A framework for aligning the supply chain throughout a radical product innovation life cycle

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Abstract: Existing recommendations for the management of supply chains in terms of product innovation primarily address the needs of companies in innovative sectors, and are predominantly based on a snapshot classification of product and market characteristics. As technology cycles become shorter and product innovations more radical, it is argued that supply chains have to be realigned step by step to fit the degree of maturity for a product innovation. This aspect has not yet been discussed in research or practice to a large degree, though product and technology life cycle discussions may clearly contribute to the debate. This paper introduces a framework for aligning supply chains based on radical product innovation life cycles: after presenting the state-of-the-art in terms of literature, technological innovation is classified and product innovation life cycle phases are systematised. The applicability and significance of this supply chain design innovation framework is demonstrated based on the example of e-mobility.

Keywords: supply chain design; SCD; supply chain management; SCM; radical product innovation; innovation life cycle; supply chain strategy; electric vehicles.


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1 Introduction

Today’s business environment is characterised by economic, political and ecological uncertainties (Simangunsong et al., 2012), by technology life cycles getting shorter and with more (product) innovations evolving [Chopra and Meindl, (2010), pp.55–56; Nyhuis et al., 2010]. Radical innovations are particularly challenging for a company’s supply chain as a high number of new products and services fail to survive long after market introduction [Garcia and Calantone, 2002; Dell’Era et al., (2013), p.133].

The management of supply chains in regard to product innovations has already been widely discussed (Pfohl, 2007; Quick and Renner, 2010). Nevertheless, existing models and recommendations like Fisher’s (1997) supply chain strategy matrix or Lee’s (2002) uncertainty matrix primarily address companies acting in innovative sectors, such as the high tech and computer industries (Huang et al., 2002). Furthermore, supply chain strategy is often chosen based on a ‘snapshot’ classification of product and market characteristics. There may be a competitive advantage if the supply chain can be aligned stepwise with respect to the respective maturity degree of a product innovation. Although this maturity has been systematised in life cycle discussions, e.g., Gartner’s hype cycle (Fenn and Raskino, 2008) and the well-established innovation S-curve model (Spath and Renz, 2005), it has not been considered in terms of supply chain alignment or supply chain design (SCD) in great detail.

From a supply chain perspective, a high uncertainty especially with regard to market acceptance and, therefore, sales volume is distinctive for any innovation. Previous methods for managing uncertainties have focused on maximising flexibility within the boundaries of the current system (Kuhn et al., 2011). Yet, current research has shown that the supply chain has to be enabled to change its strategic direction and its structure in accordance with dynamic technological changes. In the early phases of innovation life cycles, supply chain processes are not run effectively due to manifold uncertainties. Hence, the company has to interpret signs accurately to be able to act quickly and consequently. The supply chain has to be flexible in terms of structure, processes and resources (Bertsch and Nyhuis, 2011; Klingebiel et al., 2012). In later phases, when sales volumes have stabilised, supply chain processes may be run more cost-effectively.
Therefore, companies have to identify an innovation’s life cycle phase and the impact of being in the respective phase on logistics and supply chain management (SCM). To respond to this challenge, the application of a life cycle model is proposed which companies can use to track the innovation’s progress and identify phase transitions. Nevertheless, different life cycle curves may well need to be considered to create an overall picture and increase the likelihood of interpreting the signs accurately.

This paper proposes a framework for aligning supply chains throughout radical product innovation life cycles, abbreviated as the ‘supply chain strategy framework’. The remainder of the paper is organised as follows. In Section 2, the relevant literature in the field of research is reviewed. The research methodology, implemented to achieve the findings, is presented in Section 3. The framework is developed in Section 4 and its application is demonstrated in Section 5. The findings are discussed in Section 6. Finally, Section 7 draws conclusions and suggests future research directions.

2 Background literature

The following fundamental approaches and models have to be considered in order to define the problem area and identify the academic gap. First, a definition and classification of ‘innovation’ is presented to create a common state-of-the-art apprehension for the field of research and define the scope of this contribution. Second, relevant models, in the context of product life cycles, are described. Section 2.3 briefly presents the state-of-the-art, in terms of logistics and SCM literature relating to product innovation.

2.1 Innovation classes and levels

Although multiple definitions are present in the literature, two main attributes can be derived when defining innovation (Burr, 2004; Mischke, 2007; Hauschildt and Salomo, 2011):

- **Degree of novelty**: An ‘innovation’ has to differ perceptibly from a similar state. In other words, an ‘innovation’ always implies an ‘invention’.

- **Commercial use**: The commercial use (e.g., through market introduction) is the crucial attribute when assessing an ‘innovation’. Economic utilisation is what makes an ‘invention’ an ‘innovation’.

‘Innovation’ has also been classified through five dimensions (Hauschildt and Salomo, 2011):

- **Content-wise**: What is new?

- **Procedural**: What is the beginning and the end of the innovation?

- **Normative**: Does innovation mean success?

- **Intensity**: How new is it?

- **Subjective**: For whom is it new?
In the content-wise dimension, this paper focuses on product innovations, which includes physical and intangible goods that are launched on the market for the benefit of customers or clients (Gopalakrishnan and Damanpour, 1997; Pfohl et al., 2007; Hauschildt and Salomo, 2011). The procedural dimension is discussed further in Section 2.2. The normative dimension is disputed since it depends on the highly subjective objective function of the decision maker (Corsten, 2006). With respect to intensity and subjective dimensions of innovation, the typology by Garcia and Calantone (2002) is followed: Technological innovations are classified with regard to the level of ‘innovativeness’. Innovativeness, which is defined as the ‘degree of newness of an innovation’ can also be separated into three distinct classes (Garcia and Calantone, 2002):

- **Radical innovation**: To be considered radical, an innovation has to be new from a macro (e.g., market, industry) and micro (e.g., firm, customer) perspective as well as having the ability to cause marketing and technology discontinuities.

- **Really new innovation**: Really new innovations result in a marketing or technological discontinuity on a macro level, whereas on a micro level, any combination of the two can occur.

- **Incremental innovation**: If an innovation only occurs on a micro level and either causes marketing or technological discontinuity, it is considered to be incremental.

