

# Value Stream Mapping Along the Product Development Process

Uwe Dombrowski, David Ebentreich\*, and Stefan Schmidt

Institute for Advanced Industrial Management  
Technische Universität Braunschweig  
Braunschweig, 38106, Germany

## ABSTRACT

*Today's business conditions are characterized by increased competition. Therefore enterprises have to cope with shorter product life cycles, higher product complexity and more product variants. The reaction of many enterprises is to launch new products in shorter intervals. This confronts companies with the challenge to pass through the product development process faster. The product development processes need to be parallelized and waste within the processes needs to be identified. In the past, methods of Lean Production Systems have been successfully used to identify waste in production and product development processes. Lean offers an established approach to eliminate waste and increase customer value in all processes. Especially the value stream mapping method is used to identify waste in processes and to concentrate on value creation. To improve the entire product development process from development to start of production, this process has to be mapped and analyzed. Therefore, this article analyzes different value stream mapping methods regarding the specific requirements of the product development process. In the following, an approach is presented which has been tested in an enterprise in order to improve the product development process.*

## 1. INTRODUCTION

The global competition forces enterprises to launch new products in shorter intervals, with higher product diversity and higher product complexity. To launch new products in shorter intervals, enterprises have to shorten the period of time for development and production of the products. This could be realized by reducing waste in the processes. [1] Many enterprises have implemented a Lean Production System, based on the Toyota production system, to reduce waste in processes. With the value stream method, Toyota developed an analyzing method to visualize the current state of the production in a comprehensive and transparent way. In addition to that, the method supports developing an improved future state of the production. [2]

The optimization of a production value stream has shifted the focus of optimization from the single workplace to the whole production process. Thereby, enterprises could reach better results in decreasing lead time and lower inventory through the whole production process. By using the value stream method, enterprises mapped their production processes and visualized their production and information flows. The current value stream map shows the flows of a product group from the suppliers through each production step to the customer. By visualizing this process, problems can be identified and avoided in a future value stream. [2] This optimization of the whole production process has become necessary to keep up to the demands for a short delivery time and the increasing customer requirements. The reduction in production lead time is already well advanced. [3]

Before production can start, product development (PD) usually requires most of the time to market. Therefore, enterprises focus more and more on PD to shorten the time to market. Due to the results of the value stream method in production, it is reasonable that the method might improve the value stream in the development, too. However, an important aspect in this context is the big difference between processes and procedures within the production and the processes within the development of a product.

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\* Corresponding author: Tel.: +49 (531) 391-2722; Fax: +49 (531) 391-8237; E-mail: d.ebentreich@tu-bs.de

## 2. METHODOLOGY

Mapping the development value stream brings the opportunity to identify waste and improve the PD process. The challenge is to adapt the value stream method to this process, as the differences between the production process and the PD process need to be handled. This article has the research objective to identify the requirements for a PD value stream based on the differences. In the next step, existing value stream methods are analyzed regarding the identified differences. Based on a literature review, modifications are developed to cover every difference of the PD process.

Hence, the differences need to be identified to evaluate the existing value stream methods. Moreover, the article presents modifications of the existing value stream method, which have been tested in an enterprise in order to improve the PD process.

## 3. DIFFERENCES BETWEEN PRODUCTION AND DEVELOPMENT

With the purpose of adapting the value stream method to PD, the differences between production and PD have to be identified. Erlach describes six elements of a value stream, shown in figure 1. [4] In the following, these elements are analyzed regarding their differences in production and PD.

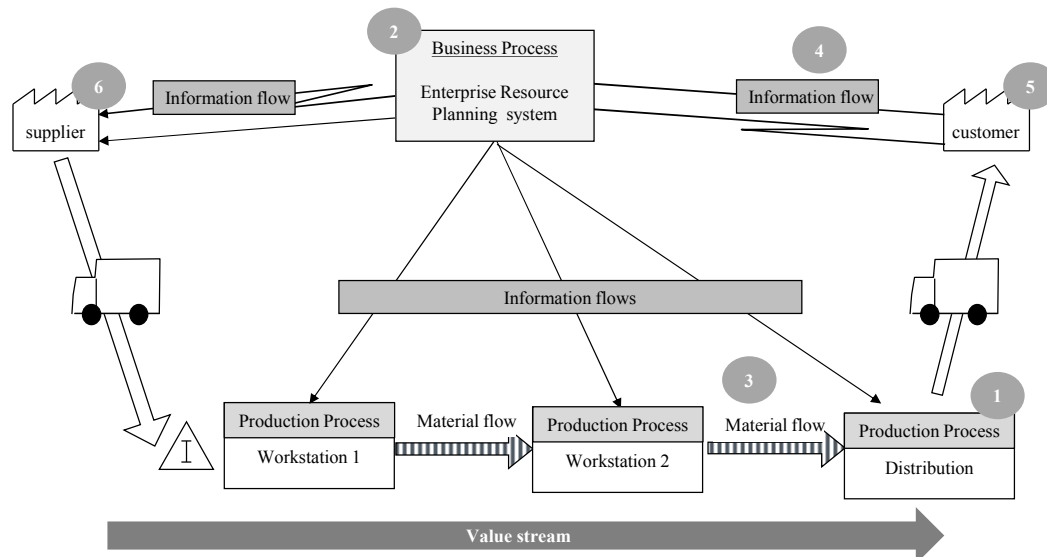


Figure 1. Value stream map elements [4].

