Sustainability Transitions”, which represents an essential innovative force within modern Geography in the concert of Sustainability Science. The multiscale context within sustainability-oriented innovation systems and spaces is a central research focus.

Thesis 6: ***Digitization can significantly favour the process of transformation from Logistics Service toward PSC Ecosystem Services as a “Lead Sustainability Service Provider” (6PL).***

It could be shown that for sustainability transformations, the supply chain and logistical point of view provide new key competencies for the solution. To do this, LSP and business innovators must continue to develop new self-concepts, acknowledge its role in a broader socioeconomic context, and expand action portfolios accordingly. Above all, potentials must be addressed that rethink business models, operationalize technology and services for the sustainable socioeconomic system, give essential data and information flows a “sustainable direction” within PSC Ecosystems and reposition infrastructure contexts in a targeted manner that is economically efficient and profitable, socially responsible, and within the system’s limited ecological capacities.

The “Lead Sustainability Service Provider” represents a new development as a consistent energy from the further development of logistical understandings and services. As a new business archetype, it offers the possibility of Kratena's (2004) ecological value-added to be operationally plannable, configurable, and controllable. The service model considers SSCM a responsible authority of the design, coordination, management, and control of sustainable operational networks. With the aim of resilience, the economic dimensions of a supply chain are integrated with environmental and social needs in a functional order of a nested organization principle.

Along the supply chain, parameters that have until now been external to an acting company – such as some legal, social, and ecological parameters – will be integrated into planning, management and controlling PSC Ecosystems. Thus, long-term cost traps and drivers of socioeconomic and ecological risks for single companies, customers, and the whole supply chain can be indicated and used in terms of supply chain governance and transparency.

Above the level of SSCM, the integration of externalities allows judgments on the planning and monitoring of economic value creation systems if a specific supply chain performance produces benefits or trade-offs for the entire system. The creation of such an integrative approach as the backbone of a sustainable economy would lead to an expansion of the current service models as Lead Sustainability Service Provider.

A major prerequisite is stronger recognition of the fusion of the digitization and sustainability agenda, since digitization per se is not automatism for better efficiency or a more sustainable business. Digital technologies have heralded many benefits across multiple sectors through establishing better links between machines and data, cloud infrastructures, and access to financial sources. Such benefits possibly include increased process/ operational efficiency, cost reduction, rapid development of innovative business models, and increased open collaboration and communication. Accordingly, digitisation can play a driving role by qualitatively changing individual stages of the value chain, as well as the interaction (and roles) between suppliers and customers at all levels of the supply chain.

A strategic focus and understanding of the desirable “system of sustainability” (portrayed within this dissertation) is still needed, including the threat of system rebounds when digitization is implemented without adequate consideration of the respective knowledge and strategies beforehand. A still growing number of scholars have deepened the scientific discourse on a more precise understanding of the possible interplay between means of digitization and the goal of sustainability, including the threat of rebounds (see Worthington, 2014; Galvin, 2015; Petschow, 2016; Walnum and Andrae, 2016).

5.2 Contribution to the Canon of Sustainability Science

5.2.1 General Remarks

The present work integrates an ecosystem approach (EA) as a strategic means to connect several previously separately processed domains of the socioeconomic system (production, supply, consumption) and its natural environment basis (natural capital), and respectively the related fields of research and of sustainability transformation toward a future sustainable economy. In terms of dynamic ecosystems and their structures and functions, these actual subsystems are interlinked to one another in multiple ways. An integrative management in the sense of a science-based innovation and with the research required, seems a logical and necessary consequence against the goal of sustainability.

By applying the EA, the work at hand provides an expanded interpretation of concepts and describes, codes and transfers the conceptual use of ecosystem understanding, structure and the emergent system functions (compare chapters 1.5.3 and 1.6.4) to the dynamic interdependencies between natural capital, production, supply and consumption as one systemic entity: the *Production Supply Consumption Ecosystem* (PSC Ecosystem). In terms of several qualitative features, this achievement differs from the previous transfer of ecosystem concepts to development areas in socioeconomic systems. On the one hand, the principle of a scientifically well-established concept (the EA) is transferred, and not a "common" understanding of ecosystems. On the other hand, the approach presented is devoted more comprehensively to the functional synergy of previously separately innovated areas of application. This can demonstrate fundamental strategic and operational alternatives for the restructuring of value creation in the sustainable economy. PSC Ecosystems furthermore represent a powerful conglomerate of the relationships between natural capital (e.g., in the understanding of ecosystem services), production (eco-industrial sources), supply chains (including innovative, reinterpreted logistics services) and conditional consumption structures and lifestyles and resulting behaviours. This connection is appropriate to carry out systemically understood transformation efforts based on a better scientific understanding and resulting framework. The resulting layouts serve as a "blueprint" for further possible research and innovation efforts.

In addition, the deeper understanding of the ecosystem and its applicability, in the sense of the EA, has been investigated for the first time outside of the classic areas of Applied Ecology (i.e.: natural resource systems, nature conservation, ecological planning of regions) in core areas of economic systems. By doing so, an alternative understanding, planning and management model is implanted in the agenda of the transformation of sustainable economic systems and their societal correspondence structures. In addition to the new application and the further development of the transfer, this offers new strategic opportunities in the sense of a new emphasis and reorientation of the sustainability transformation, for example on a more profound and system-oriented basis than "mainstream" orientations, such as triple bottom line (TBL) nourished approaches or orientation attempts from transformation to Sustainable Development Goals (SDGs).

5.2.2 Progress for a Transformative Methodology

Within the strategic and methodological framework of Sustainability Science the work at hand suggests the linking of different knowledge stocks and perspectives as vital for the systemic integration of natural capital dynamics and correspondingly in production, supply chains and consumption.

From the system-theoretical perspective, a system works successfully in the sense of "its" purpose if the interests and understandings of the stakeholders as "system agents" are not just interdependent (as they are) but synergistically represented in the research and further work process. Cross-connections must be recognized by those actors, organisations, or institutions “in the system” and processed jointly and benefits must be shared (Wiek et al., 2012). This applies also to transitions between different states of systems in the sense of “transformation management” (Loorbach, 2007).

An empirical approach in the context of system transformation, as in the context of the research presented, should therefore act in a stakeholder-integrative manner and work in concrete cases that are concise and understandable, highly relevant to sustainability and should contain transferability and scalability potentials.

Hence learning and capacity building play a vital role for system resilience, the co-production between academia, the public sector, business, and civic organizations is needed to successfully implement new sustainable development strategies. Beside the research of transformation processes, for academic stakeholders this bears a role-taking part as a promoter of sustainable development based on a suitable and specifically academic competence and through exploring new transdisciplinary methodological settings and experimental innovation designs (Wiek et al., 2012, Miller et al., 2014).

This should be taken as a strong motivation to further enhance the exchange between sustainability oriented academic disciplines together with stakeholders from business, policy and the civil society in appropriate work interfaces and platforms under a suggested stronger systems integration.

The research presented consistently includes this quality as a principle both in the empirical part and in the part of the transformation designs. Within the scope of the application spectrum of the PSC Ecosystem, or more centrally: Supply Chains, this is methodologically an innovation. In terms of the application of an Ecosystem Approach, the methods used represent a suitable enrichment and give the system approach a specifically suitable methodological component. Essential predispositions for this can be found in the EA, which in the sense of Kay et al. (1999) not only depicts system behaviour and system structures but includes systemic participation opportunities for different system agents as stakeholders in the transformation process and system governance. This participatory character is also inherent in Ostrom's SES (Ostrom, 2009) and accentuated in a very similar way. However, a shortcoming of the SES frameworks is an incomplete suitability for the nested multi-scale, particularly globalized impact hierarchies. The EA offers advanced options here in the application and further development as part of the dissertation. In addition, the introduction of the SETS (chapter 2.2) leads to a refined representation of reality compared to SES frameworks, especially in urban or – more specifically – urban-industrial contexts. Finally, it is needed to conceptually locate innovation options within the framework, as outlined in chapter 2.4 (see Figure 5.3 (Multi-Domain Framework of Sustainable Urban-Industrial Supply) in chapter 5.2.6.

