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An Integrated Innovation Life Cycle Model for Supply Chain Adaption

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Abstract: Supply chains of innovative products are subject to significant change requests during the first phases of the product life cycle. To support the proactive realignment of the supply chain strategy and structure, the early detection of transitions from one life cycle phase to another is crucial. On this account, this paper provides the necessary mathematical foundations based on the life cycle model by Parlings and Klingebiel (2012). The underlying functions and their parameters are derived and analysed to obtain the characteristics that can be used for quantitatively defining phase transitions and early warning areas in an innovation's life cycle.

Keywords: Life Cycle, Innovation, Innovation Management, Supply Chain Strategy, Supply Chain Management, Product Strategy, Forecasts, Characteristic Curves

1. INTRODUCTION

A radical product innovation is defined by a high degree of novelty combined with its commercial use (Hauschildt and Salomo 2011). Given this economic aspect of radical product innovations, the respective supply chains are subject to rapid change requests. Predominantly, this holds true in early life cycle phases when sales volumes are developing unpredictably and the supplier base is not yet fully established. The supply chain strategy determines the way the supply chain management (SCM) tasks (e.g. procurement, transport of material, distribution) are carried out (Chopra and Meindl 2010). Thus, the supply chain strategy needs to be proactively realigned repeatedly throughout an innovation's life cycle, so that the supply chain can support the economic success of the innovation efficiently (Parlings et al. 2013).

In order to detect transitions of the product innovation from one life cycle phase to another, early warning indicators are needed. Then, the status change within the life cycle of the innovation can be interpreted as one possible trigger for changing supply chain requirements and thus for the realignment of the supply chain strategy.

Nevertheless, different life cycle perspectives, such as sales volume, technology maturity and market hype need to be monitored in order to derive the right supply chain strategy (Linden and Fenn 2003; Parlings and Klingebiel 2012). In response to this challenge, the integrated life cycle model for tracking radical innovations in early life cycle phases has been introduced by Parlings and Klingebiel (2012). This paper presents a mathematical description of this model including objectively assessable facts from different life cycle phases, which support an operationalization for the early detection of phase transitions. The findings are demonstrated by analysing a historic radical innovation (MP 3) as well as a current radical innovation (autonomous cars).

2. STATE OF THE ART

This section describes the basics and recent developments in related research topics. In the first section, life cycle models for describing the progress of an innovation are briefly discussed. Following, a supply chain strategy framework for selecting the appropriate supply chain strategy along an innovation's life cycle is introduced. The second section addresses early warning systems and foresight methods.

2.1 Innovation life cycles and supply chain strategy adaption

The well-known life cycle model is the "adoption curve" or the "diffusion model" that mirrors the degree of spread of innovations in a social system and thereby considers socioeconomic aspects. Consumers are typically divided in different adoption groups (Innovators, Early Adopters, Early Majority, Late Majortiy, Laggards) depending on the adoption point in time (Rogers 2003). The curve describes the market penetration of the innovation as the percentage of target group adoption over time.

In contrast, Gartner's Hype Cycle (GHC) describes the process of creating a technological innovation as a function of expectations and the perception of innovation over time (Fenn and Raskino 2008). Five essential phases can be identified according to Gartner: the initiation phase of the technology, the phase of inflated expectations, the phase of the low point, the stage of enlightenment and the phase of the productivity level (Linden and Fenn 2003). This model provides significant input for innovation research given its focus on the early stages of a life cycle model.

The technological maturity s-curve or technology life cycle (TLC) places an innovative product along a continuum of the technological progress. Thereby the maturity within a product life cycle is usually divided into four stages of maturity (Fenn and Raskino 2008): The embryonic stage, the stage of development or growth, the stage of adolescence and

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maturity and the stage of aging. The financial performance of an innovation can be assessed on the basis of the profit contribution of the innovation (Eilenberger 2012). From the financial performance perspective, the consideration of the life cycle starts before the market launch of a product, as a significant share of the expenses for research and development occurs prior to the actual diffusion process. Characteristic for the life cycle of innovative products from a financial point of view are negative profit contributions in the early stages of a life cycle. These are, however, in the ideal case, (over-) compensated by a strong sales increase in the diffusion phase (Eilenberger 2012).

The introduced life cycle models illustrate the development of an innovation from different angles and provide relevant insights in order to pursue and understand the development of an innovation, to determine the current status, and to ultimately derive insights for adapting the supply chain. To assign different supply chain strategies to different life cycle phases aspects from all models are relevant. Thus, the four models form the basis of the integrated technological innovation life cycle model developed by Parlings and Klingebiel (2012) shown in Figure 1.

