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## Conference Paper

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# A Risk Management Approach for the Pre-Series Logistics in Production Ramp-Up

Patrick Filla and Katja Klingebiel

## **Abstract**

Due to continuing derivatisation and increasing customer requirements, automotive development projects constantly become more complex. With a shortening time-to-market, the critical ramp-up phase of a new or updated automobile is susceptible to a variety of disruptions. As the project duration is naturally restricted, a high number of unscheduled ad-hoc resources are regularly installed to achieve the previously set qualitative targets within the given time limits. For early risk mitigation, current approaches in research and industry focus on the measurement of either technical product degrees or process maturity degrees in the development process. Nevertheless, it is clearly understood, that pre-series logistics bridge both viewpoints and thus still hold significant potential to reduce project risks. Consequentially, this paper presents a methodology that assesses the risk of process-wise and quality-wise delays. After discussing the specific risk profiles within logistics processes in the automotive ramp-up phase, the application of purpose-designed product maturity degree indicators and structured knowledge from historical projects is illustrated. The developed approach enables to identify critical processes in the production readiness process. The paper concludes with a summary and an outlook on further research.

**Keywords:** ramp-up, pre-series logistics, risk management, production development

## 1. Introduction

Rising customer demands and increasing market saturation necessitate complex business strategies to ensure the competitiveness of manufacturers in the automotive industry (Nyhuis, Klemke and Wagner, 2010, p. 3). Continuous derivatisation responds to the market situation by developing new customers and satisfying existing ones (Fitzek, 2006, p. 4). Short leading positions in a single product segment have economic potential for amortizing the new product (Bischoff, 2007, p. 12). Integrated product life cycles are getting shorter by coupling the development processes (Hertrampf, Nickel and Stirzel, 2008, p. 237). Due to the highly technical and organizational interdependences, new and updated car projects further increase in complexity with derivatisation and shortening strategies (Franzkoch and Gottschalk, 2008, p. 55).

The series ramp-up phase (in the following abbreviated to 'ramp-up'), as the last step before start of production (SOP), critically presents the challenge to transfer the product from its project environment to series production. The complexity drives a high amount of uncertainty in development projects and causes a high rate of process-wise failures and disruptions. Approximately 80% of all failures appear in the ramp-up phase, though 75% of all failures originated from the previous development and planning phase (Wildemann, 2002, pp. 4–5). Research and industry have developed methodologies and approaches to reduce these disruptions. Despite the known advantages of risk management during the ramp-up phase, there are few logistic implementations for this stage (Kuhn, Wiendahl, Eversheim and Schuh, 2002, p. 3).

Section 2 organizes pre-series logistics into the product development process and presents the control of the ramp-up phase. Additionally, the risk profile of pre-series logistics is discussed. Section 3 uses the critical path method to present an approach to identify critical processes in the production readiness process by rating the indicators. Section 4 then verifies this method. The paper concludes with a summary and an outlook on further research.

## **2. Pre-series logistics in ramp-up processes**

Despite the increased attention to the ramp-up phase in the last years, there is no standardized definition. Moreover the definition and description of the pre-series logistics tasks are different (Bischoff, 2007, p. 4) (Knüppel, Tschöpe and Nyhuis, 2012, p. 428) (Kuhn, Wiendahl, Eversheim and Schuh, 2002, p. 12). The following section discusses the state of the art and presents the risk profile of the pre-series logistics.

### **2.1 Ramp-up management**

The ramp-up phase is characterized as the period between product development and series production (Fjällström, Säfsten, Harlin and Stahre, 2009, p. 179) or as the final stage in the development process (Ulrich, Eppinger, 2011, p. 12). To distinguish the innovative non-product related research and the product related development, the early phase is often called 'series development'. The start of the pre-series is triggered by varying criteria, highlighted in the literature. One such trigger is the switch from prototype production to pre-series automobiles production (Urban and Seiter, 2004, p. 58). Pre-series automobiles are built under conditions similar to series production, using mass production components and tools to prove the series readiness (Fitzek, 2006, p. 2). The definition for the end of ramp-up differs in two points of view: Some sources attribute the end of the ramp-up phase to the achievement of full capacity (Terwiesch and Bohn, 2001, p. 1) (Zäh and Möller, 2004, p. 13) while others attribute it to the production of the first series automobile (SOP or also called as Job No. 1) (Doltsinis, Ratchev and Lohse, 2013, p. 85) (Fitzek, 2006, p. 55).