Following this classification, the framework presented here focuses on supply chains that deal with radical or really new innovations. To facilitate the readability of the paper, those two innovation classes are summarised under the term radical innovations. It is assumed that incremental innovations evolve from an iterative process and are more or less a day-to-day business activity for companies. It is assumed that the management of incremental innovations can typically be handled through effective design of their respective supply chains.

### 2.2 Life cycle models for product innovations

Many different models describe innovation life cycles and the development of product innovations (resp. their underlying technology) over time from various perspectives. The most common models include the adoption curve, the performance S-curve, the maturity curve and Gartner’s hype cycle. Given their relevance for the management of radical innovations from a supply chain perspective, these models are briefly introduced in this section. Further information on theoretical life cycle models is readily available in the academic press (e.g., Burgelman et al., 2009).

One popular concept in the context of innovation evolution is Rogers’ (2003) ‘diffusion of innovation’. The diffusion process has been well established in innovation research literature as the adoption curve (Linden and Fenn, 2003; Rogers et al., 2005; Fenn and Raskino, 2008). This curve is mainly used to explain the market penetration of new technologies and divide consumers in different adoption groups (e.g., innovators, early adopters, early majority, late majority, and laggards) (Rogers, 2003).

The analysis of the financial performance of an innovation is another subject of life cycle representation and can be represented in four phases – innovation, diffusion, maturity and degeneration (Eilenberger, 2012).

Here, financial performance may be assessed based on the profit contribution of the innovation (Eilenberger, 2012). In contrast to traditional product life cycle considerations
the life cycle begins before the launch of the product since a significant share of expenditure for research and development incurs prior to the actual diffusion process. Characteristics for the life cycle of innovations from a financial point of view are negative contribution margins in the early phases of the life cycle (innovation and diffusion) due to high costs in R&D as well as the initial market. These are, however, in the ideal case quickly (over-)compensated through a strong increase in sales in the diffusion phase (Eilenberger, 2012).

Tightly related to the performance model is the concept of technological maturity that “places a technology along a continuum of technological advance” (Roussel et al., 1991). The maturity of a technology cycle is typically divided into four maturity phases along a function of time (Roussel et al., 1991; Fenn and Raskino, 2008; White and Bruton, 2011): embryonic, growth/emerging, adolescence/mature, and aging/saturation. In this context, the dissemination of technology can be the cumulative R&D expenditure or the number of patent applications over time (Gao et al., 2013).

The final innovation life cycle model to be introduced in this paper is Gartner’s hype cycle which was developed in the 1990s (Fenn and Raskino, 2008; Gartner, 2012). The hype cycle describes the evolution process of a technological innovation by depicting the variable ‘expectations’ as a function of time. The ordinate represents the expectations around an innovation; the x-axis shows time (Fenn and Raskino, 2008). Gartner holds the view that an emerging technology starts with the technology trigger, and goes through a period of inflated expectations, followed by disillusionment and enlightenment phases until it enters a plateau of productivity when broad market acceptance is reached (see Figure 1). Although historically used largely in a non-academic context, providing information and advice for their customers, the hype cycle is now increasingly being used in pure research and academic (O’Leary, 2008). It is seen as especially promising with respect to radical product innovation research presented in this article as it specifically focuses on the early phases of a new technology’s life cycle (Linden and Fenn, 2003).

The illustrated life cycle models introduced here seek to provide a comprehensive understanding of different perspectives when analysing the progress of an innovation over time. Furthermore, the models provide an indication of the criteria for describing a radical innovation’s life cycle from a supply chain perspective. The following subsection
provides a brief overview of key research in the context of SCM dealings with (technological) innovation and life cycle models, previously discussed in this section.

2.3 SCM in the context of product innovation and life cycle

SCM research has put emphasis on the design of supply chains based on product characteristics and life cycle phases since the mid-1990s (Quick and Renner, 2010). Fisher’s (1997) supply chain matrix is a simple framework that matches supply chains to product characteristics. Fisher (1997) suggests implementing a responsive supply chain for innovative products and an efficient supply chain for functional products. The idea of adjusting supply chains with regard to external characteristics has further been developed by many researchers (Mason-Jones et al., 2000; Christopher and Towill, 2000). In addition to product characteristics, the consideration of market characteristics has also been proposed. Fisher’s lean and responsive supply chains are complemented by risk-hedging, agile and ‘leagile’ supply chains (Mason-Jones et al., 2000; Christopher and Towill, 2001; Lee, 2002). Lee’s (2004) triple-A supply chain can be seen as a highly sophisticated approach that combines many state-of-the-art recommendations. Besides the classic supply chain goals of high speed and low cost, supply chains have to be agile, adaptable and aligned in order to achieve a sustainable competitive advantage (Lee, 2004). Lee’s approach is mainly applicable to extensive supply chains with a focus on retail. Furthermore, it is an ‘all-in-one approach’ that neither considers different environments, market or product characteristics. All of the approaches do not consider the development of innovative products over time. The models support an assessment of the current state and subsequently recommend a corresponding supply chain strategy. In the following, two models are presented that consider the dynamic development of products and suggest corresponding supply chain strategies.

Aitken et al. (2003) propose a life cycle model with corresponding supply chain strategies that have been derived from a case study from the lighting industry. Dependent on the life cycle phase of the respective product, a corresponding type of supply chain is matched. In this case, the model is not applicable for innovative products: The approach has been developed based on generic lighting products that do not show the characteristics of a radical innovation. The underlying life cycle only covers the ‘standard’ life cycle phases, derived from the classic product life cycle model (Levitt, 1965) and does not include any reference to innovation-specific life cycle phases or product characteristics when deducing strategy recommendations. Furthermore, it deals with production logistics strategies and requires the existence of multiple supply chains (Aitken et al., 2003).

Wang et al. (2004) and Vonderembse et al. (2006) match lean, agile, and hybrid (‘leagile’) supply chains to product types and the standard product life cycle phases, i.e., introduction, growth, maturity, and decline (Levitt, 1965). Although four life cycle phases are mentioned, only two different supply chain strategies are suggested throughout the life cycle. For innovative products, they propose implementing an agile supply chain in the first two life cycle phases. The supply chain strategy should then be ‘switched’ to be more hybrid or lean when innovative products enter the phase of maturity. However, there is no procedure described on how to identify the need for realignment or how to execute the transition to another supply chain strategy.

