NordDesign 2012
August 22 – 24, 2012
Aalborg, Denmark

Methodical approach for an efficient transition from development to production

Steffen Elstner and Dieter Krause
Institute of Product Development and Mechanical Engineering Design (PKT)
Hamburg University of Technology (TUHH), Germany
steffen.elstner@tuhh.de

Abstract
Shorter product life cycles and increasing market competition forces companies to accelerate the introduction of new products into the market. The ability to realize an efficient transfer from development to production is an important factor in the success of a company. The aim here is to develop a methodology for the early identification and minimization of ramp-up risks with the help of response strategies from product development.

Keywords: Product launch, Risk, Uncertainty, Early development phase.

Introduction

In recent decades, markets for manufacturers have become more and more competitive. The acceleration of the introduction of new products is driven by customer's needs, shortening of product life cycles and increasing globalisation. As a result, manufacturers have to cut their development time and production ramp-up has to be performed more frequently [1]. It is becoming increasingly difficult to realize the payoffs of high development costs during the market cycle when problems in the industrialization of a product occur. An international study in the automotive industry ascertained that only 40% of all investigated production ramp-ups were economically and technically successful [2]. In a survey of 48 Swedish manufacturing companies, almost 80 % confirmed that production ramp-up is a critical process [3]. As well as normal production, the development and market introduction of new innovative products represents high financial effort and expenditure of resources for companies. The use of new technologies and implementation of innovative approaches entails a risk that it may lead to unexpected problems in the development and manufacturing process. It is essential that potential ramp-up risks are identified and managed. Particular attention should be paid especially to new product technologies, as they imply high initial uncertainty.
The approach presented in this paper should help to analysis possible causes of deviations during ramp-up in the early stages of development, and support decision-making before and during the transition to serial production.

State of the art

Many firms have recognized the importance of the trends described above and tried to cut their development time and launch new products into the market faster than their competitors. The benefits include extending the effective selling period, being the first to market, increasing the market share and creating entrance barriers with the help of new standards for technologies [4]. However, to keep pace with the market, variety and complexity in generically developed product programs must be reconsidered. Simply attempting to accelerate product development without first reducing internal variety and complexity can lead to increasing costs [5]. Successful firms use platform strategies, design for variety or modularization to realize a large range of customer configurations while having high communality of product components across the firm's portfolio [6]. The advantage of modular product platforms in ramp-up is the common base for future variations and roll-outs, thereby simplifying adaptation and decreasing the time to market [7]. In this context, modular product families reduce or avoid complexity. This has a positive impact on the ramp-up performance due to the possibility of parallelizing processes (e.g. separate testing of modules), to realize cost reductions, economies of scale and learning curve effects [8–11]. Furthermore modular product families help to prepare for future variants.

Integrated PKT-Approach for developing modular product families

In addition to the approaches in the literature [6, 10, 11] this following section presents an integrated approach for development of modular product families created by the Institute of Product Development and Mechanical Engineering Design (PKT) [12]. The approach consists of several methodical units (Figure 1) which are generally divided into product and process view.

