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FROM PRODUCT DEVELOPMENT TO MARKET INTRODUCTION: A CO-CITATION ANALYSIS IN THE FIELD OF RAMP-UP

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ABSTRACT

Shorter product life cycles and increasing market competition have driven firms to cut their development times and accelerate the introduction of new products into the market. Deviations from the target can lead to significant economic consequences. The use of new technologies and implementation of innovative approaches entail the risk that unexpected problems in the development and manufacturing process may arise.

The literature review presented in this paper is based on a co-citation analysis and should help to understand the linkage between different research areas in the field of product launch. The co-citation analysis is a common tool for examining a body of literature and produces cluster-enhanced multidimensional scaling maps to visualize the subject's relatedness in an interdisciplinary literature field.

An analysis of various research streams in the interdisciplinary field of ramp-up is essential to create a better understanding of critical causes of delay in launching a new product, the correlation between factors that influence the ramp-up performance and possible gaps in the research.

Keywords: early design phases, product lifecycle management, research methodology, product launch, production ramp-up

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1 INTRODUCTION

Customized products, increasing globalization and shortening of life cycles increase the importance of product introduction into the market. The ability to develop, produce and introduce new products faster than the competition is an important factor for success in companies (Carrillo and Franza, 2006). As a result, manufacturers have to cut development time and production ramp-up has to be performed more frequently (Terwiesch et al., 2001). Companies who are first in the market with new products can obtain first-mover advantages, extending the effective selling period, positioning themselves as technology leaders in the market and, with that, increase their competitiveness (Meyer and Utterback, 1995; Langerak and Hultink, 2005). As a result, the adherence to planned time-to-market obtains special significance. An international study of the automotive industry ascertained that only 40% of all investigated production ramp-ups were economically and technically successful (Schuh et al., 2005). The development and market introduction of new innovative products represent high financial effort and expenditure of resources for companies and entails the risk that there may unexpected problems in the development and manufacturing process as a result.

The literature review presented in this paper is based on a co-citation analysis and should help to achieve better understanding of critical causes of delay in launching a new product, the correlation between factors influencing the ramp-up performance and possible gaps in product launch. In the next section the background and importance of the production ramp-up will be described. The co-citation analysis methodology of preparation, data gathering, clustering and interpretation concerning product launch will then be presented. The paper closes with the outlook for further research and the conclusion.

2 THE HARMONIZATION OF PRODUCT DEVELOPMENT AND PRODUCTION AS A KEY FACTOR IN SUCCESSFUL PRODUCT LAUNCH

According to various authors, ramp-up is a critical phase in product life-cycle (Meyer and Utterback, 1995; Schuh et al., 2005; Terwiesch et al., 2001). The major task within production ramp-up is to achieve the required volume while performance targets, such as product quality, cost and time, are fulfilled. Companies have to take several influencing factors into account to overcome the gap between supply and demand with short time-to-volume. Time delays in the development and introduction of innovative products have a strong negative impact on gross profits.

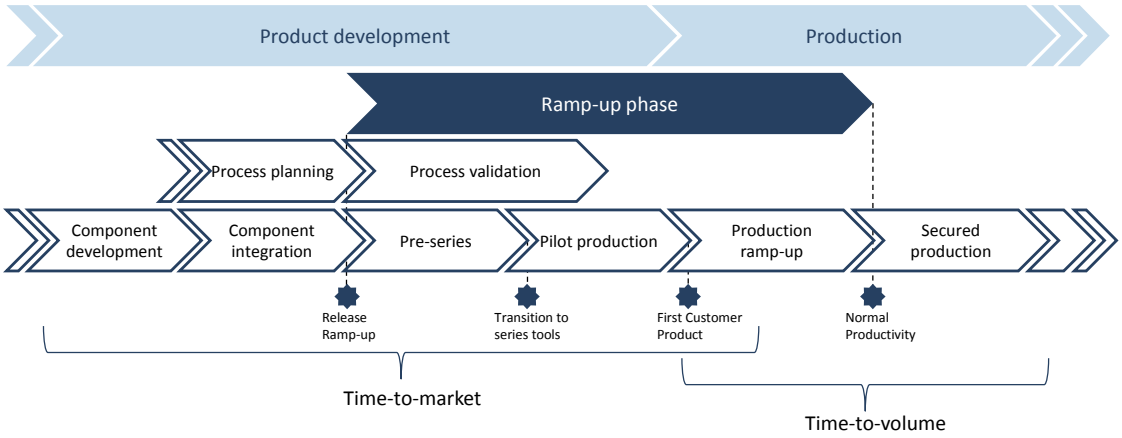


Figure 1. Overview of the ramp-up phase in the automotive industry based on Wangenheim (1998) and Terwiesch et al. (2001)