In summary, existing SCM models and approaches dealing with product innovation are applicable for companies that can inherently characterise their products as being
innovative. However, they often focus on managing incremental product innovations rather than radical product innovations. Furthermore, alignment of supply chain strategies throughout the life cycle has only been described sparsely. When changing supply chain strategies throughout the product life cycle is considered, the distinction of different life cycle phases is rather vague with transition phases, as well as their identification, not discussed in detail.

3 Research methodology

This research combines two methodological approaches for the development of the supply chain strategy framework. First, a systematic literature review was undertaken to provide the theoretical foundation underpinning the suggested framework, as outlined in Section 2. Well-known electronic databases (e.g., Elsevier, Emerald, Princeton University Database) have been used to identify contributions on SCM in the related research domains (search keywords: product innovation SCM, life cycle SCM, supply chain adaptability/alignment, strategic SCM, supply chain strategies, SCM and product characteristics). The findings contributed to gaining a theoretical understanding of the challenges for SCM of product innovations, life cycle-oriented SCM, and SCM along the maturity of product innovations. To gain a comprehensive understanding of life cycle phases in the context of radical product innovations and their specific challenges for supply chains, the same databases were additionally used to search for contributions in the field of maturity of technology and product innovations, as well as technology and product life cycles (search keywords: ‘product/technology maturity’, ‘product/technology life cycles’, and ‘radical product innovations’).

The theoretical findings attained through the literature review were further enhanced by an industry case from the automotive sector. To outline the case and validate the theoretical findings, four consultancy projects and five projects of applied research have been evaluated in cooperation with the Fraunhofer-Institute for Material Flow and Logistics (IML) in Dortmund, Germany. The consultancy projects focussed on supply chains that have been, or are currently, dealing with radical innovations with the potential for disruptive implications. These supply chains involved industries such as automotive, trucking (innovation: e-mobility, autonomous driving), printing and plant engineering (innovations: automation technology and cyber-physical-systems). Research projects on designing supply chains and strategic SCM provided representative case studies for the research presented here and included the DFG project HeliOPP, the EU-funded project ILIPT and two national projects, namely, SCD and E²Log funded by the German Federal Ministry of Education and Research. See Appendix for brief summaries of these projects.

4 Framework development

The literature reviewed in Section 2 provides a strategic and static view of managing radical product innovations from a supply chain perspective. It is clear that a single strategy may be insufficient for a radical product innovation’s life cycle. In the context of radical product innovations, changing requirements due to distinct life cycle phases with different supply chain requirements can especially be expected. For realigning the supply
chain and choosing the right strategy and structure it is essential to define the radical product innovation life cycle phases and their characteristics from a supply chain perspective. Thus, the identification, distinction and characterisation of radical product innovation life cycle phases is one of the core elements of the framework presented here. Alongside the description of the radical product innovation’s life cycle phases, the supply chain strategy framework addresses appropriate strategies and main SCM tasks for each life cycle phase, as well as the prioritisation of supply chain operations reference model (SCOR) performance attributes (Supply Chain Council, 2012).

In this section, the resulting supply chain strategy framework is illustrated. In the first subsection, an integrated life cycle model is developed and set into a methodological context that describes the progress of a radical product innovation from a supply chain perspective. The second subsection discusses appropriate supply chain strategies and the resulting prioritisation of the performance attributes to the different life cycle phases. The findings are then summarised in Section 4.3.

4.1 An integrated radical product innovation life cycle model

The objective has been to design a framework, which supports manufacturers and their supply chains in better understanding radical product innovations from a supply chain perspective. It is focussed on the early phases of the life cycle, when the product innovation has not yet fully been established and internal and external impacts cause multiple challenges for the supply chain. Therefore, a systematisation of life cycle phases for radical product innovations provides the necessary basis. Since Gartner’s hype cycle displays an innovation’s early development from a market perspective in a most detailed way and describes distinct phase characteristics from different perspectives (Linden and Fenn, 2003), it has been chosen as the basis for the systematisation. Other life cycle models do not provide a comparably detailed distinction of different phases in the early life cycle of a product innovation. To counter the risks of misjudging, the life cycle progression when relying on the monitoring of ‘one-dimensional’ indicators (cf. Christensen, 2011), additional life cycle perspectives are incorporated as an integrated radical product innovation life cycle model. The advantages of combining multiple indicators to determine the life cycle development has been previously demonstrated in the literature (Gao et al., 2013).

To track market penetration, the adoption curve has been integrated into the life cycle model. This curve displays the number of adopters as the share of the target market. The technology’s maturity provides an indication of product-based uncertainties that can influence the supply chain. The development of a product innovation’s economic success represents the fourth dimension that is integrated. This is best displayed in the performance S-curve and can be quantified by application of common performance indicators that are commonly used by most companies.

The typical progression of the integrated radical product innovation life cycle model resulting from these considerations is illustrated in Figure 2. To facilitate comparability, the graph focuses on displaying the characteristic qualitative progression (y-axis), i.e., inflection points, extrema and stationary slopes, of the different curves over time (x-axis). Specifically, the curves’ ordinates are to be individually annotated based on the specifically chosen life cycle indicators. Nevertheless, it is also possible to separate the curves, i.e., to illustrate them in individual Cartesian spaces with consistent time scale on the x-axis.
Given its most significant relevance in early life cycle phases, the underlying phases are based on Gartner’s hype cycle. The displayed graph shows an idealised life cycle progression whose realisations differ from case to case, especially with regard to the duration of the different phases. Furthermore, individual characteristics of the respective curves serve as an important basis for determining the specific progression and thus, the supply chain challenges arising in each phase. Nevertheless, this assumes a typical progression of the curves. Yet, in particular cases, some phases (hype, trough) may even be encountered multiple times (Linden and Fenn, 2003; Christensen, 2011). The work presented here focuses on the typical progression of an innovation’s path to successful commercialisation and leaves these specific cases for subsequent research.

Figure 2  Integrated technological innovation life cycle model

Based on the integrated technological innovation life cycle model, a foresight model may be setup to detect changes in a product innovation’s life cycle progress that may cause a need to align a company’s supply chain strategy. Parlings et al. (2013) have shown that an indicator system is most promising in this context, and recommend that indicators representing all four underlying life cycle models need to be assessed in order to holistically determine phase transitions. To identify the indicators, the phases and phase transitions of the integrated technological innovation life cycle model have to be analysed and described formally. The appropriate phase-specific strategies and requirements on supply chain alignment also have to be derived and formalised.

