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Sustainable Supply Chain Management: Decision Models for Transformation and Maturity

Hendrik Reefke and David Sundaram

Abstract: Academics and practitioners have realized that supply chains with their many interactions and impacts have to be investigated in order to meet corporate sustainability imperatives. Research has thus far offered only limited theoretical guidance while practical applications often lack a systematic approach. The realization of sustainability goals is impeded by disconnects between supply chain vision, strategy, and execution. This research bridges this gap and offers guidance through the identification and description of influential factors and decision models.

An exploratory Delphi study involved supply chain and sustainability experts with the goal to explore and propose factors and decision processes for sustainable supply chain management. This study builds upon the insights offered by seminal models and leverages the Delphi mechanisms of exploration and controlled feedback in order to design, refine, and validate decision models through three consecutive rounds. This Delphi facilitated the identification and assessment of vital relationships and influential factors for sustainable supply chain management. The study culminates in the design and validation of models specifically targeted at the transformation and on-going maturity development of sustainable supply chains. The combination of research outcomes provides targeted decision support to supply chain managers which is desperately needed in order to drive sustainability development and implementation. The main contributions of the study thus are (1) the design of prescriptive artefacts that describe relationships in SSCM, (2) to offer targeted and evaluated decision support functionalities for sustainable supply chains, and (3) to provide fertile ground for future research enquiries.

Keywords – Supply Chains; Sustainability; Delphi; Decision Models; Maturity; Transformation

1 Introduction

Corporate sustainability is about addressing and managing business decisions with regard to economic, social, and environmental dimensions in a balanced and integrated manner (Elkington, 1998). Supply chains (SC) are integral to almost all commercial activities nowadays and often involve global interactions as well as unknown and potentially adverse impacts. Hence, SCs need to be at the very core of sustainability developments (Kleindorfer, Singhal, & Van Wassenhove, 2005). External forces such as competitors, regulations, globalization effects, as well as stakeholder and customer demands pressure SCs to integrate sustainability principles into their strategy and daily operations (Carter & Rogers, 2008; Jayaraman, Klassen, & Linton, 2007; McIntyre, 2007; Seuring & Müller, 2008b). Sustainable supply chain management (SSCM) has emerged as a field of research and practice to address related challenges. Decision makers in SCs are increasingly required to initialize operational shifts and strategic re-orientations or even undertake complete SC re-designs (Sarkis, 1998). However, sustainability remains difficult to operationalize as SCs involve various parties with different business requirements, cultures and opinions. This study makes a contribution in this context and provides theoretical as well as procedural decision support for SSCM.

This paper firstly outlines the motivation for this research along with specific objectives. A review of the literature provides an introduction to SSCM and summarizes approaches for business transformation and maturity development. Based on this background, the focus then turns to an exploratory Delphi study, leveraging the insights of domain experts in order to design, evaluate, and validate decision models in SSCM. Discussion and concluding comments show how the findings can be utilized as a resource for academic research and SC practice.

1.1 Research Motivation

SCs are complex structures across multiple tiers of suppliers and customers (Cooper, Ellram, Gardner, & Hanks, 1997) and SC decisions can have significant, and often unforeseen, sustainability related impacts (Carter & Easton, 2011; Murphy & Poist, 2003). Focusing on SCs to push sustainability initiatives thus increases the potential for wide-ranging positive impacts and adoption (Ashby, Leat, & Hudson-Smith, 2012). And whilst sustainability is often accepted as a guiding principle it is not practically implemented (Seuring & Müller, 2008b) due to missing support mechanisms and since actual impacts of business conduct, and associated responsibilities, are difficult to assess and assign (Marshall & Toffel, 2005). Decision makers have to give consideration to all SC components which is substantially more complex than foci on individual companies or operations (Jayaraman et al., 2007; Seuring & Müller, 2008b). Research has only started to identify the requirements and practices to support SSCM and a plethora of related research avenues remain to be explored (see e.g. Reefke & Sundaram, 2017). There is a lack of knowledge with regard to practices, methods, and prerequisites for SSCM (Ashby et al., 2012; Carter & Easton, 2011; Wagner & Svensson, 2010; Winter & Knemeyer, 2013). Furthermore, key decisions regarding strategic and operational sustainability adjustments cannot be applied across the SC (Hassini, Surti, & Searcy, 2012) due to missing guiding principles. Currently available SC frameworks and models are not geared for transforming existing SC processes towards a sustainable focus and the most critical question in SSCM research today still is '*how to create (more) sustainable SCs'*. Hence, theoretical, structural, and procedural support is required (Winter & Knemeyer, 2013) in the form of conceptual insights, understanding of relationships, and practical decision models. This is further reflected by Ashby et al (2012) who recommend that "a more holistic and relational viewpoint offers the greatest potential for progressing SSCM from 'greening' to a 'virtuous circle' that addresses sustainability at all stages and interactions" as well as Reefke & Sundaram (2017) who point towards a lack of applicable models that can guide SSCM practice. Especially with regard to decision support, it has been pointed out that SSCM requires studying and modelling of the interrelation of the sustainability dimensions (Seuring, 2013) and a focus on strategic SC design and the linkages to operational decisions (Wang, Lai, & Shi, 2011).

This study is driven by the motivational aspects mentioned but cannot address all of them to the same extent. Hence, specific objectives were formulated as outlined next.

1.2 Research Objectives

Despite the realization that sustainable SCs are required, there is no agreement among scholars about the conceptual connections in SSCM (Markman & Krause, 2014). SCs and sustainability requirements are both characterized by complex interactions and SSCM transformation and ongoing development are hindered by a lack of systemic understanding, guiding principles, and structured decision models. An overview of the research motivation/rationale, approach/processes, and the main research contributions is provided in Figure 1. The detailed objectives are to:

- Design decision processes that can support the transformation of SCs towards SSCM.
- Identify influential factors for SSCM, i.e. enabling/disabling factors, capabilities, as well as characteristics exhibited by sustainable SCs.
- Evaluate the importance of the factors and aspects that influence SSCM along with an assessment of their relationships and interdependencies.
- Outline stages of SSCM development that can facilitate a structured progression, i.e. develop SSCM maturity.

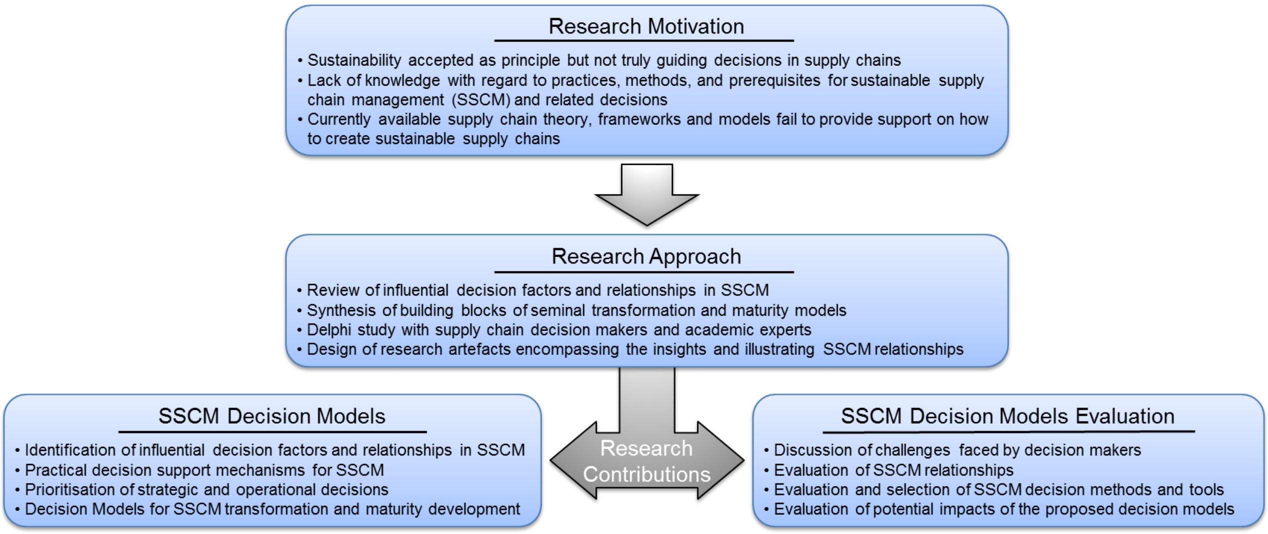

Figure 1: Study Overview and Contributions

2 Literature Review

In support of the study objectives, it is necessary to review underlying concepts. This review starts with a background to SSCM and continues with an account of transformation models and maturity development. The resulting synthesis of decision model components and characteristics is fundamental for the development and outcomes of the Delphi study.

2.1 Sustainable Supply Chain Management

While a relatively new field, SSCM is a well-established and growing research area and a sustainable focus has been correlated with positive outcomes in SC practice (see e.g. Bose & Pal, 2012). Several robust reviews of the academic literature on SSCM can help scholars to develop an overview and are evidence for the significant progression on one hand and the amount of work yet to be accomplished on the other (see e.g. Ashby et al., 2012; Carter & Easton, 2011; Hassini et al., 2012;

Reefke & Sundaram, 2017; Seuring & Müller, 2008b; Winter & Knemeyer, 2013). Researchers have approached the area from different directions and there is no true consensus on what SSCM entails. Early work tended to focus on environmental issues while a wider focus on the triple bottom line (economic, environmental, and social) is evident in recent publications. Recent additions to the academic discourse in SSCM are also explicitly critical of a traditional triple bottom line perspective and call for a reprioritization towards environmental and social considerations (see e.g.Markman & Krause, 2016; Montabon, Pagell, & Wu, 2016). Researchers also need to focus on social considerations in order to address the multifaceted nature of decisions in SSCM (Cruz, 2009; Seuring, 2013).

Along with the development of the field itself, a range of definitions have emerged over the years, the most cited ones by Carter and Rogers (2008) and Seuring and Müller (2008b). By contrasting a range of these existing definitions, Ahi and Searcy (2013) combined their key elements and delineate SSCM as

> *"the creation of coordinated SCs through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term".*

Based on this definition, it is apparent that SSCM goes well beyond traditional SCM. It involves the systemic coordination of all SC flows in accordance with triple bottom line thinking. Furthermore, the requirements of all SC stakeholders have to be met and continuously optimized. Accordingly, SC practice has to be informed by suitable frameworks in order to deal with these complexities. However, there is an apparent lack of theory-building research in the field of SSCM (Ashby et al., 2012; Carter & Easton, 2011; Winter & Knemeyer, 2013) and currently available models of decision making and tools are not customized to deal with the systemic interconnections.