The interplay between planning/ management on the one side and policy/ governance on the other is pointed out as vital for PSC Ecosystems and requires system-oriented methods. In principle, as shown in the chapters 3 and 4, it is a question of an adaptive mixed-method approach that is suitable in comprehensive research settings, enables participatory mapping of system states and research into future-oriented capabilities by using specific development scenarios (e.g. in our case, in terms of macroeconomic effects and resulting new business or cooperation models), or to enable core innovations based on stakeholder groups (e.g. in our case, between logistics service providers and consumers).

Apart from the different directions of development principally possible, the needed innovation for sustainability depends on the interplay dynamics of social agents within the PSC Ecosystem. The studies presented have applied the method of Participatory Systems Mapping (PSM) (Sedlacko et al., 2014) and refined it within the given research context. The application and implementation of PSM is based on initial experience in the EU project RESPONDER – Linking Sustainable Consumption and Production with Growth Debates –[33], to whose associated network of experts the author of this dissertation belonged. PSM took a strategically central position within the research, was used for the “hands on” stakeholder participation in the respective workshops. This was the first time PSM was used in the context of supply chain systems. The value of the method consists in the detection and visualization of actual system connections and emerging dynamics based on Causal Loop Diagrams (CLD), the enrichment of system and transformation knowledge of the stakeholders and researchers involved, the creation of the basis for further exploitation in the sense of system simulation (e.g., based on stock and flow) and forecasting and – not least – in the active integration of all stakeholders into the research and transformation process (see chapters 3.5. and 4.2.).

A special feature of the PSM applications presented here – in contrast to REPONDER – is the participation structure of the stakeholder groups: primarily “in-system” agents of the innovation system itself, regarding regional cases, but also specific innovators of system services from production (food), logistics service providers (LSP) and consumer organizations were invited

[33] https://www.scp-responder.eu/, funded within the 7th EU-Research Framework, 2011-2014

in the workflow, less an “international group of experts” of different interest groups as in RESPONDER approach.

This way, PSM was understood and used as an Open Innovation (OI) tool. Essential research results would not have been possible without this strategic implementation. This has many advantages compared to more established exploratory research methods: PSM can map multi-perspectives and make them representable in system dynamics. The method itself generates an active information flow between stakeholders and between academic disciplines and enables joint problem/ solutions awareness (chapter 3.5.).

The way to this realization and its operationalization in the sense of jointly supported solution strategies is not a simple “uniform” solution. All methods used in the underlying research, also in the context of the consumer surveys, acted against the background of a target group-specific approach and for target group-specific solution and communication formats. As the studies 3.4. and 3.5. show, neither “one size fits all” in terms of addressing nor “being all things to all people” in terms of the solutions, makes up practicable improvements for sustainability. Rather, differentiated portfolios are promising as a prerequisite for “matches” to produce synergies between the PSC Ecosystem parties.

5.2.3 Progress for Inter- and Transdisciplinary Theory Formation

With regard to chapter 2 (Theory Formation) the guiding research question was:

How must concepts of Sustainability Science be expanded and changed to present suitable theoretical building blocks for an Ecosystem Approach (EA) to rationalize Sustainable Urban-Industrial Supply Systems?

The work at hands introduces building blocks and conceptual connections of formerly disintegrated theories. In chapter 2.2. a conceptual merging of the meanings and interpretative potentials of sustainability on the one hand and system resilience on the other hand is fundamental. To this end, the dynaxity of the sustainability challenge is systematically highlighted. The general angle of observation is – and continuously within all contributions of the dissertation – systems thinking, especially with reference to the organizational principles of the nested systems hierarchy (Sterman, 2000; Meadows and Wright, 2008). Regarding the orientation value of resilience design for a deeper and better understanding of sustainable development, the role of social networks, organization and suitable (open) institutional settings is emphasized.

There are two conceptual improvements for PSC Ecosystems found in this respect:

1. The introduction of the urban-industrial connex represented in a metabolism model. Dynamics are mirrored in “functional domains”. The result represents categorical descriptions and system boundaries that can be used for PSC Ecosystems.
2. The development of suitable frameworks for the urban-industrial context from the Social-Ecological Systems (SES) to the Social-Ecological-Technological Systems (SETS). SETS can serve as a “texture” of the functional relationships in PSC Ecosystems.

As a future direction for elaborations the synthesis of the urban-industrial system with SETS as an advanced framework can formulate new impulses for transformation actions in the frame of sustainable development. Such frameworks can help:

- Understanding of sustainable/ unsustainable systems by providing a completer and more realistic picture on dynamics
- Guiding and structuring of planning and management for alternative systems or system alternatives
- Making urban-industrial systems, their governance structures, and their transition pathways comparable
- Determining future needs for research.

The work expands conventional categories of system properties for resilience design from *three* to *four* categories: *resources, structures, capabilities,* and *dynamics*. Dynamics are defined as a separate impact category for resilience design. Building on this, SETS are presented in a functional context of a platform and as a function of the four properties. For that the “Diamond Model” by Hahn et al. (2008) has been expanded.

In 2.3. the conceptual integration of supply chain systems into theory formation of sustainable systems concepts connects previously largely separate research communities. Supply chain systems form a structural and operational basis of urban-industrial systems. The expansion of the theoretical foundations of Sustainable Supply Chain Management (SSCM) is therefore essential. At this point, the research attempts to approximate the SSCM literature dominated by Economics/ Management Science with the knowledge pools of modern Sustainability Science, particularly rooted in Ecological Economics and “strong sustainability”. With Sustainable Supply Systems a proposal for a *theory of strong sustainability supply chains* is submitted. The presented model of the Sustainable (urban-industrial) Supply Systems (SuSy) allows the circular sustainable economy to be mapped on several functional levels, including the local scale and qualitative features of the urban sink, but connects to upscale structures and strategic interventions, that could in the context of the dissertation be identified and characterized, but need further research how they could be implemented. A justification for the superiority of strong sustainability models is demonstrated mathematically. Based on the metabolism model of urban-industrial systems, the supply chain context is integrated and thus set into relation to Ecological Economics for the first time. The result is an expanded definition of the SSCM as a theoretical baseline for further developments.

The connected understanding as the “urban-industrial” is particularly worked out in 2.4. As shown, urban sustainability concepts in in literature remain mostly “city-centred”, which appears misleading with respect to the global and multiscale nested complexity of urban-industrial systems. The present work finds an anchor in the economically oriented redefinition of the “urban” by Amin and Thrift (2002) with regard to the stronger emphasis on economic global networks for the development of urban systems. As part of a theoretical derivation, a multi-domain framework for Sustainable Urban-Industrial Supply is designed, which combines “strategic tasks” for sustainability transformations with “action domains” on six levels.

The results of the theory formation, also in combination with the empirical findings (chapter 3) and the predisposition of transformative solutions (chapter 4), can be stated to be of importance for both practices as conceptual backgrounds. Apparently, through the metabolism models some similarities to works in Industrial Ecology exist. Like in Industrial Ecology, the integration follows natural system prototypes and displays results as metabolisms, in more differentiated causal loop diagrams and system simulations. Unlike Industrial Ecology, the advances in theorizing are not limited to a local or regional scale at which closed or open loops can be implemented, but rather they can be taken as fundamental understandings and functional as well as structural couplings that are represented at multiple scale levels.