The ramp-up phase marks the start of the transition between completed product development and series production. The transfer from development to production takes place in stages. Changes and disturbances in the product and in the process are usually resolved within the pre-series and pilot production with the help of numerous prototypes (Figure 1). The end of this phase represents the achievement of the previously defined output quantity and quality of the product and then proceeds into series production (Terwiesch and Bohn, 2001).

The ramp-up phase is a dynamic phase with many changes and mistakes that significantly affect the following processes in the company. The complexity arises from the initial integration of the various

design objects (such as technologies, processes, products, and supply chain) and disciplines (product development, production, logistics, and purchasing) (Schuh et al., 2005). Two critical factors that characterize the phase between development and full capacity production can be identified: an initially low production capacity caused by poor understanding of the process that is inherently chaotic; and high customer demand as a result of the product's novelty in the market (Terwiesch et al., 2001). Especially in complex series products, the transition phase has special requirements for the design of the interface between development and production. Extensive knowledge is required due to the large number of systems, components and parts in which different technologies can be used. There is a highly significant correlation between the duration of the ramp-up and the complexity of new technologies, the extent of system change and the project scope. Decreasing depth of development requires additional coordination with external organizational units and generates organizational complexity (Tatikonda and Rosenthal, 2000). A successful transfer into series production is affected by the novelty or innovativeness of the product and its quality (maturity). The probability of a delay during the ramp-up phase increases with the degree of innovation of the product and process technologies (Meyer and Utterback, 1995).
In the next section a bibliometric method will be presented for identifying research streams with the help of co-citation. The co-citation analysis is a common tool for examining a body of literature and produces cluster-enhanced multidimensional scaling maps to visualize the subject's relatedness in an interdisciplinary literature field.

3 EXPLORING THE STRUCTURE OF PRODUCT LAUNCH RESEARCH

In the following section a systematic literature review in the form of a co-citation analysis is presented. The aim is to highlight the major research streams in the interdisciplinary fields of product launch and production ramp-up.

3.1 Methodology: The Co-citation method

The method of co-citation analysis is a well-established bibliometric method for analyzing the structures of scientific research fields (Meyer et al., 2009; Gmür, 2003). Co-citation analyzes the relationship that exists between several cited publications (Meyer et al., 2009). Co-Citations examine the closeness of the publications and their internal structure of research. Two papers (or authors) are co-cited if they appear in the same list of reference of a given paper. The higher the number of co-citations, the higher the content-related proximity of the two papers (or authors).
The analysis can be divided into two approaches, depending on the object to be studied, the author co-citation or the document co-citation approach (Gmür, 2003). The author co-citation analysis has the aim of examining the underlying social structures of authors who were cited together. However, the document-based analysis investigates the intellectual structure of research fields which relies on the co-cited papers (Gmür, 2003). The document-based analysis leads to more specific patterns than the author-based analysis. The aim of this paper is to find out which streams of research exist in the field of product launch and which spots remain to be filled; a document-based co-citation analysis is suitable for the investigation.
In the literature a large number of different methods exist to determine co-citation clusters (Gmür, 2003). For the analysis in this paper and to generate distinctive and clearly defined lines of research, the method of CoCit-Score is used. Absolute citation values are not suitable for defining clearly separated clusters; the most cited publications tend to be cited more often because of their dissemination. The CoCit-Score is a measure which puts the absolute citation value in relation to the frequency of citation (Meyer et al., 2009). The procedure of the analysis is based on Meyer et al. (2009) and divided into three main steps. It will be discussed in the subsections data collection, data preparation, identification and interpretation of clusters.