On the basis of the characteristics of radical product innovations and the implications of the life cycle model, the framework (to derive the right supply chain strategy) is developed in the following section.

4.2 Supply chain strategies and performance attribute prioritisation along radical technological innovation life cycles

In the following section, the life cycle phases introduced in Section 4.1 are described and the phase-specific requirements on SCM are derived. The assignment of appropriate supply chain strategies, main supply chain tasks and the prioritisation of performance attributes are discussed for each life cycle phase. As described in Section 3, the supply
chain strategies and main tasks have been identified based on the results of the extensive literature review and the analysis of various case studies involving the authors as part of research and consulting projects. Furthermore, Parlings et al. (2013) suggest applying SCOR performance attributes and metrics for implementing the strategy as guidelines for evaluating the effectiveness of supply chains throughout an innovation’s life cycle. SCOR provides five key performance attributes including an underlying set of hierarchical KPIs: agility, responsiveness, reliability, asset efficiency and cost (Supply Chain Council, 2012). Agility relates to the ability to respond to external influences, like changes in the marketplace, whereas responsiveness describes the ability to perform tasks quickly. Reliability describes the rate at which tasks are performed as expected. Cost and asset efficiency refer to the ability of the supply chain to operate with low expenditures and an efficient usage of fixed assets. These performance attributes serve to guide the strategy of a particular business and are well suited to describe the respective supply chain strategy.

SCOR elements do not necessarily require a 1-to-1 correspondence between a supply chain and a specific product. However, it may not be necessary to develop a completely new supply chain from a company point of view. Parts and elements of existing supply chains may be integrated into the supply chain of the product in focus. Thus, based on the definition of supply chain strategies, the innovation’s life cycle phases and the connected requirements on SCM, the strategy framework has been extended by the prioritisation of SCOR performance attributes according to the life cycle.

4.2.1 Phase 1: technology trigger

On the hype cycle, the first phase of a radical product innovation’s life cycle is characterised by a technological breakthrough that generates press and industry interest in the innovation through an event like a public demonstration (Fenn and Raskino, 2008). The company is developing products based on a technological invention that enter the ‘path to commercialisation’. The pre-competition status of the technology, which is a prerequisite for public-funded research, has been completed. The technology trigger phase is, thus, the entry point to the innovation life cycle as status is changed from a pure technology invention to a product innovation.

After the breakthrough, the hype begins to rise as mass media may start to explain the product innovation and its underlying technology along with its impact on business and society (Linden and Fenn, 2003). From the maturity point of view, the innovation is in the embryonic stage. While a vision of the possible application exists, the product may still be in the lab and have the status of a prototype (Roussel et al., 1991; Fenn and Raskino, 2008). At this phase, the adoption curve has not yet started to evolve since no adoption can exist without viable products. With regard to its performance, the product innovation is in a stage of emergence. There is an initial period of turbulence with little progress and companies might have to pay some ‘tuition’ in the form of reduced or negative profits resulting from high investments in the new product and little sales volume (Lu and Beamish, 2004; Spath and Renz, 2005; Schilling and Esmundo, 2009).

In this early phase of a product innovation’s life cycle, SCM has the unique chance to influence aspects like product design, vertical integration or supplier base that it has to cope with later on in the cycle. The trigger phase offers a good opportunity to integrate the supply chain with the so-called ‘design chain’. According to Cohen and Roussel (2006), the design chain is the network of all partners inside and outside of the company.
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who are involved in the definition and development of new products and services. By integrating the supply chain with the design chain, a quick and sustainable introduction of new products and technologies is facilitated and the supply chain has the ability to quickly respond to fluctuations in demand (Cohen and Roussel, 2006). SCM activities should be designed to begin analysing the characteristics of the technology. Potential supply chain risks may already be identified in advance. In summary, being aware of the trigger phase of a technological innovation offers a great opportunity for SCM to provide the basis for successfully mastering the technological life cycle from a logistics perspective.

Since the supply chain must react to uncertain demand and unknown supplier interactions, it follows that agility and responsiveness at this stage of the product life cycle are prioritised. In the initial stages of process development, responsiveness is particularly critical, as there is a high potential for market change (Williams et al., 2013). Emerging products can potentially face demand beyond the manufacturing capabilities of the firm, which can lead to an overwhelming impact that affects the supply chain from manufacturer to supplier (Amini and Li, 2011). To prevent this, agility is emphasised, even potentially at the expense of asset efficiency and manufacturing reliability. Since it is of high importance to not disappoint first customers, reliability should be a high priority to companies. Liao et al. (2011) assert that the reliability of the supply chain is essential for both supply chain relations and market reputation. In this initial implementation, cost and asset efficiency are not of premium concern, as uncertain demand necessitates that responsiveness is much more critical (Christopher and Holweg, 2011).

4.2.2 Phase 2: the peak of inflated expectations

From the hype cycle viewpoint, the second phase of a radical product innovation’s life cycle is characterised by high expectations and enthusiastic media coverage that leads to the peak of inflated expectations (O’Leary, 2008). Venture capitalists get interested in the product and its underlying technology and the number of vendors increases (Linden and Fenn, 2003). With regard to its maturity, the innovation is transitioning from the late embryonic to the early emerging/growth stage as first-generation products emerge. The adoption process begins with innovators adopting the new technology. Those ‘early prestigious customers’ (Fenn and Raskino, 2008) not only command substantial financial resources but, additionally have the ability to understand and apply complex technical knowledge (Rogers, 2003). The performance of the radical product innovation is at an emergence stage. Here, there may well be a poor return unless some specialised deployments or customised products find a high-margin niche (Linden and Fenn, 2003).

From a supply chain perspective, it is argued that this phase should be used to setup a responsive supply chain. SCM has to ensure design of an appropriate supply chain to support small-scale production of first-generation products. It is important not to get ‘side-tracked’ by, e.g., media hype and resist building excess capacities that match the level of hype. The supply chain should instead be better designed responsively in order to react to some irregular demand. A first supplier base may be built, containing suppliers that are highly reliable rather than low-priced.