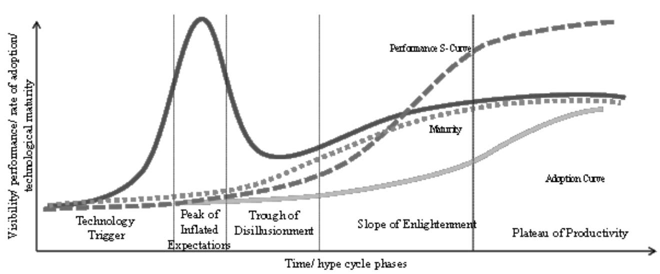

Figure 1: Integrated Technological Innovation Life Cycle Model (Parlings and Klingebiel 2012)

If a phase transition can be identified in the life cycle progress, the supply chain strategy may be adapted in time, thus ensuring the strategic fit (Parlings et al. 2013). For selecting the right supply chain strategy for each life cycle phase, the framework illustrated in Figure 2 has been developed which allows determining the appropriate supply chain strategy for the respective life cycle phase of an innovation (Parlings and Klingebiel 2012).

		Phase 1: Technology Trigger	Phase 2: Inflated Expectations	Phase 3: Trough of Disillusionment	Phase 4: Slope of Enlightenment	Phase 5: Plateau of Productivity
Supply Chain Phases		Monitoring and Integration	Supply Chain Setup and Responsiveness	Consolidation and Adaptability	Scale-Up and Agility	Efficiency and Hybrid strategy
Supply Chain Characteristics	SCM Strategy	Monitoring and Awareness	Responsive Supply Chain	Adaptable Supply Chain	Agile Supply Chain	Hybrid, leagile Supply Chain
	SCM Tasks	Design Chain Integration, Risk identification	Resist the hype Highly reliable supplier base	Consolidation of supplier base, Cost-efficiency	Scale-up logistics and supplier capabilities	High-scale production Efficiency

Figure 2: Framework for mastering innovation from a supply chain perspective (Parlings and Klingebiel 2012)

2.2 Early warning systems and foresight methods

Since the development of an innovation's life cycle progress is hardly predictable, the identification of phase transitions in the life cycles of innovative products can be assigned to the research field of foresight methods. Potential risks, opportunities and initiating countermeasures (adaptation of the supply chain) need to be predicted (Loew 2003). This requires the monitoring of short- and medium-term developments of technologies, products and markets (Loew 2003). The most promising type of foresight methods are predictive models based on indicators that monitor information from the macro- and microeconomic environment to create a basis for predicting the further development (Moder 2008).

The balanced scorecard (BSC) approach is a recognized method for the integration of different perspectives and indicators (Kaplan and Norton 1992). The classic BSC approach extends the financial perspective by three further perspectives: customer, internal process, learning and growth perspective (Vinkemeier 2008). Parlings et al. (2013) have shown that an indicator-based BSC approach as a framework for monitoring the life cycle curve of innovations, and in particular, the identification of phase transitions is suitable. Nevertheless, for each life cycle perspective indicators for tracking the progress need to be defined. The resulting innovation life cycle BSC with exemplary indicators for tracking an innovation's life cycle progress is illustrated in Figure 3.

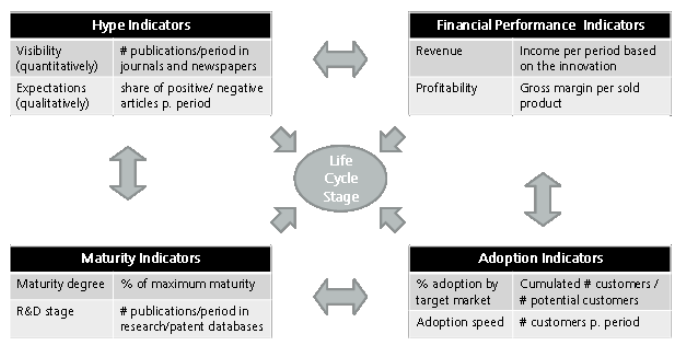

Figure 3: Innovation Life Cycle BSC (Parlings et al. 2013)

2.3 Intermediate Conclusion

For an adjustment of the supply chain strategy to the dynamic needs of the life cycle history of an innovation, early detection of phase transitions by using appropriate monitoring methods is required. An analysis of different methods has shown that indicator systems appear to be promisingly usable. Early detection should be realized by the use of an early warning system, which is based on objectively assessable facts that can e.g. be derived from the Innovation Life Cycle BSC following Parlings et al. (2013). In order to allow the quantitative determination of phase transitions, a mathematical description of the life cycle model is necessary. In the following chapter the integrated life cycle model is mathematical analysed focusing on the mathematical definition of phase transitions.

3. FINDINGS

This section first provides the general mathematical description of the curves integrated in the life cycle model. In the second sub-section the critical points that indicate a phase transition are identified and described.