3.2 Data collection

Three different databases (EBSCO Business Source Premier, ISI Web of Science and IEEE Xplore Digital Library) are used. Relevant papers were found using keywords ("product launch", "ramp-up", "ramp up", "production ramp-up", and "production start-up") that characterize the interface between development and entry into market. The co-citation analysis only included journal articles, hence it can be assumed that the contributions due to the review process have a high scientific quality and represent accepted knowledge within the research community (Gmür, 2003). The results of the search were

screened for duplicates, working papers, conference articles, and accidental search results; these were excluded from the database. The search was performed in the order of ISI Web of Science, EBSCO Business Source Premier and then IEEE Xplore Digital Library. The final database included 206 papers for analysis.

3.3 Data preparation

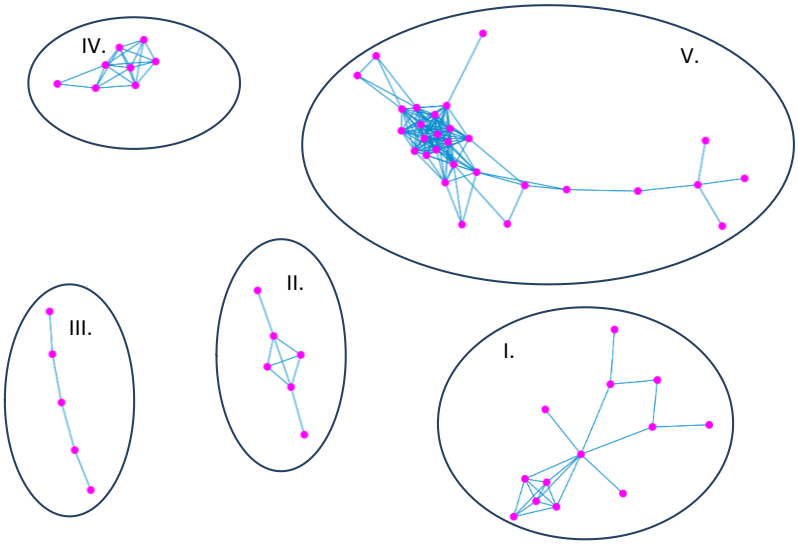
In the next section the co-citation matrix has to be constructed and visualized. The references of each publication are needed for the construction of the matrix. Therefore, the references are extracted either automatically (ISI) or manually (EBSCO, IEEE). Finally, the raw data of the database was checked for errors, such as misspellings or different citation styles. Because of the high number of journal articles the references which were not part of the dataset, i.e. those which were not included in the 206 papers, were excluded. This reduces the complexity of the analysis and the matrix can be constructed more efficiently. The next step was to build up the first matrix (206 x 206) with all publications and the indication of which publications were cited. Publications which were not cited at all and not co-cited were removed from the data set. This leads to a data set for the co-citation analysis of 71 publications. In the last step the co-citation matrix was built. For the closeness measure, as already mentioned, the CoCit-Score was calculated. The calculation of the score, which is scaled to a range of value between 0 and 1, can be calculated as (Gmür, 2003):

$$CoCit_{AB} = \frac{(co\text{-}citation_{AB})^2}{minimum\ (citation_A; citation_B) \times mean\ (citation_A; citation_B)} \quad (1)$$

The final symmetric matrix included 71 publications with the associated CoCit-Score.

3.4 Identification and interpretation of clusters

For the visualization of the co-citation network, ORA (organizational risk analyzer), developed at Carnegie Mellon University, was used. The resulting network provides different clusters which can occur in the form of isolated nodes or pairs, chains, stars or groups with different sizes (Meyer et al., 2009). In this paper a group of nodes is described as a cluster when it has at least three linked nodes.
A threshold has to be chosen to make the clusters visible for the interpretation. Only publications or nodes with a CoCit-Score higher than the threshold are shown. The threshold has to be increased until the first interpretable clusters occur. At a threshold of 0.2, five clusters emerge (Figure 2). These clusters can be considered as different themes in the field of product transfer from development to production ramp-up. In the following section the clusters will be described for their common thematic grounds and research fields.