While Industrial Ecology tends to concentrate stronger at production as a strategic starting point, the elaboration of the EA shown here provides a considerable integration of “downstream” system levels and actual subsystems. Based on the metabolistic view, the downstream functions can predominantly be characterized as for “urban sinks” within the urban-industrial connex. That allows a more profound concentration to the demands of a consuming urban system, triggered by complex interplays of different factors, with regard to the empirical findings: particularly within the “last mile”, within new service segments of local food home-delivery, or service-customer logistics innovations and fitting communication scenarios. These urban sinks are vital anchor points for alternative intervention strategies to tackle the mentioned interplay between demand and supply, respectively consumption/ lifestyle habits and supply chain services. The presented publications do concentrate here functionally on the urban core areas within regional contexts, predominantly shaped by various forms how consumption, retailing and settlement structures can be shaped by regional PSC Ecosystems and how e.g., a last mile can be organized to fulfil sustainability purposes.

In contrast to the until previously overwhelming majority of the interpretation of consumption as an essential control element of sustainability transformations in the economy, the examined understanding of the ecosystem places the emphasis differently: in the actual dynamic reinforcing interplay between lifestyles and corresponding supply chain services that facilitate collectively dynamics of unsustainable consumption. Without those services and respective infrastructures specific forms of consumption (today particularly under influence of e-commerce drivers) could not exist.

5.2.4 Supply and Welfare Functions and PSC Ecosystem Properties

Regarding chapter 3 (Empirical Analysis) the guiding research question is:

How can the interactive parts of a PSC Ecosystem change individually and in relation to each other, to facilitate ambitious sustainable solutions, particularly with respect to demand-supply dynamics?

With respect to Transformation Designs (chapter 4) the guiding research question is:

Which system-inherent transformative levers can be identified to enable and to strengthen system changes toward sustainable PSC Ecosystems?

The research was able to show that Sustainable Supply Chain Management is suitable, under the conceptual extensions described earlier, to guide the necessary strategic and operational integration in PSC Ecosystems (specifically chapter 3.3). As part of the system dynamics modelling of essential parts of the PSC Ecosystems, the flow and the resulting dynamics between the subsystems were exemplified for in particular food supply systems (chapters 3.2., 3.3). Using PSM and other further scientific elaborations, CLDs represent the dynamics and show relevant interdependencies, control loops and intervention options for the EA requirement. The key issue is the interplay between supply chain system services/ logistics and consumer behaviour, embedded in more comprehensive underlying lifestyle considerations (chapters 3.2, 3.3, 3.4).

With a view to the research results, in particular the operationalization of PSC Ecosystems, we can highlight and contextualize several results, as shown in the following:

5.2.4.1 PSC Ecosystem Coordination

Above the representation and operationalization of the PSC Ecosystem system the question of the actual sustainability impact is key. The central point is to what extent, in the context of the presented research by using the example of specific local/ regional food systems in the city-hinterland context[34], benchmarks of the performance of concurrent conventional systems for the "supply and welfare function" can be achieved. Since re-localized and regionalized supply systems have a high sustainability potential, it was demonstrated on what the increase in economic as well as overarching sustainable potential depends. At this point, the research highlights the conditional function of Supply Chain Coordination (SCC) with respect to integrating logistics, ICT designs, financial capabilities and coordinative skills and an investment in infrastructure and distributive subsystems (chapters 3.3. and 4.2.). Decentralization of supply (beside networks of multiple locations also on multiscale levels) creates a significantly higher need for consolidation and coordination in the supply chain as a key for alternative supply strategies to be met. We can deduce, SCC is not only relevant for the operationalization of PSC Ecosystems in "general", but also to run concrete (new) businesses within, to fulfil consumer needs and to achieve concrete sustainability gains.

5.2.4.2 PSC Ecosystem Scalability

All investigated cases integrate largely urbanized patterns of mostly medium sized cities and their peri-urban/ rural hinterlands and contextualize the supply chain as a mediator between the consumptive urban patterns and its markets/ retailing system and the productive surrounding region. Apart from the earlier mentioned unsolved problem of distant global teleconnections (chapter 1), we could give evidence to re-localization and regional concentration strategies of resources and product-service structures. Theoretically, as Taylor (2012) indicates on the example of economic localism of cities, sustainably innovated structures of the urban-regional production, supply and consumption systems are principally ingrained in the pioneering work of Jane Jacob's "Economy of the City" in which the set of scales of local and non-local production is fundamentally important (Jacobs, 1969, 1984). Jacob's "import replacement argument" (Jacobs, 1984) can be used to show principal compatibility between the needed economic change and sustainability.

Particularly the researched food sector, can have positive effects on sustainable development, correlated with increased regional supply independence, resource efficiency and resilience (Kneafsey, 2010; Collits and Rowe, 2015). The studies presented in the context of this research show above all principally which network and service organization of the

[34] Linz in Austria as well as Freiburg in Germany

socioeconomic infrastructure within such a regional/ urban setting can have advantages for higher shares of sustainable supply solutions in the market and how upscaling effects can in principle be achieved (chapters 3.2. and 3.3.).

However, we cannot formulate a scientifically satisfactory answer to the question of how much these regionalisation strategies of production and supply patterns as a “general downscaling and diversification” of supply patterns could contribute to the fulfilment of normative sustainability goals, such as in terms of “carbon neutrality”.

5.2.4.3 PSC Ecosystem Communications

In addition to setting up the services in a business or infrastructure context, communication between producers and suppliers is particularly important in the direction of specifically significant consumer groups and their attributes. Both communication scenarios and various supply chain innovations were tested (3.4.). Basically, the results of the surveys show that consumers (status quo) are already willing to add a sense of meaning, but primarily without major restrictions in turn. For the interpretation of this, it is important to take values, points of views, habits, and stories into account for further communication.

The decisive factor is to what extent and in what way attitudes of specific groups can be "attracted” to a transformation process. There are some enabling factors, that could be shown. Based on the results, these initially consist of a higher level of awareness about the presence and impact of logistical or supply chain services (called: “logistics awareness”). We could therefore say that end users were not sufficiently aware of the relevance of system-defining services and their core connections, just as of the unsustainable impacts of these activities. Alternative options have not only to be simply understandable, reachable, and usable but must also appear attractive to consumers. One component here is the actual integration of innovations into social contexts, attributes and chosen or desired lifestyles. In the system sense, use must also consider recognition and feedback factors in the direct and wider social system. In terms of open innovation, communication about innovations in the PSC Ecosystem should not be developed *to*, but *with* consumers. This requires a PSC Ecosystem “community” and more continuous cooperation and more flexible communication in all directions and under common and commonly chosen “rules”.

The studies also showed that retailers as well as service providers misjudged demands with a distinct sustainability impact. Particularly remarkable in this context is the significantly higher delivery time tolerance of consumers (which is diametrically opposed to the current trends in e-commerce) if (!) positive and negative sustainability effects are transparent as conditioning factors. With respect to the corporate development of the service providers and retailers as well as their cooperative grounds, this can be interpreted as connected to concepts of supply chain transparency and supply chain integrity. This again opens unused opportunities to decelerate supply, which can achieve sustainability gains in the sense of better system consolidation and capacity utilization as well as more sustainable, slower transport means (e.g., with respect to carbon footprints).

5.2.4.4 PSC Ecosystem Capabilities

System changes – initial as well as in the context of continuous processes – are determined in their quality and effectiveness by dynamic capabilities (DCs) of the system agents. Based on the research results on the relevance of the SCC, the theory of the DCs (Helfat and Peteraf, 2009; Barreto, 2010) and by using PSM, further results regarding important knowledge and learning skills for "supply chain facilitation" in the sustainability transformation process could be highlighted with the underlying research of this dissertation (chapter 4.2).