SC research is generally focused on traditional or non-sustainable SCs and truly sustainable SCs remain an aspiration rather than reality (for more details see Markman & Krause, 2016; Montabon et al., 2016; Pagell & Shevchenko, 2014). It can be stated that researchers "are far from being able to direct managerial practice toward the creation of truly sustainable supply chains" (Pagell & Shevchenko, 2014). Whilst the creation of truly sustainable SCs remains an admirable goal, this study is taking the stance that making existing or future SCs more sustainable is an equally important and constructive endeavor. Researchers in SSCM need to focus their efforts on providing companies and their SCs with a concrete toolbox that supports their sustainability objectives in the shape of structural management components and adequate operational mechanisms (Winter & Knemeyer, 2013). Hence, this study was based on a traditional triple bottom line thinking which is in line with the understanding in SC practice.

2.2 Transformation and Maturity Development

The transformation and continuous improvement of SC processes at strategic and operational levels are at the very core of sustainable development. Relevant transformation approaches and maturity models are therefore reviewed and their key building blocks synthesized in this section. All these approaches and models share significant characteristics of seminal decision making models proposed in literature such as (a) intelligence, design, choice, and implementation (Simon, 1977) and (b) iteration (Mintzberg, Raisinghani, & Theoret, 1976) (c) convergence (Hage, 1980) (d) inspiration (Langley, Mintzberg, Pitcher, Posada, & SaintMacary, 1995) and (e) sequential and lateral linkages (Langley et al., 1995). The approaches and models reviewed below in essence are decision making models to support the transformation and maturing of entities, be they organizations or SCs.

2.2.1 Transformation Models

The ability to adapt to changing requirements is a characteristic of successful businesses which has been extended to include the SC (Beamon, 1999b; Lee, 2004). Accordingly, a variety of generic and specialized transformation models have been introduced. Most transformation models are primarily practitioner oriented with only limited scholarly evaluations regarding their applicability. However, several valuable academic evaluations are available (see e.g. de Mast & Lokkerbol, 2012; Schroeder, Linderman, Liedtke, & Choo, 2008), pointing towards their strengths and limitations.

Major influences on structured process management and continuous improvement can be traced back to seminal work by Ishikawa (1985) and Deming (1986) which led to methodologies like ‘total quality management’ and ‘lean thinking’. Process management approaches have since spread from manufacturing to various organizational applications, e.g. research and design, product development, distribution and sales. One of the most recognized examples is the plan-do-check-act (PDCA) cycle

(Deming, 1986) which suggests an iterative problem solving process in order to continuously foster process improvement and understanding. Generic in nature and following the rather simple premise of continuously comparing actions and their outcomes against initial plans and targets, it has successfully been applied in various contexts. Patterned after the PDCA cycle, the DMAIC method follows a structure of five phases, i.e. define, measure, analyze, improve, and control. Thus, it is assumed that problem solving can follow predictable steps embedded in organizational routines (Schroeder et al., 2008). DMAIC is a metaroutine, i.e. aimed at changing established routines and designing new ones (de Mast & Lokkerbol, 2012). Emphasis is placed on integrating specific tools and organizational members into its interrelated steps (Schroeder et al., 2008). Thus, in addition to providing a high-level routine structure, it also offers prescriptive elements to follow during implementation and use. While originally designed for the reduction of process variation, DMAIC has been successfully applied across various service and manufacturing operations focusing on e.g. quality, efficiency and cost improvements (de Mast & Lokkerbol, 2012). A detailed review can be found in de Koning & de Mast (2006).

A well-established approach for enterprise modelling and process management is ARIS (Architecture of Integrated Information Systems). This framework captures business flows and functions, their structures and supports organizational re-design (Scheer, Abolhassan, Jost, & Kirchmer, 2003). The steps of process strategy, design, implementation, and controlling enable change and continuous improvement with regard to business and compliance processes. ARIS describes operations according to their logical relationships, e.g. processes, work flows, and locations, as well as through their technical requirements, e.g. data, communications, and performance standards. Thus, it provides a platform that integrates internal business processes and information systems.

The transformation concept with its basic building blocks has also been employed for more high level strategic development and value creation. A transformation framework aimed at increasing profitability and competitiveness is put forward by IBM Consulting Services. This virtuous value creation cycle aims to continuously increase efficiency and market share through reinvestments in processes and technology (Gilmour, Maine, & Chu, 2004). Another well-known virtuous cycle is that of the service-profit-chain. This theory explains relationships for targeting new investments in order to reach service and satisfaction levels that result in maximum competitive impact (Heskett, Jones, Loveman, Sasser, & Schlesinger, 1994).

The principles and structures underlying transformation approaches have also been successfully adapted to sustainability considerations, e.g. the Natural Step is a framework with a rigorous focus on planetary sustainability. It follows a stepwise approach for aligning businesses with sustainability principles. Firstly, the system conditions for sustainability need to be discussed and understood upon which the status and relationships of the company in this regard are described. A vision for a profitable and sustainable future is established next, followed by an action plan designed to enable a practical and successful transition (The Natural Step, 2009).

Table 1: Overview of Transformation Models

Authors	Objectives	Phases/Steps/Levels	Description
Deming (1986)	PDCA – Continuous process improvement	1 – Plan 2 – Do 3 – Check 4 – Act	Problem solving process in order to continuously foster process improvement and understanding.
Heskett et al. (1994)	Service Profit Chain – Increase service quality and profitability	1 – Internal service quality 2 – Employee satisfaction 3 – Employee retention/productivity 4 – External service value 5 – Customer satisfaction 6 – Customer loyalty 7 – Revenue growth/profitability	A description of relationships for successful service organizations, i.e. between profitability, customer loyalty, employee satisfaction, and productivity.
Scheer, Abolhassan, Jost, & Kirchmer (2003)	ARIS – Enterprise modelling and business process management	1 – Strategize 2 – Design 3 – Implement 4 – Control	Provides a structured approach for capturing business flows, functions, organization and facilitate redesign
Gilmour, Maine, & Chu (2004)	IBM Consulting – Value creation and growth cycle	1 – Increase sales and market share 2 – Earn more margin 3 – Reinvest in processes and technology 4 – Drive greater productivity 5 – Invest in differentiators 6 – Deliver greater value to customers	Exploiting a virtuous cycle that fuels continued growth in market share and profitability by expanding across business categories and boundaries.
Schroeder (2008)	DMAIC – Process analysis and control	1 – Define 2 – Measure 3 – Analyze 4 – Improve 5 – Control	A closed-loop process in order to eliminate unproductive steps and introduce new measurements and continuous improvement.
The Natural Step (2009)	The Natural Step – Sustainability implementation	1 – System 2 – Success 3 – Strategic 4 – Actions 5 – Tools	Strategic planning that focusses on a long-term vision for aligning businesses with the principles of sustainability.

In summary, the decision models reviewed share common building blocks and structures which become especially evident through the synthesis provided in Table 1. They generally start with an initial learning and self-exploration phase, followed by planning and subsequent implementation. Most approaches emphasize targeted analysis and continuous performance control in order to prevent shifting back to previous patterns. Due to their wide spread usage and general acceptance, it seems reasonable to leverage the underlying structures as a basis for SC transformations. Realizing the potential benefits in full requires that a method is institutionalized as a routine across the organization (Schroeder et al., 2008) which would need to be extended across the SC.

2.2.2 The Maturity Concept

Business characteristics can be categorized into levels of maturity describing associated behavioral, regulative, and performance standards. A maturity level is an evolutionary plateau of process improvement (Carnegie Mellon - Software Engineering Institute, 2002) with the assumption that processes can be organized into stages of development (McCormack, Ladeira, & de Oliveira, 2008). Such evolutionary stages are likely to be at the core of successful SC developments (Stevens, 1993). Maturity models usually include components related to definition, measurement, management, and business process control. Higher maturity levels are associated with more control, improved forecasting, lower costs, effective goal attainment, and established continuous improvement methodologies (Lockamy & McCormack, 2004; McCormack et al., 2008). Maturity models help businesses to gain an overview of their own processes and facilitate performance management and benchmarking. They establish a structured approach based on a common vision and language allowing for the prioritization of goals and activities. (Carnegie Mellon - Software Engineering Institute, 2002; Lockamy & McCormack, 2004; McCormack, 2001).

The maturity concept is highly applicable for business developments (CMMI Product Team, 2002) and can be adapted to suit various purposes. Maturity models also hold the potential to contribute to the theory and practice of SCM (McCormack et al., 2008). They facilitate SC transformation and development by targeting specific shortcomings and higher maturity levels are also associated with less process, supply, and demand uncertainty while increasing bottom line performance (Geary, Childerhouse, & Towill, 2002). The maturity concept with its support of defined, managed, measured, and continuously improved processes has been associated with business success (Dooley, Subra, & Anderson, 2001) whilst the quantification of SC maturity and performance levels supports aligning the SC strategy with process improvements and performance measurements (McCormack et al., 2008).

With regard to maturity progression, it is pointed out that skipping levels is counterproductive as each level is foundational for the successive level (Carnegie Mellon - Software Engineering Institute, 2002; Lockamy & McCormack, 2004). While it is up to the individual organization to decide about the timing of improvements, they may put the stability of improvements at risk if the foundation for their institutionalization has not been completed (Paulk, Curtis, Chrissis, & Weber, 1993a, 1993b).

2.2.3 Maturity Models

A seminal process maturity capability model with five levels was developed by Carnegie Mellon (Carnegie Mellon - Software Engineering Institute, 2002). Initially aimed at software suppliers, it has popularized the maturity concept for multiple applications (Dooley et al., 2001). A related approach is the Business Process Maturity Model (BPMM) (OMG, 2008). At level one, processes are ad hoc and business success depends mainly on individual competencies. More visibility is evident in level two as requirements, processes, products and services are managed. Maturity level three demands documented and standardized processes. Next, performance measures have to be established in order to manage processes quantitatively while maturity level five focuses on continuous improvement (Paulk et al., 1993a, 1993b).