Cluster 1
Bohn and Terwiesch, 1999
Ceglarek et al., 2004
Haller et al., 2003
Karlsson and Ahlstrom, 1996
Lenfle and Midler, 2009
Lin and Chen, 2004
Loch et al., 2001
Pruett and Thomas, 2008
Terwiesch and Bohn, 2001
Terwiesch and Xu, 2004
Terwiesch et al., 2001
van Hoek and Chapman, 2006
Vandevelde and van Dierdonck, 2003
Cluster 2
Calantone and Griffith, 2007
Harvey and Griffith, 2007
Langerak and Hultink, 2005
Lee and Wong, 2010
Song et al., 2010
Tatikonda and Rosenthal, 2000
Cluster 3
Fleischer et al., 2004
Hertrampf et al., 2008a
Hertrampf et al., 2008b
Scholz-Reiter et al., 2008
Straub et al., 2006
Cluster 4
Fleischer et al., 2005
Hinrichs et al., 2004
Meier et al., 2004
Reinfelder et al., 2004
Scholz-Reiter et al., 2004
Wildemann, 2004
Wildemann, 2005
Zäh and Möller, 2004

Cluster 5
Beard and Easingwood, 1996
Bowersox et al., 1999
Bruce et al., 2007
Chiu et al., 2006
Cristiano et al., 2001
Debruyne et al., 2002
Di Benedetto, 1999
Ford and Sobek, 2005
Guiltinan, 1999
Hitsch, 2006
Ho et al., 2002
Hultink and Robben, 1999
Hultink et al., 1997
Hultink et al., 1998
Langerak et al., 2004
Lee and O'Connor, 2003
Leslie and Holloway, 2006
Luan and Sudhir, 2010
Micheal et al., 2003
Qin and Nembhard, 2010
Santiago and Bifano, 2005
Savin and Terwiesch, 2005
Schatzel and Calantone, 2006
Song and Swink, 2009
Swink and Calantone, 2004
Talke and Hultink, 2010a
Talke and Hultink, 2010b
Wang and Lin, 2009

Figure 2. Co-citation network with five main clusters (threshold 0.2)

3.4.1 The consideration of learning effects on production ramp-up (Cluster 1)

This cluster consists of 13 publications and represents the most distinguished cluster of the network. They are all related to the learning effects and experience-based learning from development until production ramp-up to facilitating the market introduction. Terwiesch et al. (2001) reviewed the underlying effects on ramp-up performance (yield-driven production process) and learning effects. They pointed out that the run of engineering trials (rate of experiments) yield and speed of improvements are the main levers to increase performance during production ramp-up (Terwiesch and Bohn, 2001; Terwiesch et al., 2001; Pruett and Thomas, 2008). Influencing factors which have direct impact on the performance are complexity and newness of technologies, complex processes with low initial understanding, process changes and late realization of learning effects in the production process (Vandevelde and van Dierdonck, 2003; Lenfle and Midler, 2009; Terwiesch and Xu, 2004). Different approaches were proposed to overcome the organizational, physical, personal and cultural barriers for the realization of learning effects. Bohn and Terwiesch (1999) highlighted the importance of the quality of work (learning effects) and resulting yields compared to low labor costs and lower unit costs for production ramp-up. The mathematical model from Bohn and Terwiesch (1999) helps to understand what effects automation, process improvement and wage rates have on the yield of production process. The early integration of different stakeholders and their knowledge of supply chain, research and development and sales have to be considered for an efficient ramp-up strategy of new product launches (van Hoek and Chapman 2006; Loch et al., 2001; Lin and Chen, 2004; Karlsson and Åhlström, 1996). Other studies research the prediction and variation in manufacturing processes (Ceglarek et al., 2004) and management of cycle times during production ramp-up (Haller et al., 2003) to increase the scope of action for potential ramp-up problems.