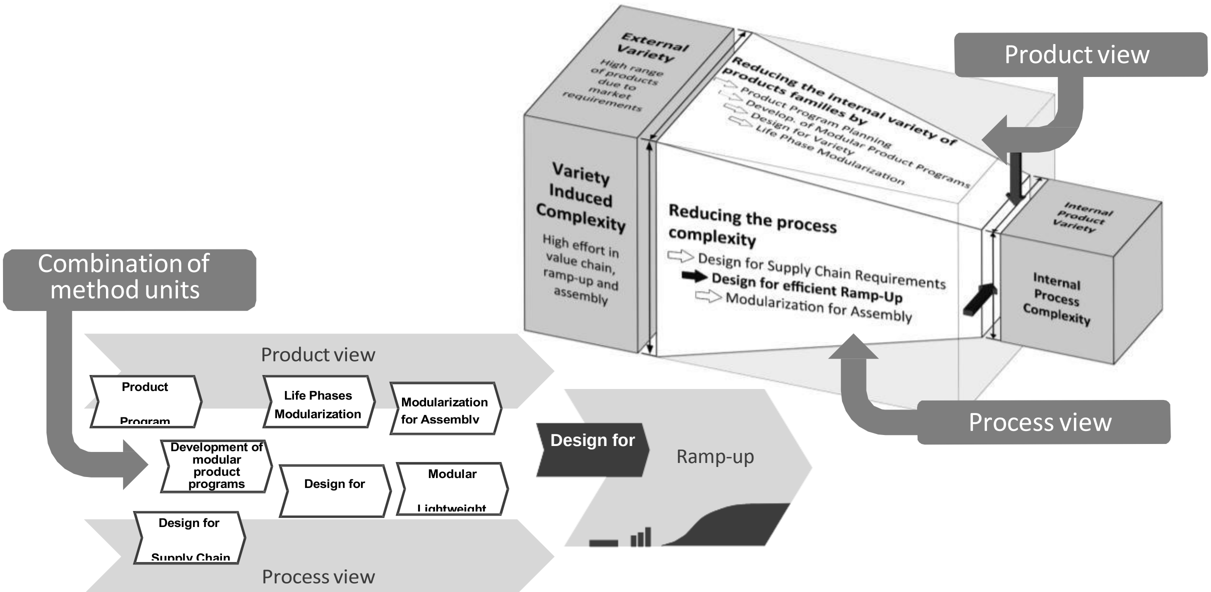

Figure 1. Integrated PKT-Approach with different views of product family development

The aim is to provide continuous methodical support for all steps in developing modular product families, maintain external variety with simultaneous reduction of the internal variety within the company. The approach consists of combining the development objectives of different methodical units. Serial and parallel applications are possible and can mainly be divided into product and process views. This represents 'Design for Variety': designing variant-friendly products for variance reduction and allowing the integration of new requirements or function. In 'Life Phase Modularization', modular structures are conducted that consider all specific requirements in the different life phases of the product family. These methodical units are described in detail in [9, 12, 13]. Ongoing research is carried out in the more strategic unit 'Product Program Planning', which supports the development of platforms and carry-over candidates at an earlier level within the product family planning. Further research will be conducted on the methodical unit 'Development of modular product programs' to deal with a broad range of variants over the whole product program. Due to the fact that there is strong interaction between product structure and corporate processes, the method units of the process investigate the link of the product structure and processes, e.g. supply chain, ramp-up and assembly.

This paper describes the extension of the Integrated PKT-Approach into the methodical unit ‘Design for efficient ramp-up’. Strategic launch decisions already take place in early phases of new product development. For instance, the firm must decide which products are introduced in different markets, what kind of technology will be used or what kind of launch strategy will be performed [5, 14]. Firms use a large amount of resources for development of new product families, which could ruin a firm if the preannounced entry into market must be shifted due to strong delays in development and production [7, 14]. Therefore, the aim is to develop a methodology for the early identification and minimization of ramp-up risks to manage an efficient transfer of development results into production, assess risk level and support decision-making in the development phase of the product. Statements about the degree of change compared to the previous product should help to facilitate reallocation of development resources.

Interface between development and production – Ramp-up phase

According to various authors, the ramp-up is a critical phase in the produt life-cycle of the product [4, 8, 14, 15]. 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. The transfer from development to production normally 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. The end of this phase represents the achievement of the previously defined output quantity, which then proceeds into series production [16]. The ramp-up 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, supply chain) and disciplines (product development, production, logistics, purchasing) [2]. Terwiesch identified two critical factors that characterize the phase between development and full capacity production: There is an initial low production capacity caused by poor understanding of the process that is inherently chaotic; the high customer demand as a result of the product novelty on the market [17]. Companies have to take several influencing factors into account to overcome the gap between supply and demand with short time-to-volume.

A significant amount of research has been conducted on product success and the linkage to time to market. The stream of research consists of analytic models to determine successful market launch strategies [4, 5, 7, 8]. Additional research addresses in a more qualitative and empirical way the manufacturing aspects to launch a new product. The focus is the preparation for production in terms of organization, manufacturing equipment, logistics, etc.[2, 3, 15, 16, 20]. A risk-oriented consideration of both development and production decisions to support an effective product launch has remain relatively unexplored.

Methodical assessment of ramp-up capability

Due to the strong influence of the ramp-up phase on the success of the product, it should be considered in the early stages of development. Risk identification and assessment of new products must be practicable with given initial uncertainties. Statements about the ramp-up capability of the developed product family and their variants will help to facilitate the development within a targeted risk communication and serve as the basis for efficient decision-making processes. In the following section, a methodical approach is presented that provides an assessment of influencing factors from development to ramp-up phase. The framework for the general procedure was first developed in [18] and will be extended here (Figure 2). The procedure is divided into two main parts. At the beginning, an initial analysis is conducted to estimate the general type of project scope (e.g. new platform, new product or variation of an existing product) and to assess the influencing factors described in the previous section. The various risk levels of the sub-assemblies of the product and their variants are pictured in a risk matrix. The input for the initial estimation can be received from different method units of the 'Integrated PKT-Approach' or from expert surveys.