With regard to SCOR performance attributes, this second stage of development continues to emphasise responsiveness in order to adapt to fluctuations in the market. Additionally, the need to establish a reliable reputation requires a responsive supply chain
strategy (Parlings et al., 2013). In relation to the priorities presented in phase 1, the responsive supply chain must place a much greater focus on asset efficiency, and generally operate as a more efficient supply chain, which becomes easier as collaboration between firms increases with familiarity (Cao and Zhang, 2011). A slight decrease in reliability may be acceptable as the extremely high volatility in this phase would otherwise require a disproportional input of resources.

4.2.3 Phase 3: trough of disillusionment

The third phase is characterised by disillusionment as the product innovation may not fulfil the overinflated expectations and becomes unfashionable (O’Leary, 2008). Failures and challenges are often publicised by the media rather than opportunities and potential value (Fenn and Raskino, 2008). With regard to its maturity, the product’s technology is at the emerging/growth stage. Early feedback regarding problems and issues from first users and enhanced knowledge are the basis for further technological improvement (Roussel et al., 1991). Although the media hype declines, early adopters may identify benefit coming with the new technology (Linden and Fenn, 2003). These ‘early adopters’ can be characterised as ‘the individual to check with’, being locally acknowledged role models (Rogers, 2003). Up to 5% of the market volume has adopted the technology at the end of this phase (Linden and Fenn, 2003), with the performance of the innovation on a transition from late emergence to an early growth state.

It is argued that SCM should use this phase to consolidate the supplier base and to systematically eliminate inefficiencies. Being cost-efficient is very important at this stage, as the low performance of an innovation, in combination with little market adoption, does not lead to sufficient profit. Additionally, it is getting harder for companies to acquire venture capital with disillusionment dominating the technology’s appreciation. If the company is not capable of diminishing its losses with the contribution by logistics and SCM, it might not make it to the next phase of sustainable growth. At the same time, ensuring the adaptability of the supply chain is of great importance in order to be able to react immediately to rising demand when the technology starts on the slope of enlightenment at the end of the disillusionment phase.

Following Parlings and Klingebiel (2014), this phase marks the turn from prioritising customer-focused metrics (agility, responsiveness and reliability) to the internal-focused metrics of asset efficiency and cost (Supply Chain Council, 2012). The supply chain can afford to be slightly less responsive than in the previous phase, but makes up for this deficiency with a greater focus on cost reduction and overall asset efficiency through lean planning techniques (Danese et al., 2013). While the management of demand fulfilment is a priority, it is additionally important to do so at the lowest cost that does not jeopardise the long-term success of the supply chain (Wagner et al., 2012).

4.2.4 Phase 4: slope of enlightenment

As the understanding about applicability, risks and benefits grows, a sustainable increase of a product innovation’s visibility rather than a media hype based on expectations begins (Fenn and Raskino, 2008). Companies acquire later-round funding for marketing and sales support and the product enters the adolescent/mature phase of the maturity cycle. Second and third generation products are launched and the pace of advance in understanding and development slows down (Linden and Fenn, 2003; Roussel et al.,
The ‘early majority’ follow the early adopters “with deliberate willingness in adopting innovations but seldom lead[s]” (Rogers, 2003). During this stage, adoption is said to rise from 5% up to 30% of the potential market segment (Linden and Fenn, 2003). With regard to its performance, the innovation is in the middle of the growth phase characterised by accelerated performance improvement and a growing profitability (Lu and Beamish, 2004; Schilling and Esmundo, 2009).

From a supply chain perspective, the appropriate strategy in this phase should be to implement agility. Although there is a general trend for rising demand, it is still volatile and cannot reliably be predicted. Availability is an important competitive factor at this stage. An agile supply chain that emphasises short lead-time and a high service level is the best match for those requirements (Mason-Jones et al., 2000; Khalarmov and Ferreira, 2012). On the other hand, SCM has to scale up the capacities of logistics and suppliers as growing market adoption leads to higher demand.

An increase in the hype level creates a more sustainable market that reinvigorates forecasting techniques, which focus on the agility of the supply chain (Parlings and Klingebiel, 2014). Minor perturbations in the market are unlikely to significantly affect the long-term fitness of the product, and the supply chain should, thus, prioritise its reliability and agility to insulate against extreme risk (Ivanov and Sokolov, 2012). Focusing on tapping the potential of a growing market leads to a decreased priority on cost and asset efficiency, as companies need to build up capacities. Coordinating supplier bases is also critical for the establishment of reliability and sustainability (Liao et al., 2011; Rungtusanatham and Forza, 2005). The shift over to an agile strategy reduces the costs and asset efficiency of the supply chain but essentially increases the agility without compromising much reliability (Naim and Gosling, 2011). Giese (2012) even states that cost is such a low priority for the agile supply chain that cost KPIs do not need to be integrated into a performance measurement system. Compared to the adaptable supply chain in phase 3, the agile supply chain ranks responsiveness significantly higher to be able to supply the increasing number of customers reliably with the product against the background of a still volatile demand.

4.2.5 Phase 5: plateau of productivity

As the benefits of the product innovation are broadly demonstrated to and accepted by the real world, the plateau of productivity is entered. An ecosystem around the product and its underlying technology evolves (Linden and Fenn, 2003). The innovation is considered proven and enters the mainstream stage of its maturity with risks being significantly lower (Fenn and Raskino, 2008). Scientific and engineering advances have reached a substantial completion (Roussel et al., 1991). The phase is further characterised by the beginning of mainstream adoption that represents the steepest part of the adoption curve (Linden and Fenn, 2003). The late majority starts adopting the technology because of economic necessities or increasing peer pressure (Rogers, 2003). At the beginning of this phase, performance is still high but with competitive pressure rising, the aging stage is reached and profits begin to diminish (Schilling and Esmundo, 2009).

Reaching the plateau of productivity, SCM has to focus on implementing efficient structures and processes for high-scale production. Since the hype cycle with its high volatility and uncertainty is left behind, a hybrid, ‘leagile’ supply chain that combines lean and agile benefits should be built up (Mason-Jones et al., 2000; Khalarmov and
Ferreira, 2012). This can be accomplished by using postponement strategies and supplier base reduction.

With regard to SCOR performance metrics, asset efficiency and cost should be prioritised higher than in the previous phase to ensure the long-term success of the supply chain as the market matures (Mason-Jones et al., 2000). Reduction of operations costs, especially, should be followed with high priority to ensure the profitability of the supply chain even if price reductions are necessary due to the higher market competition.