Maturity in SCs has been addressed from multiple angles, supporting the validity of the concept. Generally, this includes successive levels of development, from formation to collaborative SC environments with common goals and measures. Focusing on SC integration, Stevens (1993) suggests four stages of maturity development starting from a ‘baseline’ followed by ‘functional’, ‘internal’, and ‘external’ levels of integration. The goal is to evaluate the competitive environment and operations of a SC followed by the development of a customized SC strategy and finally integration with suppliers and customers based on cooperation and long term perspectives. Yusuf et al. (2004) propose a maturity model for SC agility based on a model by Venkatraman and Henderson (1998). It is organized in three stages along with three interdependent dimensions of SC maturity, i.e. customer interaction, asset configuration, and knowledge leverage. Lockamy and McCormack (2004) describe the progression towards SCM and process maturity in five stages which relate to characteristics such as predictability, capability, control, effectiveness and efficiency. At the lowest level, ‘ad hoc’, process measures are undefined resulting in low functional cooperation and high costs. At the ‘defined’ level, processes and targets are more controlled and predictable but local optimization prevails. The ‘linked’ level is seen as the breakthrough for SCM since measures and goals are shared and problems are solved on a SC level. Collaboration on a process level is common at the ‘integrated’ level along with integrated organizational structures. Finally, at the ‘extended’ level SC members engage fully in collaborative practices while risks, SC investments, and benefits are shared equitably.

Sustainability maturity is well established in literature, e.g. with regard to different levels, hierarchical requirements and performance measurement. The concept of multiple sustainability levels places the individual level at the center surrounded by organizational, political-economic, social-cultural, and ecological levels interacting through inputs, processes, outputs, and feedback (Klein & Kozlowski, 2000; Starik, 2004; Starik & Rands, 1995). These levels are interdependent and subject to different requirements in order to achieve overall sustainability. Sustainability requirements can be divided into four hierarchical steps relating to increasingly higher order constructs (Marshall & Toffel, 2005; Quak & de Koster, 2007). Most sustainability issues span across this hierarchy and need to be assessed using appropriate reference points and time frames (Marshall & Toffel, 2005). True sustainability is only achievable through coordination among stakeholders and performance measurement needs to move beyond process levels towards SC and systems implications. Performance indicators can be organized hierarchically based on the requirements at different levels of sustainability development (Veleva, Hart, Greiner, & Crumbley, 2001). The reach of the measures starts with a narrow focus on compliance and internal performance. Through the levels, the reach successively expands to include a company’s sustainability effects and SC indicators which are finally related to the carrying capacity of the environment (Veleva & Ellenbecker, 2001; Veleva et al., 2001).

The notions of sustainability and SC maturity have also been used in combination. Beamon (1999a) proposes a model with five maturity levels for environmental management in SCs. It is geared towards developing from regulatory compliance towards environmental risk management, waste prevention, and finally product life cycle management across the SC. A similar approach is put forward by the Green Business Maturity Model aimed at defining, assessing, and monitoring sustainable businesses (GCIO & OMG, 2009). Similarly, the GAIA model, developed by the LMI Research Institute, aims to assess the state of a SC and provides a framework for achieving higher levels of sustainability (Boone et al., 2009). Generally, the respective authors associate higher maturity with financial gain through increased resource efficiencies, improved brand reputation and competitive advantage, as well as risk reductions through proactive behavior.

Table 2: Overview of Maturity Models

Authors	Objectives	Levels	Description
Stevens (1993)	SC integration	4 – External integration 3 – Internal integration 2 – Functional integration 1 – Baseline	Structured development approach to reach higher levels of SC integration and remove uncertainty.
Starik & Rands (1995)	Sustainability levels and systems	5 – Ecological 4 – Social-cultural 3 – Political-economic 2 – Organizational 1 – Individual	Multiple levels and systems of sustainability and their interactions through inputs, processes, outputs, and feedback.
Beamon (1999)	Environmental management in SCs	5 – Fully integrated 4 – Managing for eco-efficiency 3 – Managing for assurance 2 – Managing for compliance 1 – Problem solving	Identifies evolutionary stages of environmental management in SCs.
Veleva & Ellenbecker (2001)	Sustainability performance indicators	5 – Sustainable systems 4 – SC and product life cycle 3 – Facility effect 2 – Facility material use and performance 1 – Facility compliance/conformance	Organizes sustainability indicators giving consideration to requirements for performance measurement at different levels of organizational development.
Carnegie Mellon (2002)	Process maturity	5 – Continuous improvement 4 – Performance management 3 – Standardized Processes 2 – Increased Visibility 1 – Ad hoc / individual competencies	Structured development approach for process maturity. Initially aimed at software businesses.
Lockamy & McCormack (2004)	SCM and process maturity	5 – Extended 4 – Integrated 3 – Linked 2 – Defined 1 – Ad hoc and undefined	Progression towards SCM and process maturity related predictability, capability, control, effectiveness and efficiency.
Yusuf et al (2004)	SC agility	3 maturity stages of SC agility for 3 interdependent dimensions, i.e. customer interaction, asset configuration, and knowledge leverage	Evaluate progress of SC agility based on three dimensions.
Marshall & Toffel (2005)	Sustainability requirements	4 – Subjective values of the quality of life 3 – Species extinction and human rights violation 2 – Reduce life expectancy 1 – Endanger human life	Sustainability requirements divided into four hierarchical steps that relate to increasingly higher order sustainability constructs.
(OMG, 2008)	BPMM – Process maturity	5 – Innovating 4 – Predictable 3 – Standardized 2 – Managed 1 – Initial	Measuring the maturity of an organization's processes, evaluate its process capability, and prioritize improvement efforts
GCIO & OMG (2009)	Green business maturity	5 – Economic returns from green initiatives 4 – Internal optimization and extension 3 – Governance structure 2 – Common understanding 1 – Ad-hoc	Aimed at defining, assessing, and monitoring sustainable businesses with a focus on environmental issues.
Boone et al (2009)	GAIA – SSCM maturity	4 – Accelerating: Integrated vision, goals and proactive behavior 3 – Innovating: Coordinated strategy 2 – Advancing: Develop strategic objectives 1 – Genesis: Compliance focus	Assess the current state of a SC and provide a framework for achieving higher levels of sustainability.

In summary, maturity development represents a logical approach to progression, especially in bigger systems like SCs, since process changes and improvements are best implemented successively (Carnegie Mellon - Software Engineering Institute, 2002; Lockamy & McCormack, 2004). Table 2 synthesizes the objectives, aims, and model structures of several recognized maturity models. In addition to these similarities, more common structural characteristics are evident including the definition of levels alongside goals and requirements for each level. Transformation and maturity concepts as they apply to sustainable SCs remain largely unexplored, with only few empirically validated models and prescriptions for practice. This research lacuna is addressed in this study by utilizing insights from academic and industry experts through a multi-round Delphi which is described in the following section.

3 SSCM Delphi Study

Delphi studies solicit and collate expert judgements through a series of questionnaires interspersed with controlled feedback based on earlier responses (Dalkey & Helmer, 1963; Delbecq, Van de Ven, & Gustafson, 1975). They provide an effective group communication process, enabling a panel of experts to deal with complex problems (Linstone & Turoff, 2002). Delphi studies can be tailored to various problems (R. Schmidt, C., 1997) in order to achieve a group consensus regarding the importance of aspects or support the development of frameworks (Okoli & Pawlowski, 2004).

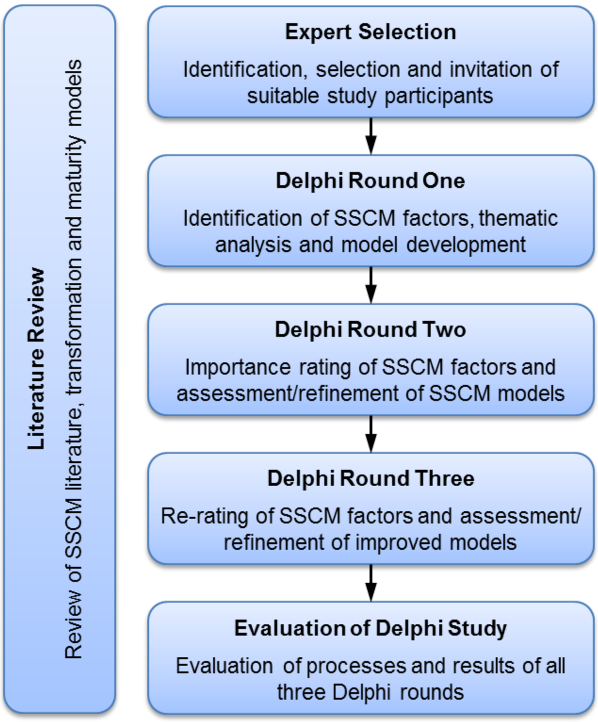

Figure 2: Sequential Order of Delphi Steps

This study explored influential factors in SSCM and modelled their interactions. Hence, this Delphi is design oriented, i.e. the aggregated insights from the participants led to the development and validation of decision models describing factors, relationships and dynamics in SSCM. A Delphi is generally structured into distinct rounds. Firstly, a qualified panel of experts needs to be appointed. For the first round questionnaire, researchers may use questions that elicit qualitative answers. After administration, the responses need to be analyzed upon which the next Delphi round is based. Through consecutive rounds the panel is asked to revise their original responses by giving consideration to the group feedback provided. This can be repeated until a consensus is reached or when sufficient information exchange is obtained (Delbecq et al., 1975). The detailed processes and decisions are outlined next following their sequential order (Figure 2).

3.1 Expert Selection

A structured approach was followed for the identification and selection of experts as suggested by recognized guidelines (Dalkey, 1969b; Dalkey & Helmer, 1963; Delbecq et al., 1975; Okoli & Pawlowski, 2004). This Delphi was exploratory in nature making the inclusion of experts from various disciplines advisable in order to capture a wide array of opinions (Rowe, Wright, & Bolger, 1991; 2002). Experts were matched to objective inclusion criteria (Williams & Webb, 1994) in order to avoid a non-representative sample and support the pooling of judgements (Hill & Fowles, 1975; von der Gracht & Darkow, 2010). They had to:

1. Have a track record in professional and/or academic practice.
2. Have experience in SCM and/or sustainability, substantiated through:
    a. employment as SCM practitioner for at least 2 years, or
    b. academic employment in areas associated with SCM for at least 2 years, or
    c. having published in the research areas in respected publication outlets, or
    d. employment at SC stakeholders, e.g. government and NGOs, or
    e. employment in sustainability related functions.
3. Demonstrate continuing professional interest in SCM and/or sustainability.

A total of 28 academics were approached for this study based on their academic output/experience in the field. 31 professionals in SCM and/or sustainability were identified through a SC research network. The experts were from the Australasian region, Europe and North America. The size of the Delphi panel throughout the study is shown in Table 3 along with response rates for each round, following recommendations which range from less than 15 to a maximum of 50 experts (Delbecq et al., 1975; Hsu & Sandford, 2007; Ludwig, 1997).