Theoretical frameworks proposed by Hassini et al. (2012), Beske (2012) and Beske et al. (2014) served to identify and structure DCs toward a stronger sustainability of PSC Ecosystems. For that, the "system service" perspective of logistics service providers (LSP) was of specific interest (chapters 4.2, 4.3, 4.4). A basic prerequisite is a supply chain transparency to everyone involved based on a "stakeholder-primacy governance" and a constructive, more active, responsible role for consumers. System service providers primarily need collaborative management skills and targeted ICT implementations as process enabling technologies. For the PSC Ecosystem community, a mode of "shared responsibility" as well as of shared risks (operational, financial) is a key to sustainable system performance. The shared responsibility corresponds to the models of "strong sustainable supply systems" in connection with the new formation of theories (chapters 2.3, 2.4). Within the PSC Ecosystem community, there should be manageable knowledge about sustainability-relevant co-flows of the supply goods (in the investigated case of food, e.g., water or energy, GHG emissions) and about performance-determining interfaces between the different PSC Ecosystem compartments. Relevant to companies, their corporate strategies and knowledge/ innovation management seems above all the internalization of external knowledge, e.g., from government and non-governmental organizations, the management of highly decentralized capacities and the willingness for a stronger co-evolution between consumers, producers, suppliers, and retailers.

5.2.4.5 PSC Ecosystem Adaptability

The research activities presented address to transformative and adaptive forces for future changes of the socioeconomic system. The ‘sustainable governance’ scenario (chapter 4.4.) represents a combination of several potential changes and is evaluated to be a desired future for sustainable socioeconomic systems, particularly at macro-scale perspectives. The adaptability of the PSC ecosystems, i.e., the ability to adapt to changing conditions, is not only generated by those dynamic capabilities of service providers or customers with respect to knowledge building/ learning ability or shared responsibility. It is also strengthened by organizational dispositions of the service providers, linked to such organizational predispositions in the further stakeholder-value context that promotes adaptability in the ecosystem.

Results of the included research show that the supply chain service/ logistics sector, then on the micro-level, can help reverse unsustainability trends if they understand their vital performances as a “system service” of newly accentuated and restructured value-added in a sustainable socioeconomic system (chapter 4.3.). This approach builds on earlier concepts such as sustainable products and services (Maxwell and Van der Vorst, 2003) or transformative product-services Systems (Liedtke et al., 2013), but is extending strategies toward the broader impact of the entire supply chain and against the more comprehensive frame of PSC Ecosystems.

For managing the transformative supply chain, this means above all a required progress in the sustainability assessments, particularly with respect to the high complexity of supply chain systems and their exchange with the ecological and social environments. Thus, co-flows (water, energy, carbon, etc., theoretically the full range of impacted ecosystem services) and their data flows alongside the actual goods flow and its services, must be internalized into supply chain cost structures, planning and decision making.

The PSC Ecosystem properties and action fields result in a strategic connection to the intended “Sustainable Supply and Welfare Function” as the goal of a transformation. The presented aspects of properties in the PSC ecosystem are centrally aligned to the fulfilment of this goal. Figure 5.1 shows an overview.

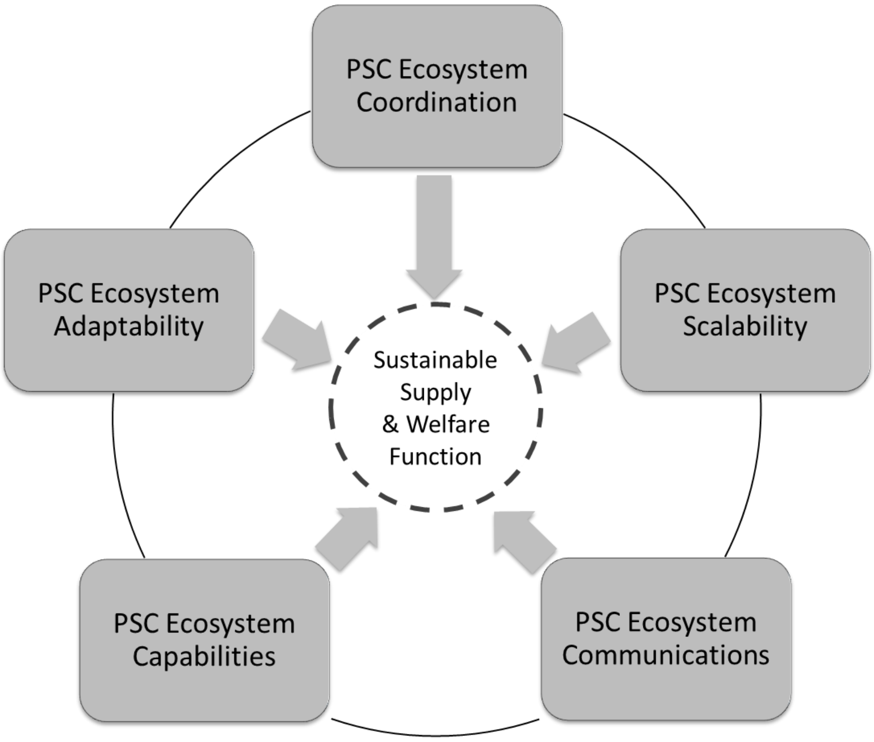


Figure 5.1 PSC Ecosystem Properties and Sustainable Supply and Welfare Function

5.2.5 PSC Ecosystems and the Systems Service Concept

Based on the research results (from 2.3, 4.3 and 4.4), the presented connection between different action domains and properties of PSC Ecosystems can present a first outline for conditions and portfolios of a sustainable system service. Positive effects of SSCM practices could already been empirically proven (Zailani et al., 2012; Ahi and Searcy, 2013; Kashmanian, 2015). The development of sustainable added-value services by LSP corresponds to the Lead Sustainability Service Provider (6PL) (chapter 4.3, 4.4).

Based on the findings in theory formation (Chapter 2.3), we can argue that 6PL should be operationalized in the sense of Ecological Economics with respect to key principles of a strong supply chain sustainability:

- Stewardship of critical capitals (CC): particularly with respect to natural capital stocks and flows, CC may not fall below certain values of qualities/ quantities.
- Supply Chain Responsibility (SCR) is a shared task and should be measurable, transparent, and understandable within value creating supply chain networks for all stakeholders.
- Equity of (critical) capitals must be well distributed among producers, traders, service providers and consumers.

The research contains as well future macroeconomic scenarios influencing supply chains and logistics service providers, as well as – the other way around – considers supply chains and their services as an essential driver of change of the economic system regarding the value-added connections between production, supply, and consumption (4.4.).

One central research finding demonstrates that only those companies, which are proactively driving the transformation of the macroeconomic systems, will be economically successful in the long run (4.4). Transformation toward sustainable socioeconomic concepts, which consider dematerialization, system servicing and investments into natural capital and ecosystem services in the meaning of the holistic supply and welfare function are complex and is requiring systemic changes, strongly supported, and incentivized by suitable governance structures and frameworks. Governments play a crucial role in guiding investments as well as alternative business practices and consumption behaviour. Regulatory frameworks, incentives, and reward systems in the interest of society can strongly promote necessary innovations while stopping opposing dynamics.