The pre-series phase ends up in theory with the SOP, as the firm now produces automobiles acceptable for customers. In practice, many departments support the start of series production to ensure product and process quality until full production capacity is achieved. Pragmatically, expansion is appropriate. To define the phase and tasks more precisely, the sub-phases of ramp-up are

categorized by the 'production ramp-up', which starts with the SOP and ends up with the achievement of full capacity production (Schuh, Stölzle and Straube, 2008, p. 2).

The ramp-up phase until SOP is divided into the pre-series and zero series, a function of the targeted process and product quality (Fitzek, 2006, p. 2). In practice, the division of the pre-series into two phases allows a step-wise transition from project to series processes. The pre-series I aims to produce automobiles under conditions similar to series production to prove the reproducibility, a method known as the 'production try-out'. A special assembly line for the pre-series or the future series assembly line produces the pre-series products using mould assembled components for mass production (Pfohl and Gareis, 2000, p. 1198). Pre-series phase II ensures the process and product quality is at a customer acceptable product level. The zero series is the last step before SOP, and serves as a 'buffer' that hands over responsibility to the series facilities (Fitzek, 2006, p. 55).

Figure 1 visualizes the discussed product development process and classifies the logistics tasks, which are described in the following section.

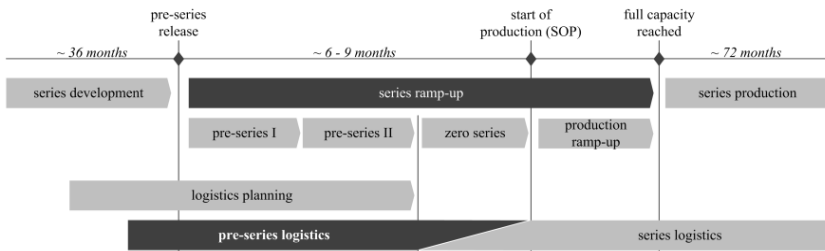


Fig. 1: The series ramp-up process

## 2.2 Pre-Series Logistics

The logistics activities before SOP are organized into operative and planning tasks. Logistics planning ensures that the production time and quality of the assembly lines are acceptable for series production (Doch, Rösch and Mayer, 2008, p. 144). Using existing material flows of other series productions, pre-

series logistics tests the production time and quality prior to SOP. Permanent changing components up to SOP require special logistics processes and cause a distinction between pre-series logistics processes and series logistics processes (Doch, Rösch and Mayer, 2008, p. 146). Romberg and Hass define the pre-series logistics as an "already series process close department with the tasks to ensure the technical quality of components from external suppliers, to coordinate the material flow for supply of pre-series production and to coordinate the information flow in the pre-series phase itself" (Romberg and Haas, 2005, p. 16). The pre-series logistics is based on tasks of the series logistics: just-in-sequence coordination, warehouse management, program planning and production scheduling (Schulte, 2008, p. 371). The permanently changing bill of material requires a program readiness prior to the SOP that guarantees the availability of the ordered component construction version until the pre-series automobile production starts. Moreover, it implements a change management process that coordinates the information-flow for the entire change process across involved departments (Schneider, 2008, p. 166).

### **2.3 State of the art in risk management of pre-series logistics**

Pre-series logistics is responsible for special functions during the ramp-up. It connects and transfers the technical product from the project development environment to the process-oriented series production (Schneider, 2008, p. 166). There are limited references in literature that discuss risk management for the automotive ramp-up phase. Present research is dominated by financially driven performance measurement systems in form of controlling tools (Nau, Roderburg, Klocke and Park, 2012, p. 233). Within highly complex ramp-up projects, costs often cannot be explicitly defined for each process. Thus, the applicability of financial approaches is limited, so non-financial solutions have typically been used. Current approaches provide methodologies for analysis and control for the ramp-up management that focus on either the product or the process, but acknowledge the importance of the interface. Weinzierl defines