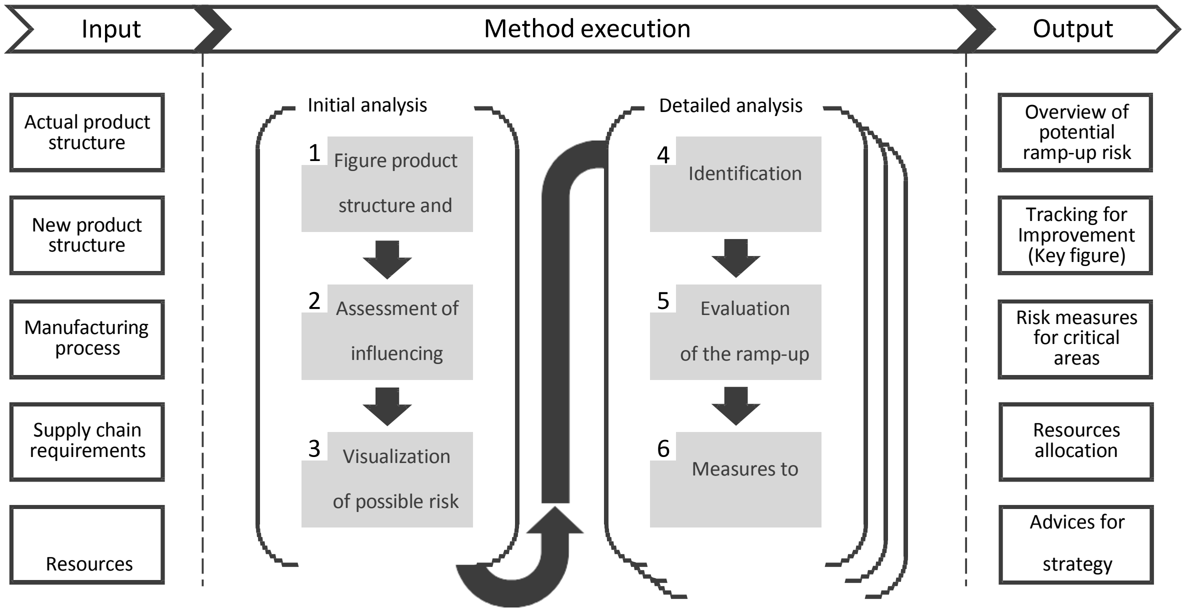

Figure 2. General procedure of the methodical assessment approach

During the initial analysis, a combination of different tools and methods are performed to establish an initial characterization of the project. A portfolio approach is useful to analyze the project scope and helps to set focus on development or operations. The modular interface graph (MIG) can be used for the investigation of product structure and interfaces [13]. In the analysis of dependencies between components and influencing factors, a design structure matrix (DSM) helps to create an understanding of the propagation of risks and the influence of changes in the project [19].

Detailed analysis is performed in the second part of the method using an iterative procedure until the end of the ramp-up phase. Therefore, critical areas at subassembly level or components (e.g. product complexity or supplier collaboration) have to be monitored at regular intervals. The ramp-up capability is calculate to realize a central key figure to monitor development progress. A sensible reallocation of resources is a shift from areas of under-expected risk to areas of above-expected risks. A package of measures can help to reduce risk: at the start of assessment in a strategic way, and later in a more operational way. In the following section, a more detailed overview of the assessment of the influencing factors (2), the evaluation of ramp-up capability (5) and the risk measures (6) are presented.

Influencing factors to launch a new product – a short review

A significant amount of research has been conducted on how firms can bring their products to market more quickly. In the following section a short selection of empirical findings on factors influencing successful ramp-up is given.

Time delays in the development and introduction of innovative products has a strong negative impact on gross profits of companies [16]. 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 (affecting the whole

product family or only a few product variants). Decreasing depth of development requires additional coordination with external organizational units and generates organizational complexity [16]. Critical causes of delay in launching a new product are late engineering changes to product design. This in turn leads to lower maturity of the product, high change effort in manufacturing, and problems in material supply due to the supplier being unable to adapt quickly enough [15, 20]. Almgren noted in his study that the number and frequency of disturbances within the ramp-up phase causes the organization to be heavily congested, which leads to a loss of production capacity. A successful transfer into series production is affected by the novelty or innovativeness of the product and its quality (maturity). According to Coughlan, the probability of a delay during the ramp-up phase increases with the degree of innovation of product and process technologies [4, 21].
Qualitative studies warn that the achievement of the target parameters (time, cost and quality) requires an efficient network across the entire value chain, including the integration of suppliers into development process and flexibility of manufacturing processes [2, 7, 16].
Terwiesch et al. identified three main ways to reduce ramp-up time. First, a gradual transfer of pilot series to series production significantly increases the performance. A step-by-step approach helps to reduce uncertainty and realize sufficient learning curve effects for novel technologies. Second, clear responsibility and a cross-functional organization promote a better transition between development and production. Thirdly, the introduction of product platforms leads to more effective use of previously collected experience of new products [1, 7, 17]. A more detailed overview of influencing factors in ramp-up capability is summarized in Figure 3. The figure is not exhaustive and will be further developed in future research. It represents a way of assessing the factors that indicates a possible risk in ramp-up.