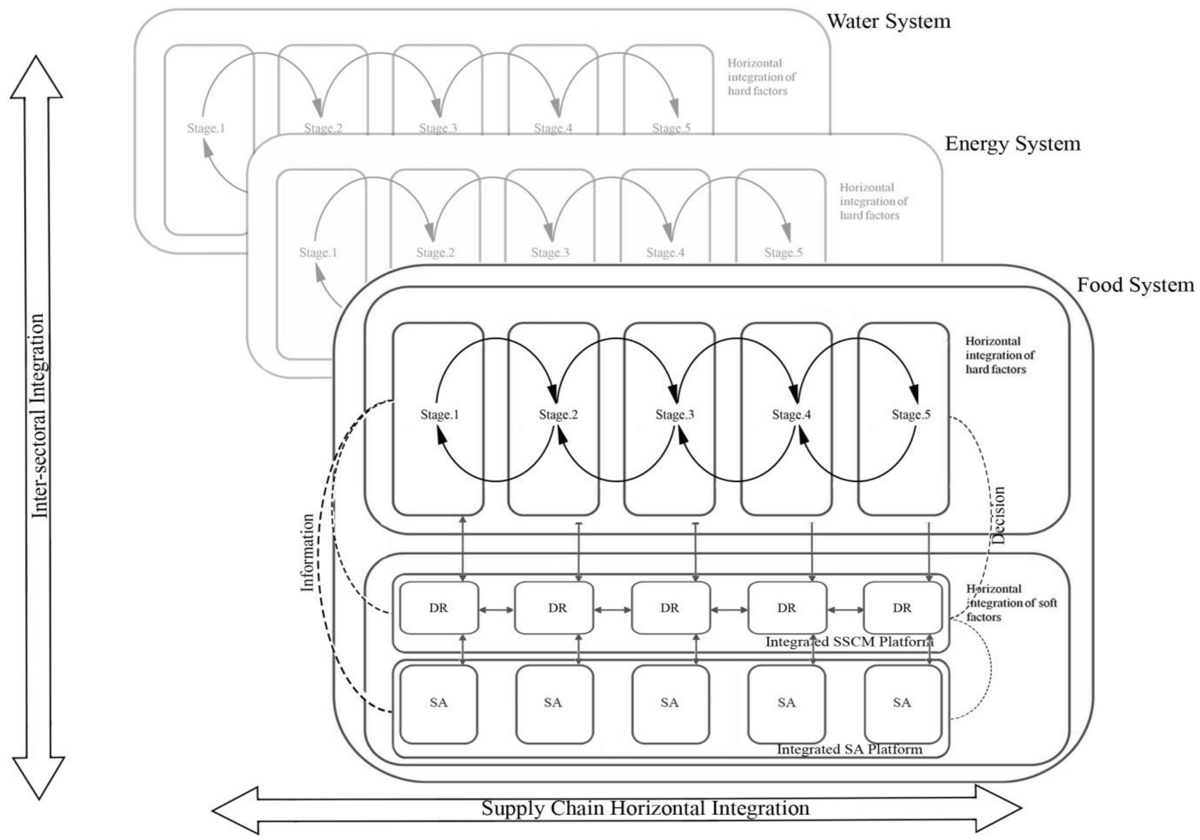


Figure 5.2 First Conceptual Model of the Lead Sustainability Service Provider's Portfolio in the Transformative Supply Chain

If the framework conditions examined are met and the target parameters in the planning, management and controlling of supply and value chains change fundamentally, the idea of the lead sustainability service provider would receive impetus. This horizon of expectation of structural features in the supply chain and their assessment leads to a first conceptual model in the management of the transformative supply chain through the connection between the research results from 2.3, 4.3 and 4.4. This is laid out in Figure 5.2.

The model outlined above is based on a food supply chain as an example and, in addition to other co-flows' footprints, integrates above all unsustainable energy inputs and water consumption in the supply chain, thus incorporating the WEF Nexus into the considerations of the research presented here. Structural features are (a) the intersectoral integration of several ecological assets (in the vertical), in addition to horizontal cooperative features "along" the stages of the supply chain (b). Both result in information flows for the sustainability assessment (SA) for SSCM based on new decision rules (DR).

5.2.6 Utilization of the Research for Geography in Sustainability Science Contexts

5.2.6.1 General Remarks

It is an intention that the present work provides impulses for future-oriented, spatial-systemic research perspectives in Geography and offers points of condensation with neighbouring disciplines in the discourse of Sustainability Science. The corresponding discussion, i.e., regarding the profiling of Geography, about a canon of topics and tasks of sustainability as well as the role of Geography in the Sustainability Science, is not new, but is currently flaring up again in view of the societal challenges and scientific positioning needs (Fastenrath and Braun, 2018; Fu, 2020). Most recently, 2020, a new Elsevier Journal "Geography and Sustainability" was founded. Its editorial board includes not only well-known geographers, but also significant figures in Sustainability Science, such as the "father" of Ecological Economics Robert Costanza.

From the findings presented so far, which are rooted in current research contexts of a transdisciplinary Sustainability Science, perspectives for a sustainability-oriented Geography can be derived. The presented research combines interesting research approaches and perspectives of inter- and transdisciplinary scientific progress with impulses for Geography. From the point of view of Geography (see chapters 1.3.2 and 1.3.3) this is not necessarily about the further development of a disciplinary core, but above all about the ability to work at the interfaces with neighbouring disciplines and to create the basis of a common understanding.

5.2.6.2 SETS and the Multi-Domain Framework for Sustainable Urban-Industrial Supply

Building on the central "DNA" of Geography with the human-environment interactions, the formation of the Social-Ecological-Technological Systems (SETS), as a centrally proposed framework, which started a rapid career in literature since 2016, offers a representation and combination of system components and system dimensions related to Geography. Many geographers have taken up and further developed the SETS conceptually, mainly up to now in the fields of Urban Geography and Urban Ecology (McPhearson et al., 2016; Markolf et al., 2018; Egerer et al., 2021). Local and regional studies are addressed here. Multiscale considerations are missing so far.

There are different scales and consequently operations levels in spatial-functional orders considered in the presented research, according to the models of the nested hierarchy in the multiscale ecosystem organization. As stated by Truffer (2016), it is particularly the effect of global networks and their sustainable transformation on the necessary multiscale levels that is still underrepresented in the discourse of sustainability related research, in and out of Geography. Since findings about scale interdependencies, such as by Truffer (2016), are particularly relevant sustainability-oriented transformation designs, the results could be contextualized to the Geography of Sustainability Transitions. SETS and their integration into the wider Multi-Domain Framework could offer valuable levels of concretion and serve as a strategic sub-concept to the Geography of Sustainability Transitions (Truffer et al., 2015). SETS can be considered a meaningful structuring framework of sustainability-oriented social-ecological-technological innovation. The corresponding five multi-domain levels of the framework visualize a multi-level example related to concepts of the Geography of Sustainability Transitions, but also (more importantly) could sharpen an interesting strategic case by the researched innovations of the specific context of Sustainable Urban-Industrial Supply Systems.

5.2.6.3 Regional Sustainable Development (RSD)

Coenen et al. (2012) and Truffer et al. (2015) emphasize the importance of the institutional role of regions for multiscale innovation and transformation as addressed by the Geography of Sustainability Transitions. With respect to RSD impulses and concepts have been circulated in Geography for longer time periods (Nijkamp et al., 1990; Roberts, 1994; Brunckhorst and Reeve, 2006; Haughton and Counsell, 2004; Counsell and Haughton, 2006; Innes and Rongerude, 2013). At the same time, the underrepresentation of regional contexts in the sense of regionality as "mid-scale" and for regional development and planning was repeatedly criticized (Pike, 2007; Haughton and Morgan, 2008; Paasi and Metzger, 2017; Harrison et al., 2021).

Transformation options in the institutional context of the regions are specifically examined regarding the upgrading of regional capacities for overall sustainable development. Regional network consolidation and management, transformation alliances and stakeholder interests have been perpetuated by the presented research. The results correspond to the basic lines of an EEG drawn by Hayter (2008): Institutional frames (also with regard to structural capacities of regions, which Hayter did not name), resource and land use pattern (with regard to decentralized, cooperatively set up production networks in “Local Food Cooperatives”), alternative value chains (especially under the aspect of “enabling logistics services” for further value-added partners).

5.2.6.4 PSC Ecosystem Transformation and Global Economic Networks

The theoretical part of the present work considered spatial-functional patterns in the sense of a globalized urban-industrial system. However, the empirical cases initially show regionally and locally limited transformation options for sustainable urban-industrial supply. These do not invalidate the teleconnectivity of globally active logistics companies in “their” supply chains and value-added contexts between global urban production and trade centres and their ecological impacts (Seto et al., 2012).