key performance indicators for components (e.g. technical quality) and weighs them for each ramp-up phase. He offers a model of aggregation that derives the overall product maturity (Weinzierl, 2006, p. 59). Hegner solves the problem of information, as the definition of components and processes changes often in the early phases, by concentrating on key performance indicators for each phase in an automotive ramp-up process. Random trend analysis is used to forecast the development situation, such as looking at the key performance indicators, and formulates the ramp-up curve (Hegner, 2010, p. 3). Different key performance indicator based approaches support stable processes by identifying disruptions and enhancing process chains. Nau et al. present a risk assessment method for hybrid manufacturing technologies based on simulation and the Quality Function Method (Nau, Roderburg, Klocke and Park, 2012, p. 233). Risse uses historical information to define a planning approach for different structure ramp-up processes while considering the prospect of optimization (Risse, 2003, p. 222). Gentner provides key performance indicators for development projects which measure efficiency by evaluating process inputs and outputs (Gentner, 1994, pp. 14–15). Czaja focuses on pre-series supply chain indicators. His empirical survey analyzes process quality between the manufacturer and supplier (Czaja, 2009, p. 345). Schmahls proposes a performance measurement system to identify and reduce technical and process-related disruptions near the assembly line from a production oriented point of view (Schmahls, 2001, p. 151). The gap in understanding the interface between technical project environment and process oriented departments in pre-series logistics is one of the main reasons for disruptions (Filla and Klingebiel, 2014).

The ramp-up phase and pre-series logistics are characterized by a high degree of uncertainty (Urban and Seiter, 2004, p. 58) which gets proved by the high degree of disruptions. The business strategies of the manufacturer create a highly complex network of process stakeholder and highly complex technical automobiles with many interdependences between the components and modules (Nagel, 2011, p. 36). The transfer from the technical development to

series processes challenges the implementation of stable reproducible processes considering recurring change requests. The complex opacity of interdependencies causes uncertainty, which creates unexpected consequences. Thus, risk methodologies as described in ISO 31000 "Risk management - Principles and guidelines" (IDW, 11.09.2000, p. 3) cannot be used because fluctuating demand depends on the project phase. Moreover, it is not possible to define fixed key performance indicators to show standardized risks (Filla and Klingebiel, 2014).

Results of a survey focusing on the risk profile of a pre-series logistics demonstrate the highly variable requirements for a controlling tool (Dietrichs, 2012, pp. 47–48) (Filla and Klingebiel, 2014). The survey stresses pre-series I as the phase with the highest logistical disruption frequency. Usually these disruptions had to be resolved 'very fast' or 'fast', requiring high effort and the use of unscheduled resources to avoid negative downstream effects. The disruptions in the zero series are described as very critical but were rated by experts as unpredictable and therefore not considerable in a risk management methodology. Regarding especially these disruptions a suitable risk management for the pre-series logistics has to consider indicators from the technical development phase and should focus on the pre-series I. During the pre-series II risk management loses its applicability and a performance measurement should thus take precedence.

However, this methodology does not yet exist. The following section presents a new approach that uses indicators and the critical path method to mitigate risks in pre-series logistics processes. The indicators should cover process-wise and quality-wise information to narrow the gap between the product development and series production (Pfohl and Gareis, 2000, p. 1190). Existing approaches offer indicators that can be used for the methodology. Example indicators from Hertrampf, Nickel and Stirzel (2008, p. 237), Juzek and Berger (2013, pp. 400–401) and Wanner (2009, p. 87) are shown in figure 2.



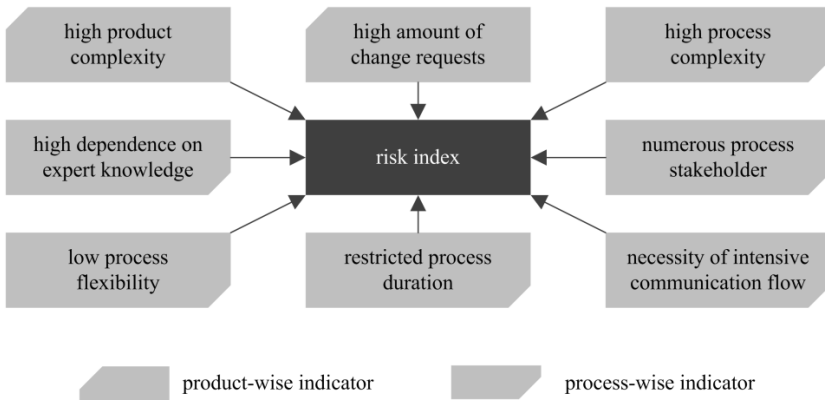


Fig. 2: Exemplarily risk indicators

### 3. Risk management approach to identify critical logistics processes in the ramp-up phase

The step-wise optimization of the pre-series logistics process chain (see figure 3) is structured into three risk management tasks that follow the generic risk process (Meier, 2011, lead text). The first step in the loop is the preparation of risk management. Risk sources need to be identified. This can be done, for example, by use of historical projects (Nau, Roderburg, Klocke and Park, 2012, p. 232). The results support to deduce risk indicators, which are necessary to identify and analyze risks in the following steps. Example risk indicators can be seen in figure 2. Risk management preparation finishes with an analysis of the specific process chain, which should be optimized. The second step (which will be explained in detail later) identifies the most critical process in the chain and develops and implements risk mitigation plans. Finally, the risk management plan must update its indicators and risk evaluations to adapt to changing conditions.