3.4.2 Market introduction and global product launch (Cluster 2)

This cluster of literature explores the product launch from the strategic perspectives of market introduction and global product rollout. Langerak and Hultink (2005) investigated the impact of different acceleration approaches on development speed and product profitability. They linked their results to different market entry strategies. Different approaches (i.e. supplier involvement and lead user involvement) are more suitable for the pioneer strategy to obtain first-mover advantages and other approaches (reduction of parts and components, and training and rewarding of employees) are suitable for the fast-follower strategy. Especially for products with a high technology novelty, it is challenging to achieve the desired unit costs and time to market (Tatikonda and Rosenthal, 2000).

A global product launch increases the complexity of strategic decisions about introducing new products without delay. The market potential and product launch timing has to be taken into account. The investigations of Lee and Wong (2010) underlined the importance of marketing proficiencies in achieving on-time development of new products for international product rollout. The relationship between new product development (NPD), organization project resources and project team capabilities must be managed by developing strategies to improve the outcome (product launch timeliness) (Lee and Wong, 2010; Harvey and Griffith, 2007). The impact of project organizational factors on timeliness in particular is strongly dependent on the capacity of the project team for new product marketing activities and insures against development and launch delays (Lee and Wong, 2010; Calantone and Griffith, 2007).

Song et al. (2010) came up with an additional aspect for global rollout of a new product. They identified and investigated the skills, resources, and knowledge needed for developing and introducing a successful first product of a new venture.

3.4.3 Reference models for efficient production ramp-up (Cluster 3)

The five papers in this cluster support the product launch from the perspective of production ramp-up. The chain-shaped cluster with no significant crosslinks assumes that authors share a common issue but that there is no dominant publication. The different approaches represent frameworks and reference models with the same goal of ensuring an efficient production ramp-up with an adapted planning and configuration of cross-company ramp-up processes (Fleischer et al., 2004; Hertrampf et al 2008a; Scholz-Reiter et al., 2008). The approach of Hertrampf et al. (2008b) is based on a classification of production ramp-ups in ramp-up types according to the starting framework conditions (i.e. complexity, technology innovation, etc.). Reference processes that describe the typical ramp-up conditions and allow the early identification of ramp-up problems and the definition of counter-measures were

developed for different types. The approaches of Fleischer et al. (2004) and Straub et al. (2006) are based on a guideline and knowledge basis supporting the ramp-up processes with different systems to observe, analyze, predict and react quickly to unforeseen influences during production ramp-up.

3.4.4 Support of manufacturing processes during production ramp-up (Cluster 4)

This cluster contains seven publications. Similar to the previous cluster, the publications focus more on the start-up of production than the fuzzy front end of development. They concentrate on the question of how production ramp-up can be supported in an operational way. Therefore, they developed different software prototypes for simulation and statistical analysis methods (Fleischer et al., 2005), and mathematical modeling of ramp-up curves (Meier et al., 2004) to plan, visualize and control the unstable production process during ramp-up phase (Hellingrath et al., 2004; Reinfelder et al., 2004).

Scholz-Reiter et al. (2004) introduced a hybrid change management for production ramp-up. The hybrid solution for technical changes combines standardized change processes with process elements of suppliers and knowledge management. In addition, a transfer of the current ramp-up experience helps to improve standard change processes for successor products to achieve a long-term improvement of ramp-up preparation.

Risk management approaches to production ramp-up provide valuable support for efficient planning and controlling (Zäh and Möller, 2004; Wildemann, 2005). The procedures are based on the classic phases of risk management (identification, assessment, controlling, and monitoring). Proactive risk response strategies are necessary to reduce and transform technical and organizational risk to achieve a robust production system (Wildemann, 2004; Zäh and Möller, 2004).

3.4.5 Strategic decisions for product launch (Cluster 5)

The last cluster consists of 28 publications that are involved in the theme of strategic decisions for launching a new product and market anticipation. For better understanding and interpretation the threshold is increased to 0.5. Two main sub-clusters emerge, with 15 (Cluster 5.1) and 4 publications (Cluster 5.2), which will be explained in the following.