Table 3: Number of Responses

Panel	Initial Sample	Round 1	Round 2	Round 3
Practitioner	31	20	8	6
Academic	28	15	16	14
Total	**59**	**35**	**24**	**20**
	Response Rate:	**59.3%**	**40.7%**	**83.3%**

Table 4: Organisation Types and Sizes

Organisation Type	Round 1	Round 2	Round 3
Agriculture	1	2	1
Business Services	3	2	2
Education/Academic Institution	15	16	14
Export/Import	2		
Government/Public/Defence	3		
Information and Communications	1		
Manufacturing	1		
Nongovernmental Organisation	1		
Transport/Storage	7	4	3
Wholesale Trade	1		
Organisation Size	**Round 1**	**Round 2**	**Round 3**
1-5	2	3	2
6-19	1	0	0
20-49	1	0	0
50-99	0	2	0
100-499	6	1	4
500-999	5	4	1
Above 1000	20	14	13

All experts from the initial sample were invited to participate in rounds one and two. In order to ensure a well-informed rating process, only respondents from the second round were considered for inclusion in round three. Attrition effects are common in multi-step studies and could be attributed to increasing time involvements throughout the rounds. The total number of responses met the recommendations for Delphi panel sizes and the rate of drop-outs from one rating based round (Round Two) to the next (Round Three) was low. In summary, a large expert panel contributed to the exploratory round one while the ratings were supported by a consistent panel. The experts were classified according to their current place of work which resulted in a higher proportion of academics. Analysis of the experts' professional background shows that many of the academics possess substantial industry experience as well.

3.2 Round One

The first round utilized open-ended questions which is advisable for ill-defined research areas (Day & Bobeva, 2005; Dillman, 2007; Hasson, Keeney, & McKenna, 2000; Zikmund, 2003). It allows experts to provide their opinions precisely and supports the elicitation of unanticipated information (Engwall, 1983; Zikmund, 2003). The experts were presented with the following questions:

1. *In YOUR OPINION, what are KEY Performance Indicators/Measures/Metrics of SSCs?*
2. *In YOUR OPINION, what are KEY Characteristics/Capabilities/Enablers of SSCs?*
3. *Please feel free to leave additional comments on:*
    - *Sustainability in SCs in general.*
    - *Other particular aspects of SSCs that require further research.*

Following a structured data collection process (Schmidt, 1997), the open-ended questions encouraged participants to provide as many suggestions as possible along with descriptions and justifications. A minimum requirement regarding answers was not imposed as this could have discouraged respondents from exceeding that suggestion.

Figure 3: Round One Analysis Process

The analytical procedure (Figure 3) followed guidelines by Miles and Huberman (1994). In a first step the data was coded with reference to individual participants, date and time, and question number. Noise was reduced by consolidating the data into ‘key findings’ that only retained information relevant for the study objectives. The resulting insights were sorted into emerging categories following a bottom-up approach, i.e. categories were not imposed onto the data. Decision models of interaction were designed next. This process was informed by existing transformation and maturity models as introduced in the literature review. Due care was taken in incorporating the findings from the Delphi into these initial modelling activities. That is, input from the experts were retained in essence but elevated to meaningful input for the decision models.

3.3 Round Two

In the second round, all findings and the respective decision models developed after the first round were rated, resulting in 147 items in the questionnaire. While Martino (1983) cautions against a large number of items, this was justified by positive pilot tests and the opportunity to utilize the rich insights gained in round one. Five-point scales (Table 5) were used to rate the importance of identified items and the experts' level of agreement with the models. The scales include a 'middle response' option and in addition a 'non-answer' option for the importance ratings. Such unbalanced scales are associated with higher stability and internal consistency (Evans & Heath, 1995) and prevent biased results (Cox, 1980). A five-point scale offers a good compromise since smaller scales cannot transmit as much information whereas larger scales are not more accurate (Cox, 1980; Preston & Colman, 2000).

Table 5: Importance Rating Scale with Numerical Values

Numerical Value	**1**	**2**	**3**	**4**	**5**	**-**
Importance Scale	Unimportant	Of Little Importance	Moderately Important	Important	Very Important	Don't know
Agreement Scale	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	

The analysis process (Figure 4) started with an assessment of potential data inconsistencies. Numerical values were assigned to the rating options, as shown in Table 5, and items were sorted by their mean ratings. The level of consensus reached for each item was determined through statistical measures. Sufficient responses within a specified range are generally good indicators for a consensus (Miller, 2006 in Hsu & Sandford (2007)). Accordingly, measures were developed based on suggestions from literature (Mitchell, 1991; Ulschak, 1983). The first measure calls for 51% of responses within one category of the five-point scale whereas the second measure requires 80% of responses within two joining categories. A non-hierarchical k-means clustering was also used while a final qualitative assessment ensured that only items with a sufficient level of agreement were removed. All measures were used in conjunction with special emphasis placed on the 80% criterion. 70 items out of the total of 147 rated in round two were retained for the third round.

In a final analysis step, the decision models were improved based on the experts' comments and ratings. They were encouraged to provide ideas and improvements with regard to structure, applicability, logic, or any other aspect of the models. Hence, for the purpose of this study, the insights of domain experts were leveraged for the development, refinement and validation of decision models specific to SSCM.

Figure 4: Round Two Analysis Process

3.4 Round Three

The third round design, while similar to the previous round, only included items without sufficient consensus and the decision models in order to gather additional comments and validation. Feedback of the group opinions from round two was provided to the experts, i.e. mean ratings were used to convey importance ratings whereas the corresponding standard deviations (SD) showed the spread of responses. Any negative influences of outlying responses on the mean could be disregarded due to very few outliers (Mitchell, 1991). Qualitative feedback was not deemed useful due to few extreme opinions and the likely increase in time commitment for the experts.

Figure 5: Round Three Analysis Process

The analysis process (Figure 5) was akin to round two and it was furthermore decided that the study should be terminated. Group opinions can improve over iterations and a Delphi should ideally continue until no further insights are gained (Rowe et al., 1991). However, unnecessarily long studies require more resources and cause fatigue among the panelists (Hasson et al., 2000; R. Schmidt, C., 1997), leading to distorted results (Martino, 1972; Mitchell, 1991). Between two and four rounds are recommended (Linstone & Turoff, 2002) with a preference for fewer rounds (Dalkey, 1969a; Dodge & Clark, 1977; Mitchell, 1991). Three rounds offer a reasonable balance between resource requirements and the Delphi aims of consolidation, evaluation and refinement of ideas (Lummus, Vokurka, & Duclos, 2005; Okoli & Pawlowski, 2004; Seuring & Müller, 2008a) whilst usually leading to a suitable convergence of opinions (Ludwig, 1997; Scheibe, Skutsch, & Schofer, 2002; Uhl, 1971).

This final round included 6 practitioners, 9 academics, and 5 experts with an average industry experience of around 20 years each currently working in academia. The ratio of academic to practitioner viewpoints can thus be considered relatively balanced and the study findings reflective of both perspectives. The experts' opinions supported each other and led to additional improvements and validations of the decision models. Based on these high levels of consensus, this Delphi could be terminated after three rounds.

3.5 Evaluation of the Delphi Process

The consensus building process can be illustrated by plotting the respondents' average deviations from the panel's mean responses in the second round against the respondents' average deviations between their second and third round ratings. Figure 6 shows how respondents adjusted their third round answers by about the same amount as their second round ratings deviated from the average responses. Significant differences in opinion between practitioners and academics were not evident. This diagram thus demonstrates the desired group evaluation and convergence effect, supporting study termination after three rounds.

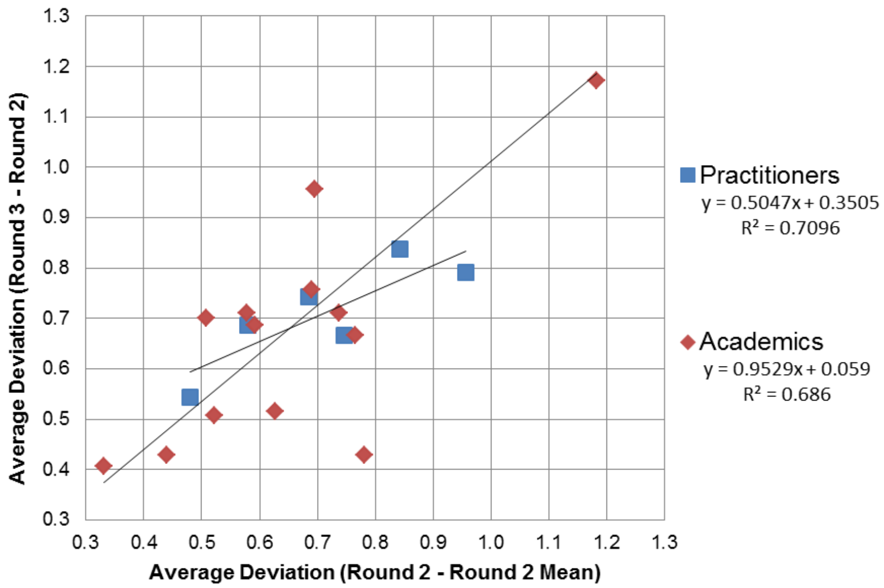

Figure 6: Consensus Building

4 Decision Models for Sustainable Transformation and Maturity of Supply Chains

Several research artefacts were developed and validated based on the Delphi experts' input. This section illustrates the theoretical value and practical usefulness of these artefacts by explaining their components, inherent logic, and the importance/agreement ratings obtained.

4.1 SSCM Transformation Model

The top-level structure of the SSCM transformation model, shown in Figure 7, was informed by seminal transformation approaches (Table 1). The bottom-up development of the specifics and detailed elements shown in Table 6 make it unique to SSCM.