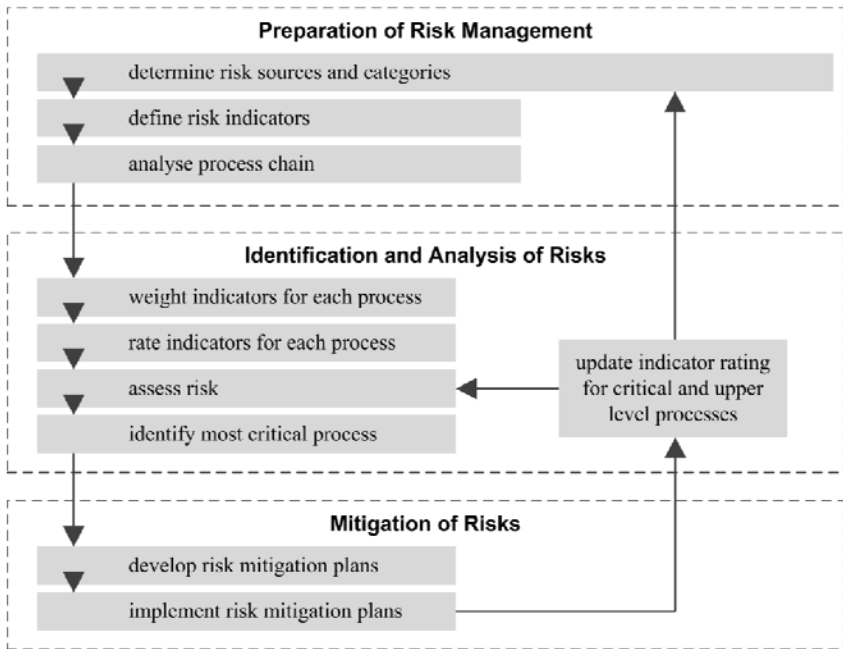


Fig. 3: Risk management process

To develop the identification and analysis approach, linear process chains and linear process level were assumed. A linear process level reduces the complexity by structuring the basic processes into major processes and sub-processes. Identification starts in the major process level, using the defined risk indicators. This process is repeated on the critical processes on the lower level, which in turn update the risk indicators of their downstream processes. All assumptions and the steps for the risk analysis can be seen in figure 4.

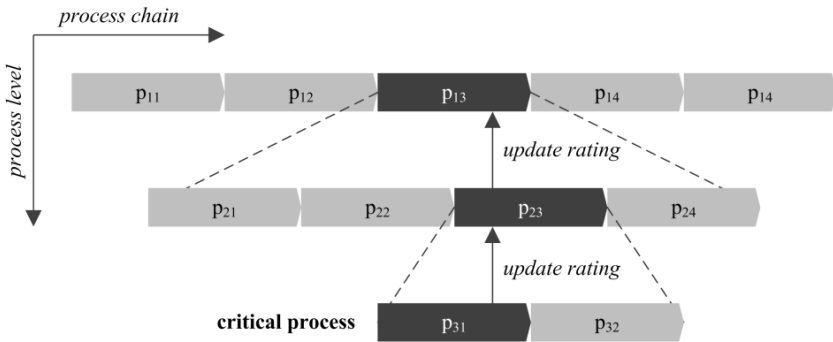


Fig. 4: Risk identification approach

The set of all processes is called 'P', defined by the order 'j' of the processes in the chain and the process level 'i'.

$$P = \{p_{ij} \mid \forall i, j > 0\}$$

The identification approach uses the set of previously defined risk indicators 'C' to analyze the risk rating. The number of indicators is represented by 'm'.