At this point, the work highlights a relevant peculiarity that can be of fundamental importance in addition to local implementation strategies: The new approach rather includes upscales to innovation levels of services in businesses in terms of overall characteristics as transformative research. The findings shown here have outlined options for the transformation of the businesses: As a Lead Sustainability Service Provider and against the understanding of supportive framework conditions for a sustainable economy, particularly “transformative supply chains”. The approach primarily operates independent from scale dimensions but can nevertheless create scale distinct solutions or combine solutions in multiscale strategies.

From a geographic perspective, particularly that of Environmental Economic Geography (Braun et al., 2003; Bridge, 2008; Hayter, 2008; Braun et al., 2018), the potential impact on space, scalability and restructuring of patterns as a step towards sustainability could be interesting. In addition, an attractive interface to sustainability-oriented Economics/ Management Science would be made. It would also be noteworthy to map (quantitative) transformation scenarios in new GPN and to integrate essential competences of Economic Geography into the questions via possible macroeconomic modelling.

It is also true: the global perspective has so far been lacking about the transformation potential of new services and transformative structural conditions, especially in the research for sustainable global telecouplings (Seto et al., 2012; Liu et al., 2013; Friis et al., 2016). The concept of global telecoupling for sustainability was until now just poorly underfitted with concrete options for operationalization.

Figure 5.3 below shows the multi-domain framework and the strategic classification into the levels and action domains against the background of the defined strategic tasks from the cumulative part (2.4), Krumme (2020).

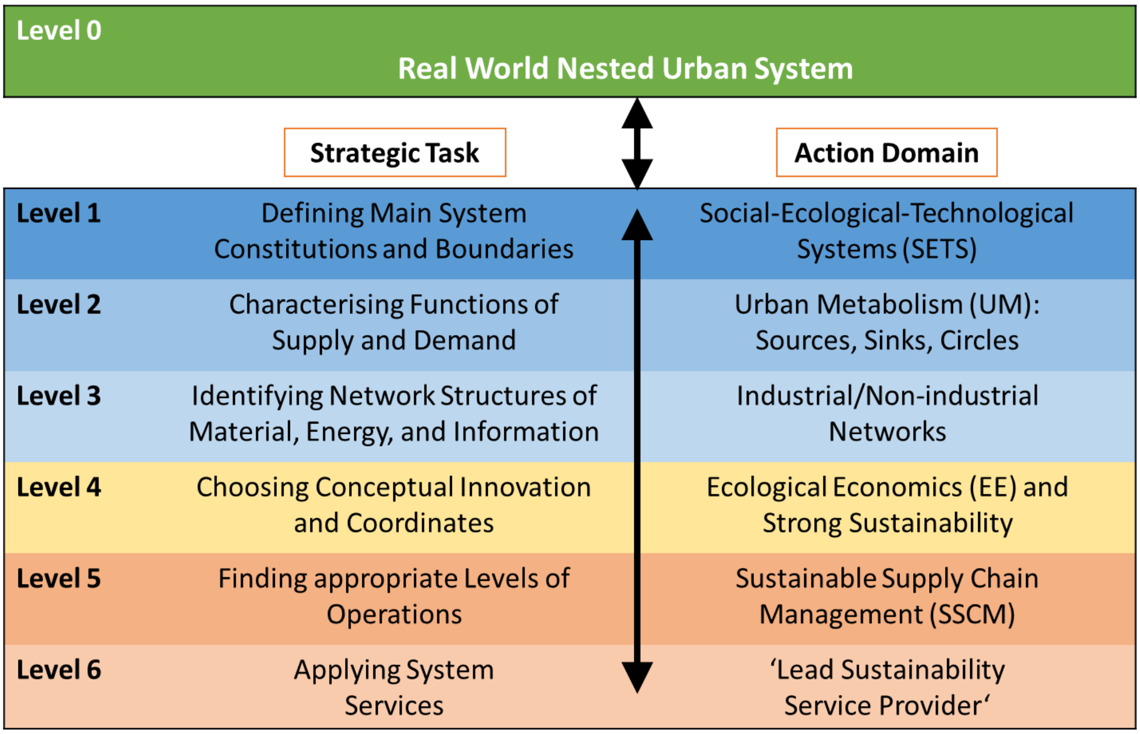


Figure 5.3: Multi-Domain Framework of Sustainable Urban-Industrial Supply Systems

5.2.7 Strategic Predisposition of Geography for Sustainability Transformations

In the dissertation's context and understanding, research is also defined in its transformative context (see chapter 1). This fundamental orientation stands out from the previous spectrum of Geography, which predominantly set accents almost exclusively in the analytical-descriptive, which has been criticized for some time (compare Haas and Neumair, 2015). This inevitably means that more concrete planning and management-oriented research must move into the centre of Geography (Fu, 2020). Another important aspect besides the transformative orientation seems to be the disposition of Geography as a "Systems Science" (Haigh, 1985; Goudie, 2017; Fu, 2020). Both interdependent characteristics are represented in the discourses of Geography, which will be discussed subsequently.

Fundamental ecological questions already played a socially and scientifically important role in the 1970s, decades ago when Porter’s recommendation for the profiling of Geography was published (Porter, 1978), and ecological problems have also been reflected in the geographic discourse as taken up by Davies (1974), Emery et al. (1974) and particularly Chapman (1977) among others.

G.P. Chapman's comprehensive book “Human and Environmental Systems – A Geographer's Appraisal” (Chapman, 1977) provided fundamental and equally in-depth considerations of integrated systems often in the sense of today's sustainability system understanding. The diverse fields of work there resemble in many respects the discipline claim formulated by Porter and, in terms of system theory. Chapman, however, remains on an above all complex to abstract level of necessary descriptions and the analysis. The similarities end where research becomes transformative, where business contexts become more of a subject of consideration, and where methodology is more participatory today.

Yet, today the problems of sustainability-relevant interactions and interdependencies at the human-environment interface are more urgent than ever and the importance of Sustainability Science has increased significantly, to which Geography can make essential contributions. It is precisely this development perspective of Geography that has been prominently emphasized in the American Association of Geographers (AAG) by its president Thomas J. Baerwald (2010).

Today’s geographical work in the fields connected to sustainability is often interdisciplinary, but above all in the implementation of a research strategy it is predominantly occurring in space- and case-specific settings (e.g., with respect to subjects such as foodsheds, ecotourism, urban transformation, etc., in). This seemingly contradicts to Fu (2020), who criticized the too abstract policy focus, but in fact only demonstrates a contrastive picture: on the one hand detailed space-specific cases are analysed, but with missing links to the upcycle in terms of system transformations for sustainability. On the other hand, resulting policy recommendations, also based on specific cases and an empirical value of the research, are less related to alternative operationalizations in the direct social or economic stakeholder context. One could, however, still agree to Hobson (2003) and Fu (2020) that this agenda is fundamentally scarcely equipped and described.

With respect to Fu’s “policy vs. transformation” argument (Fu, 2020) one would argue differently: Policy recommendations should be included but contextualized differently. The interplay between changing framework conditions is to be concretized, as well as the social organization matters via politics, but also the dimensions at the management and planning level of the PSC Ecosystems, to design transformations and to map research bases in an application-safe manner. So, it is not about proportional shifts in the orientation of geographical research, but about the linkage on the level of the interaction between planning/ management – policy/ governance, which could also be shown by this dissertation.

In this respect another – more strategical and value-oriented issue – is maybe more significant: It is noticeable that the conceptual innovation efforts within Geography, in particular within Economic Geography (compare Hayter, 2008), remain strongly within the boundaries of the neo-classical reference, or do not interpret the change in the frame of the determining sustainability models "far enough". This at least contradicts with essential works in Sustainability Science. Sustainability effects in the sense of a transformation of the subsystems are there based on the frameworks of strong sustainability, whose main academic representatives, such as Eric Neumayer from the London School of Economics (LSE), understand Geography with Political Sciences and Economic Science in the sense of a Sustainability Science (Neumayer, 2001, 2003; Dietz and Neumayer, 2007). Those conceptual fundamentals display more systemic critique with respect to the dependencies between natural capital and socioeconomic subsystems and have created (as explained in chapter 1) a scientific basis for stronger system alternatives with Ecological Economics (Costanza et al., 1992). This is not important only with respect to transformative research but also for the analytical-descriptive set-ups in (Economic) Geography.