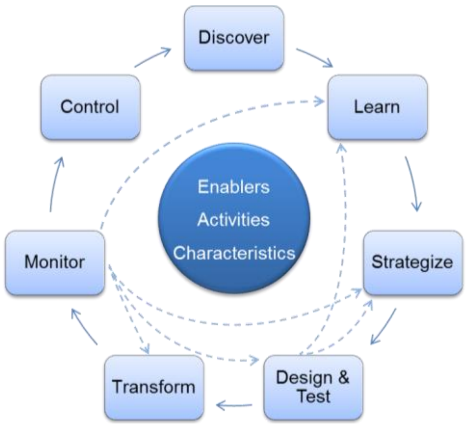

Figure 7: SSCM Transformation Model

Many transformation approaches highlight the need for ‘discovering’ and ‘learning’ in order to guide process and sustainability transformation. While discovery is mainly about the evaluation of external and internal requirements, learning is about assessing internal capabilities and support mechanisms. ‘Strategizing’ deals with the development of a SSCM strategy and respective SC processes. Strategic choices have long-term implications for all SC stakeholders and many transformation approaches encompass a similar phase (e.g. Scheer et al., 2003; The Natural Step, 2009; WBCSD, 2004). It is essential to define transformation goals and balance resulting trade-offs accordingly. The ‘design and test’ phase translates the strategy into implementable activities and methodical procedures while testing offers validation before actual implementation. Feedback loops to previous steps support the remediation of unfavorable test results. A tested design is then implemented during transformation which puts the strategy into action. The aim of the ‘monitor’ phase is to assess the success of the transformation and to inform SC stakeholders accordingly. Again, several feedback possibilities ensure that any issues discovered can be addressed from the most appropriate phase. The ‘control’ phase finally focuses on the success of process transformations and SSCM as a whole. Full and partial cycles can be performed to support sustainability improvements at process and strategic levels. While this transformation model is primarily a decision support model it also serves the purpose of managing risk strategically and operationally.

The cyclical SSCM transformation model provides a concise overview of the steps, activities and requirements that may enable SCs to establish a common methodology, guide transformation efforts, align sustainability goals, and lead to continuous improvements. Several representative elements for each phase were identified by the experts and subjected to an importance rating as shown in Table 6.

Table 6: SSCM Transformation Model Elements – Ranking

	SSCM Transformation Model Elements – Importance Ranking	*Round 2*	*Round 2 SD*	*Round 3*	*Round 3 SD*
	Discover				
1	Appropriate performance measurement tools	4.46	0.66		
2	Alignment of sustainability goals with current operations	4.38	0.71		
3	Awareness and documentation of SC impacts	4.00	0.83	4.20	0.41
4	Awareness of the need to be sustainable	4.13	0.68		
5	Development and documentation of SSCM vision and goals	4.08	0.72	4.05	0.69
6	Models/Frameworks for SSCM	3.63	0.97	3.95	0.60
	Learn				
1	Positive attitude towards SSCM including: 1) awareness of SC impacts and the value of sustainability; 2) mentality that allows for change	4.42	0.78		
2	Analysis capabilities to assess and select between strategic options	4.17	0.92	4.35	0.59
3	Education in terms of sustainability and SC concepts	4.21	0.66		
4	Mapping of operations and processes in SC	4.21	0.72		
5	Improvement of professional knowledge and qualification of staff	4.00	0.66		
6	Exploration of SSCM Models for improved sustainability in SCs	3.88	0.68		
	Strategize				
1	Clear SSCM vision and positive attitude towards strategy and goals	4.63	0.65		
2	Goal definition for entire SC	4.13	1.03	4.50	0.76
3	Key performance measures to enable consistent measurements and documentation	4.25	0.74		
4	Selection of most crucial aspects/problems	4.21	0.72		
5	Active management, i.e. investigation of alternatives	4.17	0.76		
6	Improvement strategies aimed at models and processes	4.08	0.58		
7	Evaluation of options for transportation, warehousing and distribution	3.92	0.65		
	Design & Test				
1	Design in accordance with strategic vision and goals	4.54	0.66		
2	Management support for design activities and commitment to SSCM	4.42	0.83		
3	Information availability and appropriate technology to support transformation processes	4.29	0.62		
4	Realizing benefits from previous improvement efforts	4.25	0.74		
5	Design of strategic SC locations	4.00	0.66		
6	Optimization of entire SC with regard to every sustainability dimension	3.67	1.24	3.85	0.81
7	Incremental improvement approach which supports a step by step redesign	3.75	0.85	3.85	0.59
8	Consulting companies/experts to support the redesign of processes	3.50	0.72		
	Transform				
1	Transformation of operational practices towards sustainability	4.08	0.72	4.35	0.67
2	Collaboration and trust with all stakeholders	4.29	0.75		
3	Integration of SC activities	4.29	0.62		
4	Increased collaboration and communication to ensure robust relationships	4.29	0.62		
5	Agility to ensure responsiveness and flexibility	4.08	0.72	4.15	0.49
6	Streamlining of all internal and external business processes	4.04	0.81	4.05	0.69
7	Incentives that drive the transformation process, e.g. regulations and requirements	3.83	1.09	3.85	0.81
	Monitor				
1	Alignment of vision and actual state of SC processes	4.54	0.72		
2	Regular monitoring and reporting practices of economic, social and environmental aspects	4.17	0.87	4.45	0.60
3	Access to information/communication technology and physical infrastructure	4.38	0.77		
4	Visibility/transparency of all processes	4.38	0.71		
5	Measurement and documentation of defined performance levels	4.25	0.74		
	Control				
1	Control SC operations based on SSCM principles/vision	4.08	0.83	4.30	0.57
2	Recognition and competitive advantage as result of SSCM efforts	4.29	0.69		
3	Full information visibility	4.21	0.72		
4	Sustainable operational performance as result of SSCM efforts	3.92	0.72	4.00	0.56
5	Contract management that enables full control along SC	3.83	0.96	3.85	0.67
6	Standardized management standards that allow for performance comparisons/checks	3.96	0.81	3.85	0.59
7	Usage of technology to ensure full control	3.71	0.75		

The decision model may be instrumental for the transformation of SC strategy, structures, processes, systems, and ultimately the sustainability culture. It is proposed that certain elements are particularly supportive, or even essential, for each step. Due to the exploratory nature of the Delphi, this list should not be regarded as comprehensive. It rather presents a wide-ranging overview that can guide transformation efforts by supporting prioritization and resource allocation.

4.1.1 Validation and Refinement of the SSCM Transformation Model

As shown in Table 7, a high level of agreement was established with regard to the model's applicability, logical structure, and usefulness. Refinement of the SSCM Transformation Model through the Delphi process was based on the quantitative ratings and qualitative comments of the experts. Comparing the results from round two and three, it is evident that the level of agreement with the decision model improved through this process.

Table 7: SSCM Transformation Model – Evaluation Statistics

Delphi Round 2 Question	Mean Rating	Standard Deviation	% in Highest Category	% in 2 Categories
Applicability of process	4.21	0.66	54.17%	87.50%
Sequence of process steps	4.00	0.88	50.00%	79.17%
Usefulness of the proposed elements for each model step	3.96	0.75	58.33%	79.17%
Delphi Round 3 Question	**Mean Rating**	**Standard Deviation**	**% in Highest Category**	**% in 2 Categories**
Sequence of process steps	4.15	0.75	60%	90%
Usefulness of the proposed elements for each model step	4.10	0.45	80%	95%

In their comments several experts called for a more flexible structure with regard to the sequence of steps, while the overall layout was found to be sound. A SSCM transformation exercise would usually progress until it could be evaluated in a meaningful way. Based on the experts' suggestions, feedback loops were included in the decision model connecting 'monitor' to 'learn', 'strategize', 'design and test', and 'transform'. Feedback loops also seemed sensible between 'design and test', 'strategize', and 'learn'. Early testing could likely indicate that more information or strategic development is required before a practical implementation or a re-design is started. Joining 'design and test' into a single phase was deemed useful since testing would not only occur after but most likely also during the design phase, i.e. testing of preliminary designs. However, especially for strategic SSCM developments, testing might not be a viable option and actual implementation may be required.

4.1.2 SSCM Transformation

There has been much debate on the applicability, benefits, and shortcomings of structured process management methodologies (Andriopoulos & Lewis, 2009; Benner & Tushman, 2003; Gupta, Smith, & Shalley, 2006). As reviewed earlier, process management approaches differ in terms of focus area and scope, but they are generally based on measurement, improvement, and the rationalization of processes (Benner & Tushman, 2003). The generic nature of some models makes them versatile in terms of possible applications but may also limit their reach and potential impact. Domain specific methods can overcome these shortcomings and be more operational as they draw on domain knowledge (de Mast & Lokkerbol, 2012). The SSCM transformation model follows a cyclical continuous improvement approach targeted at establishing sustainable SC processes. It entails well-proven building blocks and follows accepted design guidelines but includes targeted, domain specific elements. Its focus is on the identification of redesign opportunities, the mapping and improvement of SC processes, and subsequent integration and control. The decision model offers an overview of structured management steps and feedback loops fleshed out by the identification of enabling factors and elements specific to each step. The associated importance ratings offer additional guidance as they show the relative importance of elements for each step and hence support prioritization. The SSCM transformation model therefore addresses the problem that SC decision makers fail to incorporate the knowledge of previous successes into new initiatives (Carter, 2005; Carter & Easton, 2011).

Most companies and SCs are also not willing, or unable, to abruptly abandon established SC relationships and practices. It is even more doubtful that companies and SCs would be willing to drastically change their business idea and associated operational targets. Truly sustainable SCs are rare or even non-existent (Montabon et al., 2016; Pagell & Shevchenko, 2014) due to the market requirements and business structures they are operating in – a fact that is especially bemoaned by literature critical of the traditional triple bottom line perspective. However, taking into account the need for continuing SC operation and the common social reluctance towards change (Munro, 1995), sudden radical changes towards sustainability appear rather unrealistic for most SCs. Hence, a structured management process constitutes a more viable option for SC transformation. This does not preclude SCs from utilizing the SSCM transformation model in order to actively introduce radical improvements.

The success of transformation methodologies in general depends largely on their integration as an institutionalized routine across all affected entities (de Mast & Lokkerbol, 2012; Schroeder et al., 2008). A similar stance is advisable for the transformation towards SSCM. Hence, agreement needs to be reached among the SC members with regard to the institutionalization of the decision model and adherence to its logic and stepwise approach should be ensured.

4.2 SSCM Maturity Model

Companies and SCs generally aim to continuously improve, or mature, their processes, structures, policies, and capabilities in order to increase competitiveness. As explored in the literature review, maturity models define different levels of development and offer a structured approach for improvement. Accepting that a maturity model should adopt the logic of established seminal work (Carnegie Mellon - Software Engineering Institute, 2002; Lockamy & McCormack, 2004), it also needs to be adapted to the purpose at hand. A maturity model for SSCM should therefore:

- outline the purpose of the transformation,
- provide a common language by setting goals, objectives and guidelines,
- determine responsibilities,
- establish a clear direction and shared vision,
- help users to communicate and evaluate their decisions,
- outline a progression strategy between the current state and the long-term strategy.