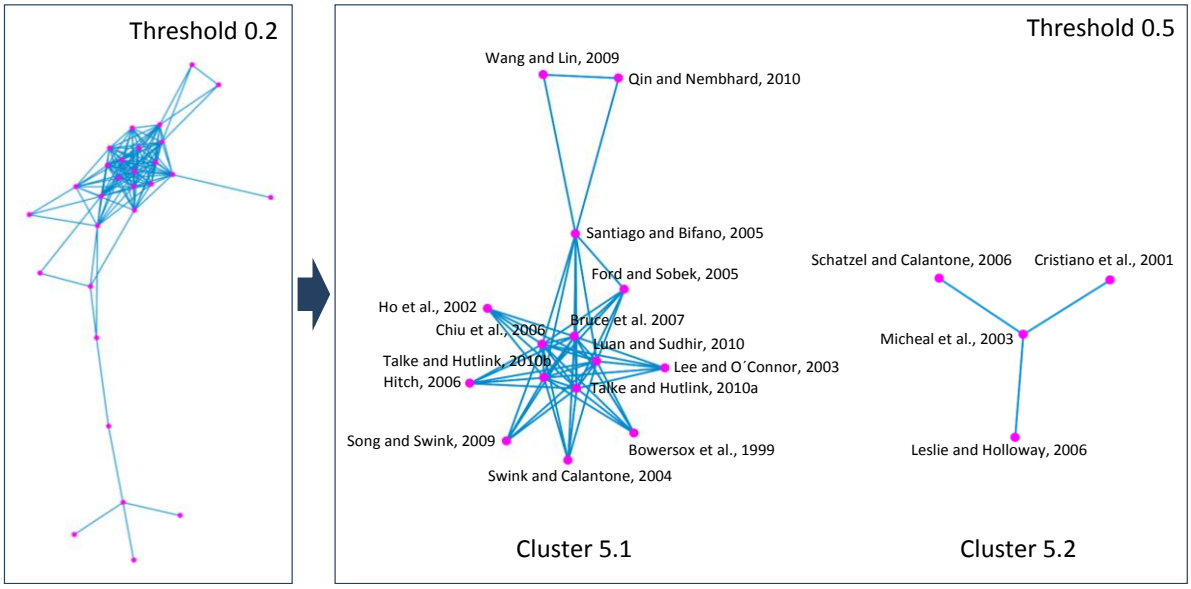


Figure 3. Cluster 5 and emerging sub-clusters

Fuzzy front end decisions for product launch strategies (Cluster 5.1)

The grouping of the cluster indicates a core of about five papers that are strongly interconnected and surrounded by different papers, which themselves show little connection to each other. The core of the star-shaped cluster covers all main aspects of decisions for launching new products, while the satellites represent part-aspects of this topic. Especially for the new product development manager decisions have to be made in advance and under uncertainty (Talke and Hultink, 2010a). Market success is strongly correlated with the product launch strategy (Chiu et al. 2006; Bruce et al., 2007), selecting target markets, positioning the new product (Luan and Sudhir, 2010; Talke and Hultink, 2010b) and

lowering diffusion barriers when launching new products (Talke and Hultink, 2010a). Diffusion barriers related to customers, suppliers and stakeholders of the network especially need to be lowered during product introduction (Talke and Hultink 2010a; Swink and Calantone, 2004). Before and during the product launch the companies have to overcome the gap between supply and demand of the new product. This is correlated to the market dynamics, entry strategies and network effects. Pioneers, for example, could lose market shares if they underestimate demand and have an insufficient base to overcome the diffusion barriers (Lee and O'Connor, 2003; Hitsch, 2006). Ho et al. (2002), investigate the supply processes for new product diffusion, and consider the influence of backorder and lost sales. Bowersox et al. (1999) approach of response-based logistics claims to increase the flexibility of inventory and supports rapid reacting to actual demand. Other papers in this cluster focus on supporting new product development and manager decisions with an early integration of marketing and set-based strategies (Song and Swink 2009; Ford and Sobek 2005; Santiago and Bifano, 2005), and simulation-based models (Wang and Lin, 2009; Qin and Nembhard, 2010).