In this line, geographical aspects of the presented work open a further interdisciplinary context of modern sustainability research. This applies particularly to urban-industrial issues and relates to domains of analysis as a classic strength of Geography as well as aspects of development and transformative research. Contributions of the chapters 3 (Empirical Research) and 4 (Transformation Designs) show expanded possibilities here and present Sustainable Urban-Industrial Supply Systems as the overarching research subject.

5.3 Overarching Limitations and Future Research Directions

To conclude, it must be stated that the presented work, in its broad overall context and through the cumulative contributions, has examined and assessed a wide variety of aspects that follow the idea of establishing the Ecosystem Approach. However, there are still gaps or incomplete processing of research or methodological contexts. The following section summarizes the main aspects to be mentioned and priorities for the future research are pointed out.

5.3.1 Theory Formation and further Conceptual Innovations

The presented conceptual theory building represents a rather classic theoretical approach in a conventional academic research setting. Here too, like in other parts of the cumulative dissertation, ***methods of knowledge co-creation*** could initiate interesting new conceptual developments and enrich theory through participatory processes (Edelenbos et al., 2011; Hegger et al., 2012; Hegger and Dieperink, 2015). In the recent past, studies have emerged that examine fundamental transformational concepts of sustainability with methods of collaborative knowledge management, especially considering the approach of “boundary work” for sustainability transformations (Benn et al., 2013; Pan Fagerlin et al., 2019; Franco-Torres et al., 2020). Collaborative knowledge formats establish new strategies of knowledge based sustainable development (KbSD) (Yigitcanlar, 2009; Carrillo et al., 2014). These development directions explicitly and implicitly refer to the “knowledge economy” related frameworks of the quadruple helix (Carayannis and Campbell, 2009). The approaches are often meaningfully of a specific, local nature and relate to specific entities (companies, cities, or districts). Kumar et al. (2021) just recently underlined the meaning of a collaborative culture for joint knowledge building for supply chain systems and for establishing a “joint responsibility ecosystem of firms”, which is close to the here chosen research subject.

The presented theoretical considerations, conceptual extensions, models, and their derivations are elaborated on the level of ***conceptual illustrated models***, rarely include mathematical derivations or justifications as in the case of Sustainable Supply Systems (SUSY). They require further validation, refinement, quantification on a case-by-case basis and, above all: discourse. Taking them as a basis for exploratory transformative research projects is appealing. Empirically proven conclusions about their content would be desirable and necessary.

Nothing speaks against applying these strategies at higher aggregation levels of planning and policy, regarding global sustainability strategies, e.g., in global panel organizations of different stakeholder groups. The conceptual developments presented here offer starting points that can be considered in transdisciplinary initiatives and agenda-processes and thus can also influence decision-making processes at multiple policy levels.

In general, the ***scope of the theory*** formation is broader and more comprehensive than the empirical research and transformative derivations can be. A selection and an initial prioritization were necessary. Using the example of the international literature about the SETS published since 2016, shows impressively the variety of research contexts that can (and must) follow. Since this example also makes clear that the research is predominantly locally and regionally oriented, greater value should be attached to large-scale research projects and the multi-scale organization of problems and solutions, as it was already stated in the discussion of the findings earlier, especially for Geography (5.2.6, 5.2.7). Environmental Economic Geography and the Geography of "Sustainability" Transitions have great potential that has not yet been sufficiently implemented.

The claim of the ***Ecosystem Approach*** to higher validity in the concepts of sustainable development should be supported after it could be shown which transfer contexts and design prospects are offered by its application. The scientific activity around the EA, which was initially halted in the decade before, should certainly be intensified and new application contexts, especially in the social and economic area, offer valuable orientation for the sustainability transformation.

In the context of the ecosystemic consideration of the functional entity of natural capital base, production, supply, and consumption initiated here, there is only a beginning. Within this ecosystem alone there are many blurry areas that were not or only little considered in the research: The focus (arguably) was placed on "supply functions", but specific research contexts arise, e.g., at the terminal ends of the eco-industrial source and the urban sink, as well as – not surprising – in the combination of the two. An important question lies in the loop between the sink and the source. Within the spheres of natural capital and production, new questions of an Industrial Ecology are moving, in the urban sink even before the circular economy above all issues of the sharing economy. Both could only be taken up on the fringes of the research.

A grand research vision could be the case-based "system dynamics exploration" of the entire ***PSC Ecosystem***. There would be options for complex modelling of all spheres and dimensions, which could be qualitatively modelled in system dynamics via causal loop diagrams individually on different scales and transferred into quantifiable simulations via stock and flow diagrams. Information and communication technologies and software, such as internet of things (IoT), internet of services (IoS) architectures and in particular artificial intelligence (AI), could play an important role not only in the analysis, but above all in the sustainable transformation and management of such relationships.

5.3.2 Empirical Research and Transformation Designs

Generally, regarding the ***methodological dimension*** of the presented empirical research we must explain that data samples in the researched areas are not or hardly representative (also not unreservedly for 3.3). Small samples, e.g., in expert interviews or group workshops, enable in-depth research findings within the research context, but there are narrow limits to scalability. Although these limitations are not uncommon for qualitative research, interesting perspectives would also result here, for example through comparative samples from a critical number of regions, similar in their features, and higher numbers of respondents from the stakeholder groups involved. The effort would be balanced by a benefit in favour of the transformation agendas to be developed from such studies.

One focus of the research undertaken on PSC Ecosystems was in ***local food systems***. The clothing industry is included in one case (service provider-consumer communication scenarios, 3.3). Although the food sector has a special societal position in terms of services of common interest, this also applies to other economic sectors. Transfers to other sectors, which are as significant as the food industry, such as energy supply, construction, electronics, are hardly possible. Although the focus on system services has “advantages” and certain transferability in terms of initiating exploratory studies in other sectors, there are fundamentally further research opportunities here to form and re-contextualize PSC Ecosystems in other sectors.

In connection with the regionalized research contexts, the knowledge gained about the ***urban last mile*** can be rated positively. However, this focus, no matter how justified it was regarding the research design, is a strong reduction of the system-dynamic reality. The dynamic impact of downstream interventions in supply chain management on upstream structures (in production or other value-added services) has in principle been proven (e.g., via phenomena such as the bullwhip effect, Lee et al., 1997, or more specifically the green bullwhip effect, Klumpp, 2019). Even in the sphere of supply services focused here, only small sections of the system dynamics are represented by the research, which as a whole still harbours major challenges.

It is not clear how impactful the potential of the last urban mile is against the backdrop of ambitious sustainability goals, such as climate neutrality. In the last decade, considerable research and practical innovation have taken place in the last mile. Overall, however, the effect is doubtful. It certainly requires the investigation of more complex system effects that encompass the entire PSC Ecosystem.

In addition to their primarily thematic function as sinks and delivery areas (last mile), cities also (again) increasingly play a role as places of ***urban production*** or ***urban first mile***. Although the renaissance of urban production has been recognized in most recent research (compare Busch et al., 2021), the far-reaching implications in terms of urban PSC Ecosystems have not yet been placed and could not play a specific role in the context of the dissertation and the underlying research.

As a working thesis, the resulting new structures between city and region, industry, craft and trade, digital and real space, production and consumption via newly emerging supply chains could achieve interesting value creation patterns for producers, service providers and consumers with high sustainability advantages.