As a result, a SSCM maturity model was developed with descriptions of each level and specific goals and requirements. The top level structure has been informed by the maturity models reviewed and summarized in Table 2. Their insights and essential building blocks were leveraged towards a design targeted at SSCM. The proposed maturity progression is organized in six levels ranging from ‘un-aware and non-compliant’ at the lowest level towards ‘extended and sustainability leadership’ as the highest level. As shown in Table 8, the levels correspond to specific stages of SSCM maturity and provide directions and a vision for further development. Goals and requirements are identified at each level, thereby establishing an overall SSCM vision as well as an iterative development strategy. The model maintains a neutral, generalizable approach with the intention to be customizable towards specific SC requirements and decision challenges.

Table 8: SSCM Maturity Levels (Reefke, Sundaram, & Ahmed, 2010)

Level	Description	Goals and Requirements
6	Processes are systematically managed through continuous improvement. Full SC collaboration embracing sustainability leadership position.	*Continue* to optimize processes and ensure future leadership position.
5	Sustainability has become a fully integrated concept and SC has moved towards proactive measures.	*Propagate* strategic concepts and move towards leadership position.
4	SC is linked and includes a comprehensive sustainability performance measurement system.	*Develop* from compliance level towards proactive sustainability efforts.
3	Sustainability goals/standards have been defined and SC members are compliant with regulations.	*Establish* key indices to measure sustainability performance within SC.
2	Sustainability measures are disconnected from strategic direction. Compliance on a basic level.	*Align* sustainability goals and efforts with defined processes. Establish consistency.
1	SC is unaware and non-compliant to any regulations and undertakes no sustainability efforts.	*Create* sustainability awareness. Introduce sustainability initiatives.

The SSCM maturity model, shown in Figure 8, maps the dynamic relationships between maturity and SSCM factors. The components (SSCM factors) and relationships of the SSCM maturity model are based entirely on the Delphi results while the levels of maturity progression were informed by the maturity models reviewed. The logic of the decision model can be summarized as follows:

> *The existence of certain enabling factors helps a SC to perform activities that support SSCM, whereas disablers prevent a SC from doing so. In combination these result in certain characteristics that the SC possesses. As a SC develops such characteristics, it reaches higher levels of maturity. Along with higher maturity levels the amount of disabling factors and/or their effects decrease and the amount of enabling factors and/or their effects increase, which allow for more activities directed at sustainability in SCs.*

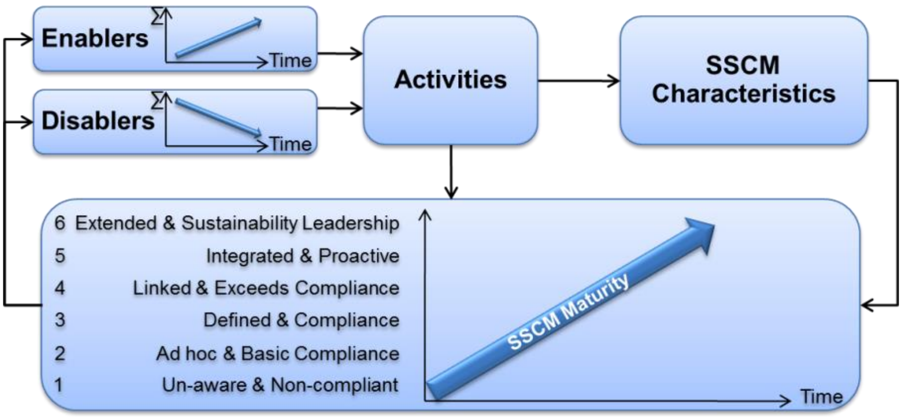

Figure 8: SSCM Maturity Model

The relationships proposed by the decision model can be illustrated by using a selection of SSCM factors proposed by the Delphi experts with regard to performance measurement. The activity 'definition and measurement of clear key performance indicators' (Activity 1 in Table 11) can only be performed if the enabler 'performance measurement tools for consistent and accurate measurement' (Enabler 6 in Table 9) exists. However, it can be hindered by disabling factors such as a 'focus on short term financial performance' (Disabler 1 in Table 10) or a 'misguided focus in the sustainability movement' (Disabler 4 in Table 10) which may potentially lead to performance targets that do not reflect a balanced sustainability orientation. Accurate performance measurement will ultimately support the characteristics 'alignment and synchronization of SC and sustainability initiatives and goals' (Characteristic 1 in Table 12) and 'true cost allocation' (Characteristic 12 in Table 12). Hence, this logic implies that the development of SSCM characteristics necessitates performing certain activities which, in turn, require appropriate enablers and the absence or active control of disabling factors.

A total of 96 SSCM factors were identified in the first round and subsequently evaluated. These are split into 26 enablers, 21 disabler, 23 activities, and 26 characteristics. The following tables rank them according to importance with priority given to the third round ratings.

Table 9: SSCM Enablers – Ranking

	SSCM Enablers – Importance Ranking	*Round 2 Rating*	*Round 2 SD*	*Round 3 Rating*	*Round 3 SD*
1	Top management support and approval	4.87	0.46		
2	Collaboration with staff	4.54	0.51		
3	Awareness of potential benefits/pitfalls of sustainability efforts	4.04	0.95	4.50	0.51
4	Collaboration with suppliers	4.50	0.66		
5	Common SSCM vision along SC	4.50	0.66		
6	Performance measurement tools for consistent and accurate measurement	4.48	0.67		
7	Consumer awareness and resulting market pressures	4.13	0.74	4.45	0.69
8	Collaboration with customers	4.42	0.72		
9	Realization of benefits through sustainability efforts, e.g. cost savings and reputation increase	4.42	0.72		
10	Sufficient capital to cover initial investments and long-term goals	4.38	0.77		
11	Awareness and acceptance of necessary time and cost investments	4.29	0.86		
12	Models, frameworks, roadmaps to support transformation towards SSCM	4.17	0.82		
13	Efficient information/communication technology to increase sharing and updates	4.13	0.68		
14	Continued education for qualified and motivated staff	4.00	0.78	4.10	0.72
15	Documentation of the impacts of SC	3.78	0.74	4.05	0.78
16	Availability of sourcing and sale options	3.96	0.75	3.95	0.69
17	Behavioral architecture, e.g. employee reward systems	4.00	0.78	3.95	0.76
18	Incremental improvement approach	3.71	0.95	3.89	0.99
19	Sustainable material inputs, e.g. renewable, not harmful, organic, fair trade	3.83	0.72	3.89	0.81
20	Government intervention, e.g. compliance requirements and penalties	3.61	0.89	3.68	0.89
21	Low cost solutions for documentation, payment, and traceability	3.83	0.87	3.55	0.60
22	Collaboration with government	4.04	0.81	3.40	1.05
23	Green-house gas schemes, e.g. emission trading or carbon offsets	3.43	0.95	3.40	0.75
24	External consultants/partners to improve strategies and operations	3.46	0.83	3.30	0.92
25	Joint ventures, e.g. to share facilities and equipment	3.46	0.83	3.30	0.86
26	Subsidies to encourage more sustainable operations	3.46	1.02	3.30	1.03

All enablers shown in Table 9 were considered important, but the top ranking items appear to be more fundamental for SSCM and universally applicable across most SCs. It could be argued that these enabling factors have to be established for successful SSCM, including e.g. securing 'top management support and approval', engaging in 'collaboration with staff, suppliers, customers', or establishing 'a common SSCM vision along the SC'. While the low ranking enablers were also considered reasonably important, they might not be of value to every SC. They are more specific in nature and point towards aspects that are more dependent on the kind, layout, and requirements of a SC, e.g. the use of 'subsidies to encourage more sustainable operations', engaging with 'external consults/partners', or also establishing 'joint ventures'.

The ratings of the disablers (Table 10) show a less pronounced spread, albeit with high ratings overall, indicating their influential nature. Similarly to the enablers, the top rated disablers could be interpreted as more fundamental issues that should be avoided.

Table 10: SSCM Disablers – Ranking

	SSCM Disablers – Importance Ranking	*Round 2 Rating*	*Round 2 SD*	*Round 3 Rating*	*Round 3 SD*
1	Focus on short term financial performance, e.g. quarterly results	4.33	0.87	4.26	0.93
2	Missing collaboration and strategic alignment	4.25	0.94		
3	Cost of sustainability efforts/strategy	4.21	0.93		
4	Misguided focus in the sustainability movement, e.g. only on green-house gas emissions	3.96	1.20	4.05	0.97
5	Dependence on fossil energy	3.79	1.10	4.00	0.86
6	Long distances to import/export goods	4.00	0.88	4.00	0.91
7	Price war battles	4.04	1.16	3.95	0.83
8	Loss of business to free trade zones/cheaper competition	4.08	0.93	3.95	0.85
9	Missing research on the linkage/impact of SCs on environment and society	3.71	0.81	3.89	1.05
10	Competition forces cost reductions regardless of other sustainability requirements	4.17	0.82	3.89	0.90
11	Effects of sustainability strategy are too long-term	3.70	0.93	3.84	0.96
12	Unaccounted costs, e.g. allocation of negative SC effects and related costs	3.78	0.95	3.83	0.79
13	Unverified claims of sustainable practices companies	3.58	1.18	3.83	0.71
14	Missing research on the service profit chain in logistics and SCs	3.92	0.72	3.79	0.98
15	Competition encourages sub-optimal use of resources	3.96	0.86	3.76	0.90
16	Uncertainty about infrastructure/operational requirements and necessary investments	3.70	0.97	3.74	0.65
17	Missing research on employee satisfaction and societal welfare	3.63	0.77		
18	Missing research on particularities/restructuring needs of SCs	3.63	0.71		
19	Nature of SCs, i.e. SC operations can never be fully sustainable	3.59	0.96	3.50	0.63
20	Uncertain science on green-house gas emissions and carbon footprints	3.59	1.18	3.47	1.02
21	Sustainability not applicable to low value products/services	3.70	1.18	3.37	0.76

Some of these may often be outside of direct SC control, e.g. 'dependence on fossil energy', 'long distances', or a 'misguided focus in the sustainability movement' in general. Acknowledging this potential lack of direct control, the SSCM maturity model puts forward that their effects may be decreased if counteracting enablers are put in place. Several of the highly rated disabling factors are connected to financial concerns, e.g. the 'cost of sustainability efforts' or the predominant 'focus on short term financial performance'. This was seen as the most influential disabling factor which reflects the need for more sustainability oriented performance assessments and incentives. Disablers connected to uncertainty, e.g. 'infrastructure or operational requirements' and 'missing knowledge or lack of research', were rated as being of moderately high importance. It is insightful to note that the 'nature of SCs, i.e. that SC operations can never be fully sustainable' is considered to be important but not necessarily an inevitable obstacle. It is furthermore not indicated that sustainability is 'not applicable to low value products/services'.