By amalgamating lean and agile principles, this style of supply chain is highly reliable, though slightly less responsive and agile than the wholly agile supply chain (Naim and Gosling, 2011).

4.3 Framework outline

The characteristics of the life cycle phases, appropriate supply chain strategies and priority SCM tasks as well as the relative prioritisation of SCOR performance attributes in the individual supply chain phases of radical product innovations are summarised in Table 1. The upper part of the framework is used for the placement of a company’s technological innovation into its respective innovation life cycle phase. The appropriate supply chain strategies, main SCM tasks and the phase-specific prioritisation of SCOR performance attributes are presented in the lower part.

To use the framework for aligning the supply chain throughout a radical product innovation’s life cycle, a process cycle consisting of four steps is recommended. The process is illustrated in Figure 3. The first element is the continuous monitoring of the life cycle development of the radical product innovation. The life cycle monitoring should be done based on the integrated life cycle model presented in Section 4.1. To cope with the challenge of integrating indicators from different perspectives, the foresight model is proposed as a balanced scorecard, i.e., the ‘innovation life cycle BSC’ (Parlings et al., 2013; for exemplary configuration see Figure 4).
A framework for aligning the supply chain throughout a radical product.

### Table 1: Supply chain strategy framework

<table>
<thead>
<tr>
<th>Hype cycle phases</th>
<th>Phase 1: Technology trigger</th>
<th>Phase 2: Inflated expectations</th>
<th>Phase 3: Trough of disillusionment</th>
<th>Phase 4: Slope of enlightenment</th>
<th>Phase 5: Plateau of productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life cycle characteristics from a supply chain view</td>
<td>Level of expectations and visibility</td>
<td>Technological breakthrough mass media coverage rising hype</td>
<td>High expectations enthusiastic media coverage venture capital</td>
<td>Disillusionment, unfashionable failures and challenges publicised</td>
<td>Sustainable increase of visibility later-round funding</td>
</tr>
<tr>
<td>Level of maturity</td>
<td>Embryonic stage technology in lab prototype status</td>
<td>Embryonic to early emerging first-generation products</td>
<td>Emerging technological improvement early feedback</td>
<td>Adolescent 2nd- and 3rd-generation products</td>
<td>Mainstream considered proven lower risks</td>
</tr>
<tr>
<td>Level of market adoption</td>
<td>No adoption</td>
<td>Innovators adoption starts</td>
<td>Early adopters &lt; 5% market adoption</td>
<td>Early majority &lt; 30% market adoption</td>
<td>Steep adoption &gt; 30% market adoption</td>
</tr>
<tr>
<td>Level of economic performance</td>
<td>Emergence companies paying ‘tuition’</td>
<td>Emergence poor return</td>
<td>Late emergence to early growth</td>
<td>Accelerated improvement growing profitability</td>
<td>Profit beginning to diminish</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supply chain phases</th>
<th>Monitoring and integration</th>
<th>Supply chain setup and responsiveness</th>
<th>Consolidation and adaptability</th>
<th>Scale-up and agility</th>
<th>Efficiency and hybrid strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply chain characteristics</td>
<td>SCM strategy</td>
<td>SCM tasks</td>
<td>Priority of SCOR performance attributes</td>
<td>Agility</td>
<td>Responsiveness</td>
</tr>
<tr>
<td>Monitoring and awareness</td>
<td>Design chain integration, risk identification</td>
<td>Responsive supply chain</td>
<td>High</td>
<td>High</td>
<td>Neutral</td>
</tr>
<tr>
<td>Responsive supply chain</td>
<td>Adaptable supply chain</td>
<td>Agile supply chain</td>
<td>High</td>
<td>High</td>
<td>Neutral</td>
</tr>
<tr>
<td>Adaptable supply chain</td>
<td>Scale-up logistics and supplier capabilities</td>
<td>Hybrid, leagile supply chain</td>
<td>High</td>
<td>High</td>
<td>Neutral</td>
</tr>
<tr>
<td>Scale-up and agility</td>
<td>High-scale production efficiency</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Efficiency and hybrid strategy</td>
<td>High-scale production efficiency</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

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If a product innovation’s life cycle phase transition has been detected by monitoring the life cycle indicators, the supply chain strategy needs to be aligned accordingly to ensure the ‘strategic fit’. For this step, marked as the ‘supply chain strategy adaption’, the recommendations of the strategy framework are applied. As a result of aligning the supply chain strategy, the underlying supply chain performance targets have to be adapted to provide guidance for the supply chain performance management. This is carried out by applying the prioritisation presented in the strategy framework to setting target corridors for different supply chain performance metrics as proposed by SCOR. In the following, the performance is continuously measured against the phase-specific targets. If the supply chain is not capable of meeting the targets, the supply chain processes and/or structures need to be reconfigured. However, the details of the supply chain reconfiguration are not subject of the research work presented in this paper.

5 Demonstration and test of the framework

This section provides an application of the supply chain strategy framework using the electric vehicle (EV) case example as being a product innovation. From a macro-perspective EV might not be considered a radical innovation since its basic technologies and functionalities have generally been known for a long time (Kirsch, 2000). Nevertheless, from a micro-perspective, EVs have the characteristics of an innovation. Especially if the concept of ‘purpose design’ is being pursued, EVs may be regarded as really new for automotive manufacturers. From a customer point of view, e-mobility is new since most customers have never been in touch with EVs before. Both, marketing and technological discontinuities occur in the context of e-mobility. New marketing concepts have to be developed to spread the advantages of electric cars. And new mobility concepts like car sharing and new ownership models (e.g., battery leasing) evolve around e-mobility. Furthermore, the development of electric cars requires paradigm shifts in automotive technologies, e.g., battery concepts, wheel hub motors or light-weight construction [Spiegelberg, (2009), pp.69–74]. Hence, it may be concluded that with regard to the degree of innovativeness, e-mobility is classified as being a new emerging technology for the automotive industry.