A further aspect relates to a structural problem of approaches for the sustainability of ***cities, hinterlands and regions*** cited and further developed in the dissertation, in particular for sustainability gains of re-localisation or regionalization strategies. We were able to determine that regionalization and re-localisation strategies have a considerable effect and have not yet exhausted capacities for sustainable socioeconomic systems. However, this only applies within certain conditions and is only a limited means in relation to global urbanization. The phenomenon of increasing megacities must be a motivation to build up more extensive approaches. Classic city conceptions are no longer valid against this background. What applies to urban agglomerations in general – and forms one of the foundations of the work presented – is even more applicable for megacities that spatially and functionally exceed regional standards: They are interwoven in a complex net of ***global teleconnections***. Regionalisation (Newman, 1999; Newman and Jennings, 2008) or also “glocalization” (Robertson, 1995) – often put into connection with sustainable development – do not help here sufficiently.

Taken together from the aspects mentioned above, cities could play an interesting role as drivers of concrete, system-effective innovations in sustainability: The main question here is about the adequate experimental spatial and organizational formats. A methodically tested option is local urban living labs. Living lab settings of producers, service providers and consumer/ prosumers could include their activities in open innovation processes for products and their related service portfolios within local urban-industrial PSC Ecosystems. They could theoretically be testing different intervention scenarios, such as regional, seasonal supply and also global supply.

It has been around half a century since the early days of the Ecosystem Approach inspired the United Nations Man and Biosphere Program (MAB). In the course of this, biosphere reserves were established in rural areas as “living laboratories” to combine economic benefits and the protection of natural capital (see chapter 1.3.3). Today it would be time to transfer the MAB to cities in order to develop future sustainable forms of business in cooperation with the regions and under active integration of telecouplings.

The presented dissertation suggests an alternative approach and focuses on the inherent structures of value and supply chains (regardless of the spatial extension) and the business-led services that manage these urban-industrial networks. At this point there are considerable research and implementation needs about both the ***“Transformative Supply Chains”*** (4.4.) and the ***“Lead Sustainability Service Provider”*** (4.3., 4.4). Both key components of a future strategy cannot be put into practice – not even experimentally – without a policy framework. Both, such new solution attempts and needed regulatory frameworks still require further research *and (!)* a societal discourse.

In this connection, we would ask which methodological-technological approach underpins an ***“ecological value-added”*** (Kratena, 2004), especially regarding water and energy, but also other ecosystem service features with regard to appropriate data acquisition, evaluation and integration into strategic and operational management, or purchase and consumption decisions. In this context, a point was already highlighted in the discussion under 5.2.5: In questions of ***sustainability assessments***, the present work refers in a reductionist and pragmatic manner to a predominant “general” resource consumption and climate-relevant decarbonization strategies. The claim of an Ecosystem Approach should “naturally” be to relate further indicators of the natural capital. This would at least be water footprinting, since – based on research – practice can already be implemented here. Principally, however, the effects of economic activities would have to be measured against the entire spectrum of ecosystem services, or a comprehensive indicator set of the planetary boundaries would have to exist, which includes far-reaching very fundamental research questions that have not yet been set up.

6 Conclusions and Perspectives

The relevance of the Ecosystem Approach to the context of urban-industrial production, supply, and consumption relationships is not only an innovation in the sense of the application context, but also as a conceptual expansion for the approach itself. Its effectiveness, from a perspective of system-oriented sustainability transformation, could be well demonstrated.

The development of PSC Ecosystems could be highly relevant for a sustainable socio-economy and offers starting points for further research and conceptual alternatives, that could also be pointed out. The resulting research questions are diverse, ambitious, and highly relevant.

The overall approach presented, and the individual results are based on breakdowns of the problem context with a view to the “Urban-Industrial Supply System”. Solutions should be oriented in this direction to be able to move effective levers for the “Great Transformation”.

However, even if Castells' statement on the paradigm shift regarding the “Dominance of the Space of Flows” is now exactly 20 years old, it is not recognizable in academia, in society, business and politics that knowledge about the basic determinants and functioning of the globalized socioeconomic system would have been mobilized in the direction of sustainable development. In this context, Castell's question on the mindset of planning, which is again 10 years older: *“Times have changed – can planning change?”* (Castells, 1992) must be answered doubtfully.

There is no doubt that the need for adaptation and transformation for an alternative socio-economic system is urgent. Apparently, the need for transformation does not primarily affect the target system, but rather the stakeholders who shape the sectors and processes of the system. This also applies – not least – to the academia.

The present research can only make a small contribution to this endeavour. It provides some theoretical foundations based on a shifted perspective. This concerns the upgrading of technological dimensions in SES to SETS or also expanding of system boundaries of supply chain management or delivering a first outline for the Multi-Domain Framework of Urban-Industrial Supply as a nested organization for sustainability relevant innovations on different strategic and operational levels.

Together with the co-authors, it could be proven that functional couplings between production, supply, and consumption in the sense of PSC Ecosystems can be translated into concrete transformation designs. This applies in particular to the interface between service providers and consumers. The spatial structuring (e.g., regionalization of food supply and design of the "urban last mile" or communication on logistics innovations) offer options concreted by research. The fuller completion of the transformation designs is dependent on certain crystallized PSC Ecosystem properties. It concerns activities of coordination, working in multi-level systems and scalability, effective interactive communication, dynamic capabilities of learning and competence development, as well as the adaptability of organizations.

Of particular importance is the concept of the system services, more precisely: the "Lead Sustainability Service Provider" (6PL). Here there are solution potentials and design options for regional (a focus of the dissertation), but also bigger scales of transformative supply chains. However, the researched development of the service providers of the supply chain requires, in addition to the interaction with the consumer level, a societal and political framework. These framework conditions and the willingness of all stakeholders must follow a "truth of costs" strategy. Its design is not only a political question, but also contains the necessities of academic participation and considerable research activities as an inter- and transdisciplinary task. From the perspective presented here, additional sustainability assessments would have to be deepened and expanded at the same time with regard to the ecosystem services already mentioned in the introduction of this dissertation (1.1). The goal must be the valorisation of the stocks and flows of the natural capital for future-oriented planning and management. This vision of Ecological Economics is more than thirty years old. An "ecological value added" (Kratena, 2004) would have to stand on this foundation.

Geography, especially Economic Geography, has dealt intensively with global phenomena and the phenomena of globalization. Until now the analytical view prevails at the expense of a transformative orientation. With respect to a future role of Geography in transformative research, the question should not only refer to Geography itself, but consider gaps to be filled in covering complexity of the problem and in interdisciplinary cooperation for research-based solutions.

With respect to a future sustainable economy a large proportion of research - particularly from Management Science – has its focus on companies and their direct value-added environments. Effective transformation, as we were able to show in the cumulative contributions, would involve shifting these boundaries. Geography has traditions here (as shown in chapter 1.3) and can provide levels outside of the narrower company and value chain context. This allows more comprehensive perspectives than typically in Management Science and of classical Economics. So far, this potential has not been sufficiently used. A particular weakness of the state of the art - and this also applies to large parts of Sustainability Science

- is the underexposure of globally effective solution mechanisms, or the upscaling from regional or local approaches to higher levels of organization.

A geographical perspective on the problem context, specially pointed out by the Geography of Sustainability Transitions, would be advantageous, since the spatial, multi-scale resolution of the problem is central to a solution. In terms of sustainability research, it is important to combine ecological and socioeconomic system factors, as it is a principle of Environmental Economic Geography.

Basically, it can be stated that there is nothing to be said against greater heterogeneity in the research contexts or multi-perspective directions in Geography. Doing this by a transformative, targeted effort at the interfaces to neighbouring disciplines in the canon of Sustainability Science is certainly a productive prospect for all those disciplines and scholars involved.

It would be a success if this work would have provided some impetus.

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7.1 References Chapter 1

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7.2 References Chapter 2

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