$$C = \{c_k \mid k = 1 \dots m\}$$

Each process gets rated by all defined indicators. The changing demands in the ramp-up process require the dynamic use of the indicators for each process in the chain. A weighting matrix 'W' fulfils the demand and shows the impact of each indicator 'c' on each process 'p' (see also table 1). The impact weight 'w' is classified between 0 (indicator is not relevant) and 'n' (high relevance). The number of rating options 'n' depends on the individual ramp-up project. As more rating are added, the analysis becomes more descriptive, but also more complex.

$$W = \{w_{ijk} \mid i, j, k > 0\}$$

$$w_{ijk} \in \{0 \dots n \mid n > 0\}$$

Similar to the weighting matrix 'W', the matrix 'R' assesses each process using the known indicators (see also table 1) showing the process criticality. The classification of the rating is between 1 (indicator fit is insignificant) and 'q' (indicator fits perfectly). The knowledge and experience of experts (employees

with ramp-up experience of different car projects) are one of the most important data source for ramp-up projects, this approach focusses willful on it (Bischoff, 2007, pp. 31–32). The rating factor 'r' uses the same indices ('i', 'j', 'k') as the weight factor.

$$R = \{r_{ijk} \mid i, j, k > 0\}$$

$$r_{ijk} \in \{0 \dots q \mid q > 1\}$$

	$p_{11}$	$p_{12}$	...	$p_{1max}$
$k_1$	$r/w_{111}$	$r/w_{121}$	...	$r/w_{1max1}$
$k_2$	$r/w_{112}$	$r/w_{122}$	...	$r/w_{1max2}$
...	...	...	...	...
$k_m$	$r/w_{11m}$	$r/w_{12m}$	...	$r/w_{1maxm}$

Tab. 1: Exemplarily weight / rating matrix for the first process level (i = 1)

The risk index 'x' for a process consists of the single indicator rating and weight.

$$x_{ij} = \frac{1}{n * q} * \frac{1}{m} * \sum_{k=1}^m w_{ijk} * r_{ijk}$$

Assuming linear process chains and level the process with the highest potential for risk mitigation the most critical process are identified by the risk calculation top-down. After the critical process has been identified the weights and ratings are updated.

#### 4. Use case - Quantification Results

The method mentioned above was applied to the automotive industry. This case focusses on a ramp-up project of a new developed automobile. The risk

indicators were worked out previously with experts in interviews (25 experts of the pre-series logistics were consulted - most of these experts had already supported more than five ramp-up projects, in most cases in different functions and departments). The 24 indicators are divided into 11 product-wise and 13 process-wise indicators and were weighted by the experts with one of three options, 'low impact', 'medium impact' and 'high impact'. The indicators comprised for example the 'stability of the bill of components', the 'number of stakeholder' and the 'readiness of heavy items', the full set cannot be presented here due to the confidentiality agreement. Rating options were limited to 'low accordance', 'medium accordance' and 'high accordance'. The risk calculation results have been clustered as:

*low risk* ( $0 \leq x \leq 0,33$ )

*medium risk* ( $0,33 < x \leq 0,66$ )

*high risk* ( $0,66 < x \leq 1$ )

The example processes were the planning and production of 673 pre-series vehicles. The indicators for the risk identification were rated and weighted for each single week in the product development process. The disruption analyses of the project data identified 130 postponed prototypes, 42 postponed pre-series I automobiles and 172 postponed pre-series II automobiles. The zero series had no postponements. Using the presented risk management method, 57,8% of all pre-series productions were labelled as "risky" due to their high risk index, which totals to 389 automobiles. The difference to the in fact postponed cars is in total +45 (= +13%). Similarly, 35,6% of produced vehicles were rated as "medium risk" and 6,7% with a "low risk".

Considering the identified risks according to the calculation methodology, the risk management approach provides progress in risk mitigation and ensures the development timeline. The results show that the risk management approach is applicable to identify the probability for disruptions.

## **5. Conclusion and future work**

The risk profile of pre-series logistics shows the benefits and challenges of risk management during the ramp-up phase. Considering the high levels of uncertainty in this early phase, the effort to acquire relevant data (key performance indicators) is often not justifiable. As a solution, the knowledge of experts and information from previous ramp-up projects can be applied to identify risks more easily. Nevertheless, the uncertainty of information and data necessitates information integration in the business process. The presented risk management approach enables the successive identification of critical processes using both process-based risk indicators and product-based risk indicators to show risk. Future research will examine the assumed linear relation between processes and furthermore consecutive risk mitigation plans need to be analyzed and integrated in the overall approach.

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