In terms of the procedural/life cycle dimension, e-mobility’s entrance to the trough of disillusionment phase can roughly be dated to the years of 2011/2011 when news about technological failures [e.g., the battery explosion of the Chevrolet Volt (Reed, 2012a)], unmet sales expectations (Nationale Plattform Elektromobilität, 2012) and financial trouble of market participants [e.g., Think! bankruptcy (Reed, 2012b)] replaced the excitement about potentials. With established car manufacturers such as BMW entering the market with purpose design EVs (e.g., BMW i3) and new market players such as Tesla still surviving the early drawbacks, it seems that EVs might soon enter the slope of enlightenment. In summary, EVs and their respective supply chains can be considered as being an appropriate use case for the framework.

Once EVs have been classified as being a radical innovation given this paper’s understanding, the next step is the monitoring of the life cycle progress of the innovation. The methodology used for this task has been introduced in Section 4.1 as the ‘innovation life cycle BSC’. An exemplary recommendation for indicators for tracking the life cycle progress of electronic vehicles is presented in Figure 4. However, the individual
configuration of the indicator system has to be case-specific in order to consider the innovation, the company, its respective supply chain and the industry sector.

With regard to the hype perspective, the levels of visibility and expectations towards EVs are monitored [Steinert and Leifer, (2010), p.2]. This visibility can best be determined by bibliometric analysis of publications related to EVs in industry-specific journals such as the International Journal of Automotive Technology as well as general news media sources. The level of expectations towards e-mobility can only be approximated indirectly by integrating qualitative measures [Fenn and Raskino, (2008), pp.12–13]. Therefore, the headlines of news media as well as journal articles need to be categorised as being negative or positive towards e-mobility. The progress of technological maturity of EVs may be determined by internal evaluation as well as by monitoring external trends. The actual maturity degree, which is expressed as the percentage of maximum maturity, can be determined by consulting experts methodically, e.g., by using the Delphi method [Lichtenthaler, (2008), pp.63–65]. Bibliometric measures may be used for externally monitoring the maturity progress. The number of items in databases such as the Science Citation Index, patent databases or general newspaper databases emphasise different maturity phases [Watts and Porter, (1997), p.29; Martino, (2003), p.720].

The progress of financial performance may be monitored using absolute and relative indicators [Möller et al., (2011), pp.50–52]. Examples for absolute indicators include income per period generated by EV sales, gross margin per car sold and growth in sales per period. As an appropriate relative indicator, the ratio of the revenue to R&D costs per period should be integrated. For measuring market adoption, the target market for EVs needs to be defined and the market adoption needs to be measured in means of the cumulated number of customers or sold products over time (Linden and Fenn, 2003; Rogers et al., 2005). Another important indicator for predicting phase transitions from an adoption perspective is the adoption speed that may be measured as the number of new customers per period [Rogers, (2003), p.221].

**Figure 4** Exemplary indicators for tracking the EV life cycle

<table>
<thead>
<tr>
<th>Hype Indicators</th>
<th>Maturity Indicators</th>
<th>Adoption Indicators</th>
<th>Financial Performance Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility (quantitatively)</td>
<td>Maturity degree</td>
<td>% adoption by target market</td>
<td>Revenue</td>
</tr>
<tr>
<td># publications/period in journals and newspapers</td>
<td>% of maximum maturity</td>
<td>Cum # customers/# potential customers</td>
<td>Income per period</td>
</tr>
<tr>
<td>Expectations (qualitatively)</td>
<td>R&amp;D stage</td>
<td>Adoption speed</td>
<td>Profitability</td>
</tr>
<tr>
<td>share of positive/negative articles p. period</td>
<td># publications/period in research/patent databases</td>
<td># customers p. period</td>
<td>Gross margin per e-car</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sales growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sales increase p. period</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Return on R&amp;D expenses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ratio of innovation revenue to R&amp;D expenses</td>
</tr>
</tbody>
</table>

Source: Parlings et al. (2013)
After a phase transition has been detected, the appropriate supply chain strategy needs to be determined by using the supply chain strategy framework introduced in Section 4. As has already been pointed out, first theoretical applications of the indicator system on a macro level, considering general news coverage and company examples, implies that for many companies, EVs are in a transition phase that is potentially entering the slope of enlightenment. Hence, applying the framework, it is proposed that companies should look to agile SCD, which includes preparations for scaling-up capacities.

In the next step, the prioritisation of supply chain performance attributes needs to be aligned to any new strategic guidelines. The framework can be used to advise companies on how to prioritise agility and reliability at a higher level, compared to the previous phases. Responsiveness remains neutral. The internal performance attributes asset efficiency and cost may be pursued with less priority in this phase. For tracking the adherence to the prioritisation of the performance attributes, a performance measurement system based on SCOR metrics is recommended (Parlings et al., 2013). If the performance measurement detects that the aligned supply chain targets cannot be met, the supply chain configuration needs to be adapted (Chopra and Meindl, 2010). To change the supply chain configuration, design (SCD) measures need to be enforced. In this context, the SCD task model is helpful to gain an overview and a categorisation of design tasks (Parlings et al., 2013). Companies can individually categorise their design measures and classify the impact on performance attributes. Subsequently, design measures can purposefully be selected according to the deviation of the performance KPIs.

Finally, the performance measurement system may be used for providing ‘internal’ feedback: If the supply chain targets cannot be met, although the supply chain is configured according to unchanged supply chain targets, the supply chain strategy might not be appropriate anymore. In this case, the process of aligning the strategic fit is initiated bottom up due to internal performance measurement contrary to the standard ‘top down’ approach in which the trigger for changing the supply chain strategy is derived from monitoring life cycle indicators (Parlings et al., 2013). This feedback loop closes the control circle for aligning supply chains along the life cycle of radical innovations.

6 Discussion

In this paper, a supply chain strategy framework for aligning the supply chain throughout a radical innovation life cycle has been presented. Being of descriptive/prescriptive nature the findings have mainly been derived from related literature in the fields of innovation management and strategic SCM, but also from several case studies. Two key contributions to theory are as follows:

This new approach provides detailed insight into early life cycle phases of product innovations from a strategic SCM view. It thus closes the gap between strategic SCM research related to product innovations (e.g., Fisher, 1997; Lee, 2002; Vonderembse et al., 2006) and current developments in the field of innovation life cycle research that focuses on shorter life cycles, hype-driven innovation, etc. (e.g., Linden and Fenn, 2003; Järvenpää and Mäkinen, 2008).