Several of the top ranking activities are related to the measurement and assessment of SC performance. These activities range from the 'definition and measurement of clear performance indicators' towards measuring and quantifying SC 'outputs, impacts, and damage' from a sustainability perspective.

Table 11: SSCM Activities – Ranking

	SSCM Activities – Importance Ranking	*Round 2 Rating*	*Round 2 SD*	*Round 3 Rating*	*Round 3 SD*
1	Definition and measurement of clear key performance indicators	4.65	0.65		
2	Measurement of performance areas on all sustainability dimensions, i.e. outputs, impacts, damage	4.48	0.73		
3	Minimizing energy/material consumption through 'reduce, reuse, recycle'	4.25	0.90	4.45	0.60
4	Reduction of pollution to air, water, and land	4.43	0.59		
5	Identification and elimination of non-value adding activities	4.42	0.65		
6	Reduction of waste, e.g. damaged items, time, costs	4.39	0.66		
7	Accurate demand forecasting and balancing inventory	4.38	0.71		
8	Quantification of impacts of SC operations on all sustainability dimensions	4.35	0.65		
9	Considering end of life during design stages	4.33	0.76		
10	Discussion, investigation, and selection of alternative methods/options	4.04	0.69	4.30	0.66
11	Continuous improvement process	4.13	1.03	4.25	0.97
12	Minimization of unnecessary freight movements	4.25	0.74		
13	Risk Management	4.25	0.74		
14	Integration, e.g. forward and backward integration	4.17	0.92		
15	Utilization of renewable and alternative forms of inputs	4.13	0.68		
16	Reverse logistics	4.00	0.74	4.11	0.74
17	Evaluation of market and sourcing locations, e.g. local vs. distant	4.08	0.58		
18	Examining the feasibility of transportation modes for commodities	4.08	0.78		
19	Usage of sustainable transport systems, e.g. lower emissions, noise levels	4.04	0.62		
20	Carbon foot-printing, i.e. measuring and tracking emission levels	4.04	0.91	3.90	1.02
21	Regular and comprehensive updates/reports	3.96	0.86	3.90	0.72
22	Triangulation of containers	3.76	0.77		
23	Transport during off-peak times	3.61	0.78		

More traditional SC performance areas are also reflected in activities such as 'accurate demand forecasting and balancing inventory' and the 'identification and elimination of non-value adding activities'. Sustainability oriented performance measurement can thus be considered crucial for SSCM. In this context, the Delphi experts also identify the need for a targeted 'continuous improvement process'. The SSCM transformation model developed through this study may support this requirement. Additional commonalities can be seen between activities 3, 4, 6, and 9 in Table 11 which call for the reduction of resource consumption and related pollution, waste minimization, and goods as well as processes that are designed with these goals in mind. The lower ranking activities seem less universally applicable and their value may again be dependent on the specifics of a SC. Examples here include the 'triangulation of containers' or 'transport during off-peak times'.

The overview in Table 12 covers a total of 26 SSCM characteristics, covering a wide range of features and traits that a sustainable SC exhibits. Many of these were rated highly important and may serve as guiding goals while the ratings help to prioritize efforts and the investment of resources.

Table 12: SSCM Characteristics – Ranking

	SSCM Characteristics – Importance Ranking	*Round 2 Rating*	*Round 2 SD*	*Round 3 Rating*	*Round 3 SD*
1	Alignment/synchronization of SC and sustainability initiatives and goals	4.67	0.48		
2	Collaboration and trust among all SC stakeholders	4.50	0.59		
3	Long term relationships with SC partners and robust SC	4.50	0.78		
4	Sustained competitive advantage through SSCM	4.42	0.65		
5	Satisfied stakeholders, e.g. community and investors	4.21	0.78	4.40	0.68
6	Sustainability mentality, i.e. embracing change and supportive of sustainable developments	4.39	0.72		
7	Driven by a sustainability vision shared by SC, customers, and stakeholders	4.38	0.65		
8	Existence of short/middle/long term plans with specific goals and objectives	4.21	0.78	4.35	0.67
9	Satisfied customers, internal and external to SC	4.33	0.70		
10	Qualified staff with expertise in SCs and sustainability principles	3.96	0.86	4.30	0.57
11	Satisfied employees	4.13	0.85	4.30	0.66
12	True cost allocation, i.e. all SC impacts and costs are fully accounted for	4.29	0.75		
13	Minimal waste and sustained efficiency throughout SC operations	3.91	0.73	4.25	0.44
14	Good contracts and contract management from 'cradle to cradle'	4.21	0.72		
15	Increased visibility/transparency and information sharing among SC and stakeholders	4.17	0.64		
16	Responsiveness/agility to react to changing market requirements	4.17	0.64		
17	Recognized for SSCM, sustained efficiency, and sustainability mentality	4.04	0.75	4.15	0.67
18	Internal structures to develop organizational capabilities	4.13	0.68		
19	Up-to-date technology, e.g. information technology, transport/manufacturing options	4.00	0.82	4.05	0.40
20	Following and setting best practice standards	4.00	0.67	4.05	0.76
21	Increased return on capital investments and low operating costs	4.04	0.62		
22	Low process variability including social and environmental aspects	3.59	0.73	3.75	0.64
23	Strategic operational locations, e.g. proximity to SC partners	3.75	0.61		
24	Full utilization of operational facilities/equipment	3.63	0.92	3.70	0.57
25	No excess inventory or dead stock	3.57	0.84	3.58	0.69
26	Exceeding regulations and compliance requirements	3.54	0.93	3.55	0.76

Special emphasis should be placed on developing SC alignment and collaboration as indicated by the three highest rated items which highlight these requirements from different focal points. The expert panel agrees that SSCM needs to result in competitive advantage, i.e. in measurable business success. The aspect of satisfaction is furthermore highlighted which should extend from SC stakeholders to its customers and employees. A clear 'sustainability vision' has to be established for the SC, driven by a corresponding pro-active 'sustainability mentality' and 'short/middle/long term plans with specific goals and objectives'. Additional key characteristics were identified ranging from e.g. 'full SC cost allocation' to 'contract management', 'up-to-date technology', and 'following best practice standards'. Interestingly, some "more traditional" SC aims were, by comparison, rated less important for SSCM. This includes factors such as 'full utilization of operational facilities' and 'no excess inventories'. It is also not indicated that SCs should strive to 'exceed regulations and compliance requirements'.

4.2.1 Validation and Refinement of the SSCM Maturity Model

The design process and expert validations provide support for the notion that the SSCM maturity model offers a practically useful and theoretically accurate overview of relationships in SSCM. In addition to its rigorous development process, the SSCM maturity model was validated through a group consensus of the modelled relationships as evident from Table 13.

Table 13: SSCM Maturity Model – Evaluation Statistics

Delphi Round 2 Question	**Mean Rating**	**Standard Deviation**	**% in Highest Category**	**% in 2 Categories**
Applicability of the model	3.75	0.90	54.17%	70.83%
Relationships between the elements of the model	3.67	0.87	54.17%	75.00%
Delphi Round 3 Question	**Mean Rating**	**Standard Deviation**	**% in Highest Category**	**% in 2 Categories**
Applicability of the model	3.90	0.31	90%	100%
Relationships between the elements of the model	3.75	0.64	70%	90%

The high overall agreement after the second round did not indicate a need for major alterations of the decision model's essential design. Several improvements were nevertheless implemented based on the experts' comments. Firstly, the decision model was altered to reflect that the actual number of enablers or disablers would not necessarily change along with maturity developments. Rather their effects could increase or decrease, depending on the nature of the enablers and especially in case of the disablers. The decision model was furthermore changed to reflect that activities may potentially affect SSCM maturity directly. Lastly, the decision model description was improved in order to emphasize its idealized view of a SSCM maturity progression and to avoid misinterpretations. In the third round, a consensus among the experts was reached regarding the applicability of the decision model and its relationships. Refinements based on the comments did not include significant modifications but rather emphasized the decision model's neutral and customizable approach.

4.2.2 SSCM Maturity Progression

As evident from the review of the literature, process transformation and maturity development are tightly linked concepts. Based on this realization, the stepwise SSCM transformation approach can be integrated with the dynamics in sustainable SCs put forward by the SSCM maturity model.

This maturity progression proposes a cyclical multi-step approach, commonly used for transformation methodologies (Scheer et al., 2003; The Natural Step, 2009) as well as iterative, convergent and linked decision making processes (Simon, 1977; Mintzberg et al., 1976; Langley et al., 1995). The progression between the levels of SSCM maturity is supported through an iterative transformation process consisting of defined phases which can be performed on a continuous basis. The time dimension is addressed specifically by outlining the strategic progression between the current state of a SC, its long-term vision, and transitional states of development. This approach follows the recommendations of seminal work in the field (see Table 1 and Table 2) and addresses the need for a virtuous SSCM improvement methodology that is grounded in a deeper understanding of relationships and interactions in SSCM (Ashby et al., 2012).

The SSCM factors, i.e. enablers, disablers, activities, and characteristics, constitute essential components and considerations for SCs moving towards sustainability. The categorization of these factors and their importance rankings significantly informed the development of the SSCM transformation and maturity models. Through their identification and evaluation, this study addresses some of the uncertainties surrounding sustainable SC practices and requirements that have beset SC research and management. Accessibility and understanding are enhanced further through the discussion of the factors as part of the SSCM maturity model. The presentations within higher-level relationships allows for an easier grasp of their applicability and implications by providing a context and by illustrating connections between the factors. Apart from these advantages, it needs to be acknowledged that empirical data can be interpreted in multiple ways (Ketokivi & Mantere, 2010). Hence, other categorizations of the factors may also be coherent. Despite this potential shortcoming, SC scholars can use the SSCM factors and decision models as a basis for improved models for SSCM. SC practitioners are well advised to utilize the neutral nature of the decision models along with the factor evaluations in order to customize SSCM developments according to their unique SC requirements.