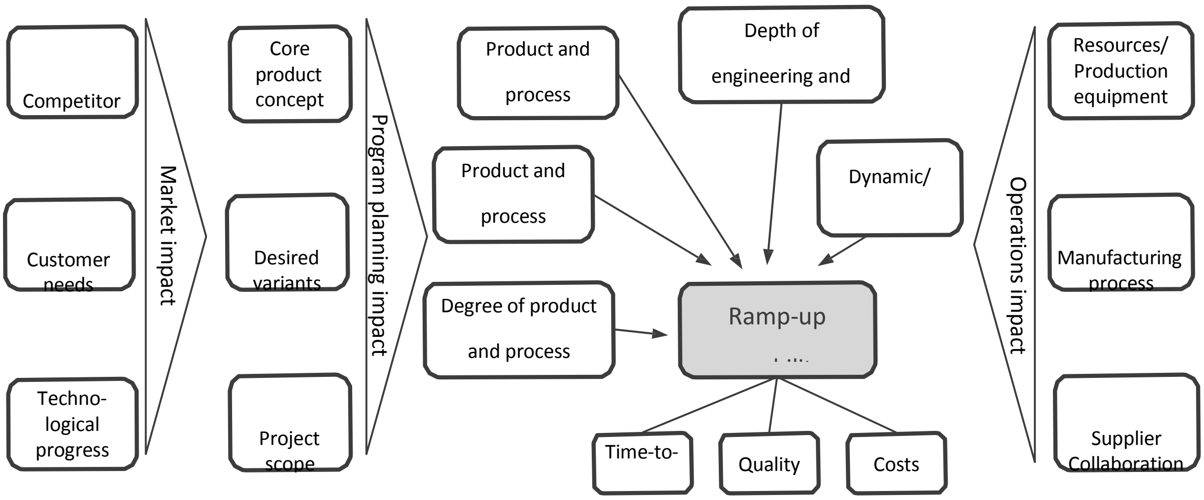

Figure 3. Factors that influence the ramp-up capability, as derived from the literature

Evaluation of ramp-up capability in terms of influencing factors under uncertainty

The assessment of factors in the very early stages of development is based on incomplete information. The evaluation approach must cope with the evolutionary character of the transition between development and production and must be in a position to deliver decisions in the absence of information. New products have an element of novelty, which implies an element of technical risk [22]. To supplement missing information in the early stages, the approach must use empirical analysis or expert assessments; the performance of the product and the manufacturing processes can only be predicted, not definitely determined. The allocation of resources to design and testing in early design phases helps to reduce the uncertainty and create valuable information for the assessment [4, 23]. In addition the

preparation for production development (e.g. modification or complete redesign) can be aligned with suggested launch rhythm of product family variants.
Despite high uncertainty, the assessment is required to secure the highest possible response time. It is important that the assessment supports the decision maker in a transparent way, despite the uncertainty of the available information. Therefore, based on [23] and [24], the approach enables the estimation of risk probability and its impact, a density function. For simplification, a rough triangular function is used for the assessment, with three values (low risk, most probable risk and high risk) (Figure 4, left). To calculate the ramp-up capability, the individually assessed risk factors of the subsystems are summarized for the final evaluation. The potential risk and the impact will be divided and calculated separately to get a comparative value. For the calculation, the estimated range of deviation of each risk character will be summarized across the scale for potential risk and impact (Figure 4, top right). The application of the individual values is limited by a closed surface (curve) of the maximum values. One value for the potential risk and one for the impact can be calculated based on the area formed with the help of the center of gravity [24]. The classic multiplication of potential risk value by impact can be performed to get an overall value.
The risk potential and scope can be applied to the state of development at different times. As part of a trend analysis, the ramp-up capability can be expressed in terms of area calculations. The smaller the center of gravity of the area under the curve of the maximum values the more likely an efficient ramp-up of production. The aim should be to achieve the lowest possible center of gravity of the area to reduce the impact and probability of deviations. A detailed comparison and investigation of the maximum values must be analyzed in advance. The calculation of area only provides a basis for the monitoring of the entire ramp-up capability at this point.