Secondly, by focusing on the early life cycle phases and pointing out different strategies and main tasks, the findings contribute to ‘early market survival research’
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Given the strategic perspective of the framework presented, the results are predominantly qualitative. However, the findings may be consolidated, with more quantitative research. The identification of a phase transition serves as a trigger for adapting the supply chain strategy. This trigger element should be integrated with the quantitative research on early warning systems in the field of life cycle analysis (e.g., Gao et al., 2013; Martino, 2003). Additionally, because Supply Chains have to be optimised against strategic guidelines provided by the framework, quantitative decision models of SCD can be applied widely to support this specific task. Especially the integration of Amini and Li’s (2011) approach appears promising: the authors focus on tactical tasks such as optimising sales and production planning as well as safety stock levels for supply chains dealing with new product diffusion. Their findings may be applied when the product innovation enters the ‘slope of enlightenment’ phase and as sustainable, but still highly volatile, demand sets in.

However, the supply chain strategy framework has limitations. The application of straightforward life cycles to draw conclusions for life cycle progress and, thus, to derive supply chain strategies draw on an idealised image of the real world. Nevertheless, due to a research gap in the area of supply chain alignment in the context of innovative products, this framework can allow for decision support in this field of SCM. Under the same argument, the presented findings assume a generic radical product innovation independent from industry-specific characteristics of life cycles or supply chains (see for example, Amini and Li, 2011). The framework presented is open in this context: When aligning the supply chain strategy and configuring the supply chain structure and processes throughout the radical innovation life cycle, industry-specific constraints may be integrated. Nevertheless, the specifics of these constraints may be an aspect to explore in future research.

7 Conclusions and further research

The discussion of the state-of-the-art in literature has clarified that existing models and approaches are primarily designed for companies that can inherently characterise their products as being innovative. A wide variety of life cycle models could potentially form the basis for a distinct innovation characterisation. However, only the standard life cycle model has been applied to SCM so far. Thus, previous research is not directly applicable to managing radical product innovations, as these have to be accompanied by changing supply chain strategies throughout the innovation life cycle until a stable process of product and market maturity is reached.

Based on Gartner’s hype cycle model, an innovation’s early life cycle is divided into five phases whose characteristics in terms of performance and technological maturity point to the supply chain challenges arising in each phase. As a reference model for a company’s supply chain strategy, the supply chain strategy framework supports the classification and monitoring of an innovation’s progress. The insights acquired through this work support metric-driven models for SCM as well as the use of prioritisation of SCOR performance attributes. During each phase of the innovation’s early life cycle every performance attribute category will be prioritised to a different extent in response
to the changing market environment. The framework provides guidance for setting up boundaries for KPI systems by relating supply chain strategies to SCOR performance attributes. Moreover, the framework provides strategies to assist the implementation of these changes.

Finally, the necessity arises to approve the selection of the life cycle models and the division into the phases by further empirical research. Indicators that are more precise have to be integrated into the framework to determine the life cycle phases and identify criteria for the early determination of phase change. The prioritisation of performance attributes provided in this contribution needs to be broken down to the performance metric level. This can help to distinguish between typical and abnormal variance in supply chain efficiency by measuring the deviation within acceptable channels. Furthermore, subsequent research should focus on validating the findings through further empirical investigation and case studies.

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References


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Supply Chain Council (2012) SCOR 11.0 Model Reference, SCC, Houston, TX.

Notes
1 Purpose design is defined as the fundamental new development and design of a vehicle according to the technological constraints and freedom of design of e-mobility [Wallentowitz et al., (2010), p.117].
Appendix

Related research projects

Research project SCD

SCD deals with long-term and strategic decisions on the structural design and configuration of supply chains. The project ‘supply chain design’ (project reference 01IC12L03, funding period 2013–2015) has been funded by the Federal Ministry of Education and Research and aimed to develop a continuous and holistic network design approach. Based on the requirements derived from three industrial use cases in the automotive and manufacturing industry, a generalised planning workflow for agile supply chain design has been designed. The conceptual developments have been prototypically implemented in ‘on-demand’ usable, modularly designed services. The results support the tool-supported design of agile and adaptable supply chains.

Research project energy efficiency in logistics and production (E²Log)

The research project energy efficiency in logistics and production (E²Log, project reference 03ET1012A, funding period 2010–2013), funded by the Federal Ministry of Economic Affairs and Energy, dealt with the development of the ‘eco-tool-suite’ for the assessment of strategic design alternatives in logistics and production networks. E²Log specifically focussed the balance of ecological, economical and performance targets. The ‘eco-tool-suite’ has been applied and validated within use cases in the automotive industry, the manufacturing industry and within logistics.

Research project integrated design and evaluation of logistic networks (HeliOPP)

The research project HeliOPP (project KU 619/19-2, funding period 2009–2014) has been funded by Deutsche Forschungsgemeinschaft within the Brazilian-German Collaborative Research Initiative on Manufacturing Technology (BRAGECRIM). The aim of project phase 1 has been to develop a methodology for order penetration point (OPP) positioning in global automotive supply chains across a complete product life cycle, considering a systematic investigation on the influence of product diversity and resource flexibility under a supply chain perspective. This methodology allows the assessment of OPP design options by providing a structured process as well as analytical and simulation-based evaluation methods. Furthermore, it integrates a framework of OPP drivers and objectives. Beyond broadening the scope from the automotive industry to other industries, the work in renewal phase 2 has been focussed on integrating the two significant arising research fields of supply chain risk management (SCRM) and green supply chain design (GSCD). The supporting research was conducted through three multi-tier case studies which also served as dynamic validation of the developed methods. The first empirical study developed a risk-profile along three Brazilian automotive supply chains. A case study of an eco-balanced German-Argentinian transportation network proved the potential of OPP positioning. In a third case, the benefits of an intra-simulative assessment approach have been evaluated in the context of a supply chain for spare part of agriculture machines.
Research project intelligent logistics for innovative product technologies

The research project intelligent logistics for innovative product technologies (ILIPT) funded by the European Union (project IST/NMP-2004-507592, funding period 2004–2008) was concerned with the concept of the ‘5 day car’ (a customised car that is delivered within five days after its ordering) and encompassed extensive research on the required production and logistics network structures and processes. As car manufacturers rely heavily on their suppliers, the major challenge lies in the efficient organisation of inter-enterprise cooperation.