5 Discussion and Conclusion

A lack of theoretical SSCM developments and practically relevant research has been bemoaned in literature (Carter & Easton, 2011; Markman & Krause, 2016; Montabon et al., 2016; Pagell & Shevchenko, 2014; Reefke & Sundaram, 2017; Winter & Knemeyer, 2013). This study makes a contribution in this context through the investigation, description, and evaluation of structures, relationships, and dependencies in SSCM.

5.1 Overview of Research Artefacts

The shown adaptation of the Delphi method supported the simultaneous creation and evaluation of SSCM factors (Tables 9, 10, 11, 12) and decision models of their interactions, i.e. for SSCM transformation (Figure 7 and Table 6) and SSCM maturity development (Figure 8 and Table 8). Thus, the characteristics of the method were uniquely leveraged, especially the combined insights of domain experts, the possibility of providing structured feedback, and the refinement of ideas and decision model designs over multiple rounds. The decision models may provide integrated operational, procedural and strategic support for SSCM transformation and maturity development through the description of strategic goals, operational and tactical priorities and structured processes to follow. Detailed overviews regarding the importance of influential factors can further support decision makers in SCs. Evaluation of the artefacts is achieved through the positive expert ratings supporting their credibility and applicability. This is further strengthened by discussing the impact of these tools in order to support SC managers in their daily operations as well as the long term strategic trajectory of the SC.

5.2 Application of SSCM Decision Support Models

The research artefacts presented can benefit SC stakeholders by allowing them to assess, implement, transform, continuously develop and advance SC sustainability. Due to their neutral and customizable nature, this research offers support to SC endeavoring to become more sustainable. In the following paragraphs the models and study results are used to analyze the Mattel SC (Gilbert & Wisner, 2010; Hoyt, Lee, & Tseng, 2008; C. W. Schmidt, 2008).

Mattel is an American multinational toy manufacturing company which, in its recent past, had to recall millions of toys that contained magnets which could be swallowed by children or could have lead paint (Gilbert & Wisner, 2010). At the heart of this recall was an unsustainable SC. At least 7 of the

SSCM disablers (Table 10) were apparent in this SC setup. At the top of the list “focus on short term financial results”, “price war battles” and “competition forces cost reductions” led Mattel to shift their manufacturing to low labor cost countries and “collaboration” with their second tier suppliers was weak as a result. The above decisions also led to “long distances to import/export goods” which in turn led to low visibility in the SC and potentially “unverified claims of sustainable practices” of their suppliers. Another impact was their “dependence on fossil energy” both for manufacturing as well as transportation.

In contrast more than 7 of the SSCM Enablers (Table 9) need to be strengthened or enhanced in the context of Mattel to improve the sustainability of their SC (Hoyt et al., 2008). Chief among these are “sustainable material inputs”, “collaboration with suppliers”, and “performance measurement” of various vital KPI’s related to quality, research and development, and production. They also need a “realization of benefits through sustainability efforts”, “awareness and acceptance of necessary time and cost investments”, and “documentation of the impacts of SC”. There is obvious need for application of “models, frameworks, roadmaps to support the transformation towards SSCM”. Furthermore an “efficient information/communication technology to increase sharing and updates” would have allowed Mattel to be aware of the problem early on and address it in a proactive manner rather than reactively.

Ameliorating the disablers and enhancing the enablers identified and introducing key SSCM support activities (Table 11) would have enabled Mattel to progress on their sustainability journey. Almost every one of the activities in Table 11 is relevant for Mattel, even extending towards “reverse logistics” considering the product recall. These activities would help the Mattel SC to develop the SSCM characteristics listed in Table 12. And as these characteristics develop the hope is that the “un-aware and non-compliant” parts of the Mattel SC would be able to move towards higher maturity levels and potentially (if desired) to “extended and sustainability leadership” (Figure 8).

The disablers, enablers, activities and characteristics are intertwined and have causal relationships. But how does a SC go about ameliorating the disablers, enhancing the enablers, and executing the activities? It is in this context the SSCM transformation model illustrated in Figure 7 and its details in Table 6 come to the fore. Applying this model systematically over a period of time could enable the SC to mature in terms of sustainability (Figure 9).

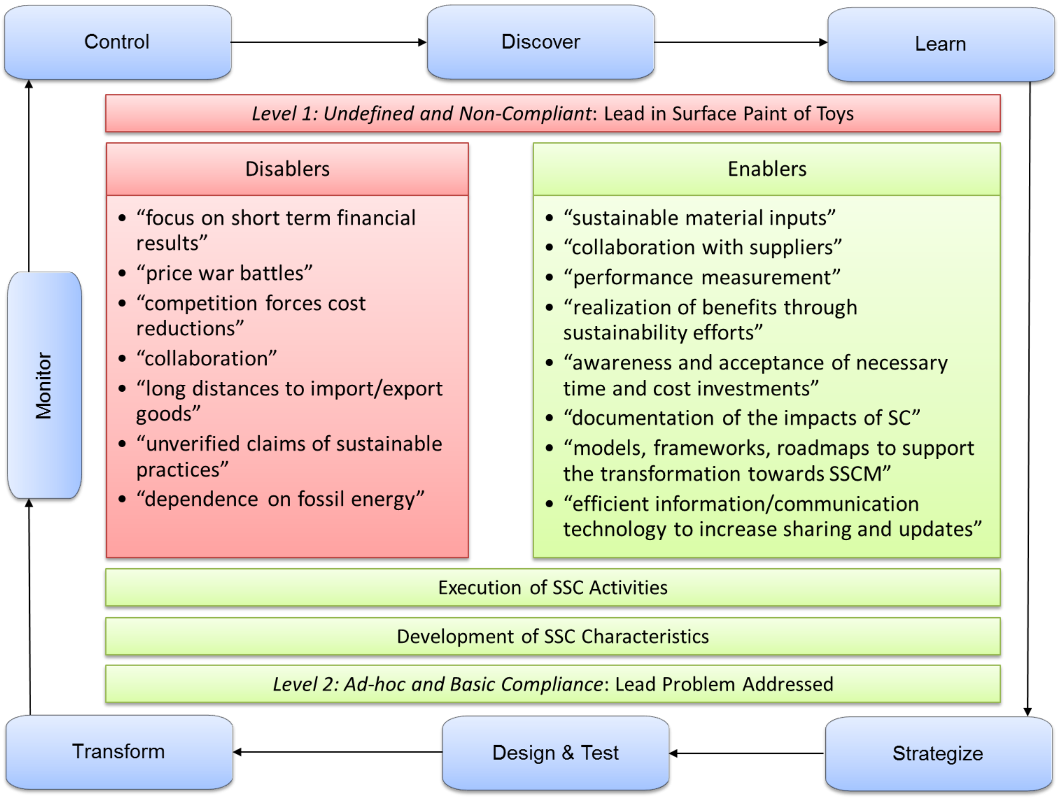

Figure 9: Maturity Progression Applied to Illustrative Case Scenario

In the previous paragraphs the models were applied as a whole and used to analyze the Mattel SC keeping in mind the toy recall. Now the focus moves to one of the identified problems, namely the excessive levels of lead in toy surface paints. The transformation model is utilized in order to illustrate how the problem could have potentially been addressed through robust data driven decision making (Figure 9). In early July of 2007 one of the European retailers selling Mattel toys ***discovered*** the lead on some products. While this discovery was external to the organization it is hoped that as a SC progresses in sustainability maturity it will discover problems further upstream and close to source of the problem rather than close to the customer. Appropriate performance measures (Table 6 – Discover - item 1) would have helped in the discovery of the problem early on.

Learning about the problem more and analyzing the capabilities of Mattel's contractors, sub-contractors, and even Mattel itself would help in understanding strategic options available and the appropriate SC processes and operations (Table 6 – Learn - items 2 and 4). Part of the learning process is also to educate the various stakeholders in the SC regarding the problem at hand but also wider sustainability concepts and improving their professional knowledge and qualifications to help in addressing the problem (Table 6 – Learn - items 3 and 5).

The next step is ***strategizing*** and almost every one of the activities in Table 6 under strategize apply. Particularly activities 1-6 are very relevant to the lead paint problem. The next steps are ***Design & Test***, ***Transform***, ***Monitor***, and ***Control*** and all the activities under each step are relevant. The monitoring and control will hopefully help to identify problems earlier both in terms of time as well as further up in the SC. While a way of applying the SSCM Transformation Model (Figure 7 and Table 6) is described here, when there is a need to address a problem the process the transformation model follows can also be used in a positive manner where one can pro-actively identify areas for improvement and enhancement. As can be seen the SSCM transformation model can also be used explicitly to address risk strategically as well as operationally.

The Mattel SC example illustrates how a continuous improvement approach helps in adapting to new processes, learn from experiences, and overcome common barriers to strategic and operational adjustments. The decision models outline structures, processes and guidelines to follow while maintaining flexibility and adaptability in order to adjust to specific user requirements. The importance evaluations of the decision model elements allow for the prioritization of activities, initiatives, and investments. This guidance for decision makers is further supported by the specific goals and development steps outlined in the SSCM maturity model. Radical changes are less likely to succeed in a SC due to often global relationships, inherent complexities, and general averseness of company cultures towards change. The suggested improvement methodology offers adaptable solutions that account for the steadily evolving nature of SCs and priorities in SCM. The proposed decision models therefore follow modular structures which allow for customized configurations and alterations as a SC matures and as SC knowledge increases. The research artefacts thus contribute to decision support in SSCM by providing advanced functionalities i.e. these models would be at the core of decision support systems catering to SC managers tasked with sustainability integration and furthermore hold potential to be generalized towards other contexts.

5.3 Limitations and Future Research

Limitations of this study can be attributed to the composition of the Delphi panel. This study suffered from participant attrition effects resulting in an unbalanced distribution of academics and practitioners. There may also be additional influential SSCM factors or relationships that were not identified. Furthermore, the ratings can only provide a general indication on what to prioritize and individual companies or SCs may have different priorities. Regardless of these issues, we strongly believe having an overview of crucial elements to focus on is of great value for decision makers.

These limitations offer avenues for future research. The identification of influential factors in SSCM could be further supplemented. Verifications of the importance levels of SSCM factors and the proposed decision model relationships are needed. The application in diverse contexts and respective differences in the perception of importance levels need to be evaluated. The SSCM maturity model identifies causal relationships between its elements. While these appear theoretically valid, empirical verifications are required to confirm the correlations proposed. Such targeted research extensions should ideally be based on independent samples from SCs in different geographical regions and industries. Lastly, actual application and testing of the developed artefacts is required for further refinements and model development.

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