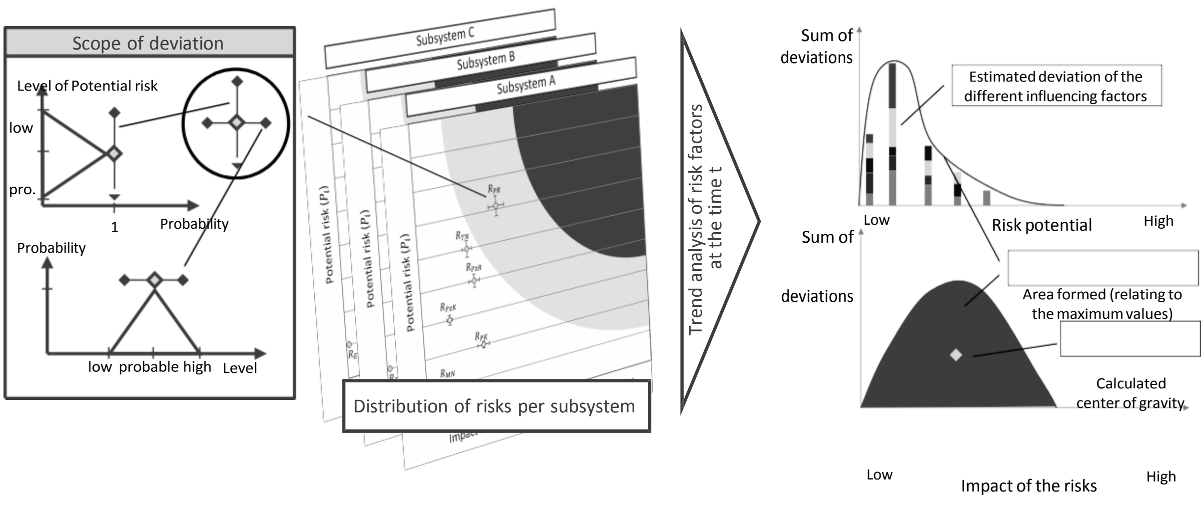

Figure 4. Consolidation of individual risks in ramp-up capability

Measures to reduce risk

In this section, a few strategic measures to reduce risk from the literature are presented [1, 5, 7, 8, 15]. Generally, the smaller the changes to the previous product, the smaller the deviations in the transformation of development results into production.
Strategies to mitigate the identified risks depend on the influencing factors and the development phase. For example, a low level of maturity in the components can be improved by greater use of prototypes and test scenarios. Identified problems in innovation and the degree of complexity in the concept phase can be addressed with the help of product structuring measures, such as modularization or platform development. In particular, platform development delivers long term benefits to ramp-up. This supports the increasing share of

parts carried over and the standardization of interfaces to reduce potential risk drivers. For detailed recommendations, the degree of change of new product structures can be used as a starting point. Figure 5 provides examples of opportunities created by potential risks.

Potential risk		Opportunities
Degree of innovation	Degree of market novelty	• Develop easily customized products • Lead-user approach • Separate new technologies in modules
	Degree of technology novelty	• Carry-over components • Standardization • Experimentation rate and testing strategy
Complexity	Product complexity Process complexity	• Modularization • Platform development • Postponement strategy (Time and Form) • Design knowledge • Product and Process communality
Maturity	Product maturity	• Allocation of resources to design and testing • Carry-over components
	Process maturity	• Changeover flexibility • Flexible manufacturing during ramp-up • Allocation of resources to manufacturing development
Supplier integration	Depth of engineering	• Development of core components and technologies in-house • Share actual development information across the engineering
	In-house production depth	• Close long term supplier collaboration • Locating customization sites close to customer • Share inventory information across the supply chain
Dynamic	Late changes	• Step-by-step change of technologies • Long-term and stable product development team • Cross-functional teams

Figure 5. Opportunities to reduce risks in early development phase

Conclusion and further research

This paper highlights the need for early consideration of the ramp-up phase in the development of product families. Empirical studies in literature show a variety of influencing factors that have to be taken into account to launch new products into market. The aim of the methodical approach presented is the early identification and minimization of possible ramp-up risks. The generated transparency helps to identify potential problems before production begins. The approach will provide response strategies adapted to the project characterization and should help to realize an efficient transfer of development results into production. Concrete recommendations for action must be substantiated with heuristics for different risk scenarios. Further development of the approach requires the investigation of interaction of risk factors, as well as mapping for a holistic assessment of the ramp-up capability of the product. A case study for initial validation of the approach is also required. The interfaces with other method units in the 'Integrated PKT-Approach' have to be finalized.

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