Sales aspects for launching products (Cluster 5.2)

This cluster consists of four publications that main concentrate on sales aspects regarding new product launch. The sales effort and strategy for new products is a key driver for successful market introduction (Micheal et al., 2003; Leslie and Holloway, 2006). Product introduction of the category "not-new-to-market" but "new-to-the-firm" benefits from the experience of competitor strategies and make an adaption of their own launching strategy more easy (Micheal et al., 2003). Leslie and Holloway (2006) suggest connecting the sales learning curve effects with launch strategies to plan resource allocation more accurately. Beside classical manufacturing learning effects the company has to understand the market and customer to avoid increasing lead-time and costly adaptations of their products (Leslie and Holloway, 2006; Cristiano et al., 2001). Additionally, the study of Schatzel and Calantone (2006) examines the preannouncing of new products as a strategic marketing communication and underlines the positive effect on product launch success.

4 TOWARDS A CONSIDERATION OF RAMP-UP PHASE IN PRODUCT DEVELOPMENT

The co-citation analysis highlighted the main areas in the field of product launch research. The examination is limited to the journal article of the databases and does not claim to be exhaustive. The selection of keywords represents an essential part of the analysis. Nevertheless, it is a helpful method to understand the focus of research. Generally, the research streams can be classified according to a focus on the fuzzy front end of product development with strategic aspects (Cluster 2 and 5) and numerous contributions to support new production processes and immediate manufacturing ramp-up (Cluster 1, 3 and 4). Table 1 gives an overview of the identified clusters and their specific research fields and influencing factors. The overview is limited to the database of 71 publications which were analyzed with the help of the co-citation method.

Table 1. Summary of research clusters and their research subjects

Support production process and immediate ramp-up	
Cluster 1 - The consideration of learning effects on production ramp-up	
experience based learning	yield & speed of improvements
complexity of technologies	rate of experiments
variation of manufacturing process	newness of technologies
Cluster 3 - Reference models for efficient production ramp-up	
ramp-up types according starting conditions	guideline and knowledge basis
planning and configuration of cross-company ramp-up processes	
Cluster 4 - Support of manufacturing processes during ramp-up	
simulation and statistical analysis	planning and controlling
robust production system	technical changes

Fuzzy front end of product development	
Cluster 2 - Market introduction and global product launch	
market entry strategies	marketing proficiencies
product launch timing	unit-costs and time-to-market
Cluster 5 - Strategic decisions for product launch	
product launch strategy	diffusion barriers
supply chain network	market dynamic
sales effort and strategy	market prediction
preannouncing	

Despite the very heterogeneous network, the interdisciplinary topic of ramp-up and numerous publications create a gap in the literature for the methodical support of product development regarding the ramp-up phase or the transition from development to market introduction. Strategic decisions concerning new products are made in the fuzzy front end, but what happens during product

development will have a similarly strong impact on the initial capabilities and performance of ramp-up. The linkage between success factors for efficient market introduction and events during product development process provides an interesting field of further research. Product structuring strategies, i.e. platform strategies, modularization, and commonality, can help companies to realize positive effects on ramp-up, as well as all well-known aspects of advantages. The identified themes, methods, empirical studies and research subjects in the different clusters can be broken down into a few main influencing factors which should be considered for a new product launch. Decisive in this are the project scope (new product family or derivative), product and process complexity, newness of product and process technologies, depth of engineering and vertical range of manufacture, uncertainty and dynamic during development. These factors are mainly driven by the development and should be considered to ensure market introduction.

A risk-oriented consideration of both development and production decisions to support an effective product launch remains relatively unexplored. Therefore, the aim must be to provide a basis for decisions during development of the product. The risk identification and assessment of new products must be practicable with given initial uncertainties. The increased consideration and implementation of ramp-up processes in the design field becomes more and more necessary to compete in a global market.

5 CONCLUSION

The acceleration of the introduction of new products is driven by numerous factors and represents a research field with increasing importance. The co-citation analysis performed in this paper provides a systematic method for literature review of the field of product launch. Three different databases were used to create a data set of 206 publications. With the help of the calculated CoCit-Scores a co-citation network was visualized. Five different clusters of research focus could be identified that mainly concentrate on strategic decision support, market aspects and hedging the manufacturing process regarding the product launch. The interface between product development decisions and production processes as well as the consideration of factors for successful market introduction represent an interesting avenue of research. An additional aspect of research is the risk-oriented support of ramp-up along different product life cycle phases.

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