### 3.1. PRODUCTION PROCESSES

The production process is the main stream in the value stream method and contains all manufacturing activities in an enterprise. The processes of enterprises in serial and mass production industry are mostly repetitive operations, which are defined by standards. Standards enable production employees to reproduce a predetermined result. These blue-collar workers are usually skilled for job rotation, so that several employees can work on a similar qualification level. The time, that elapses between consecutive parts in production, called cycle time in the value stream method, take only seconds or minutes. [2]

In PD, the main stream does not include manufacturing activities, leading to an adaption of this element. The PD process is the main stream in development. Aim of this process is to deliver all relevant information, like the production drawing or the bill of material, to manufacture the product. As this information has mainly a unique character, the result of the process might not be defined. [1], [5] Due to the uncertainty of the development result, regular monitoring of the intermediate results is necessary. [6] Especially the complexity of products and the high variability of tasks demand a high qualification of employees in PD. Knowledge creation activities belong to the tasks just as knowledge reuse activities or administration tasks. [7] Hence, the qualification level of these white-collar workers in the PD varies more than in the production. [8] In contrast to production, the process time in development takes weeks or months. [1]

### 3.2. BUSINESS PROCESSES

The business processes in production comprise the order processing and the production planning and controlling. The aim of these processes is to transfer the orders received from the customer into production and purchase orders. The purchase orders are sent to the suppliers, whereas the production orders are usually scheduled for production by an enterprise resource planning system. Mostly, information is transferred in business processes. [4] In PD the business processes are almost the same. Orders from the customer or from the management start the development process. The development is often project driven, so that a project leader or chief engineer plans and controls the activities of the development teams. Furthermore, the proportion of the administrative processes is larger than in production. [8]

### 3.3. MATERIAL FLOW

The material flows along the production process from one work station to another. Between the work stations the material can be stored in inventories or directly transported to the following station. [2] In PD the essential flows consists of information instead of material. Based on this difference, it is easier to follow the value stream in production than in PD. [8]

### 3.4. INFORMATION FLOW

The information flow describes the transfer of information. [4] The information flow is probably the most noticeable difference between production and PD. In production, information flows are mostly for planning and controlling the value stream. Besides the information flows for planning and controlling, feedback, iterations as well as the main product design and construction are information flows in PD. The product design and construction flows in the direction of the value stream, whereas the feedback, iterations and controlling flows in the opposite direction. [9] The different types of information and material flows are illustrated in the figure 2.

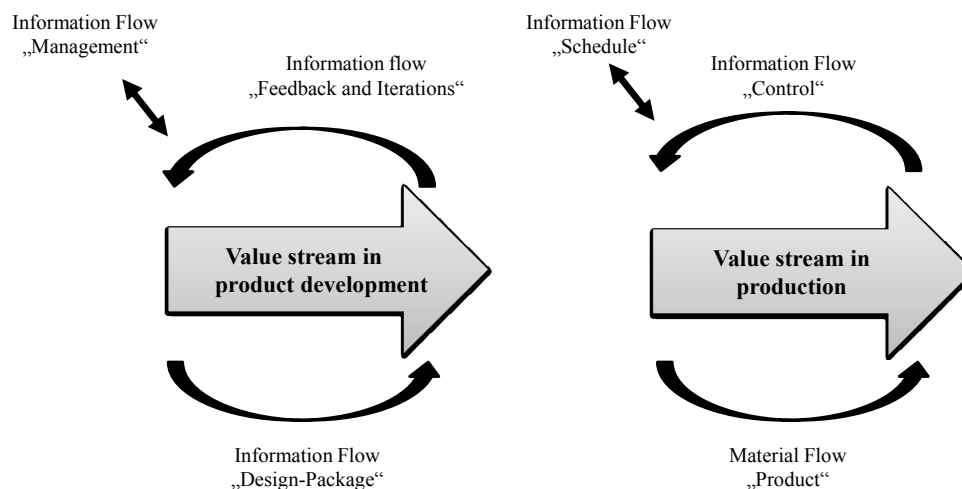


Figure 2. Flows along the value stream [9].

### 3.5. CUSTOMER

The customer is the most important stakeholder in the Lean Production System. In production, value is defined by what the customer pays for the product. So, the whole value stream is designed to create value for the customer. The customer of the final good defines the demand of the product, the delivery time and the quality. Based on the orders, the production process is balanced to produce only the products demanded. Moreover, each work station has an internal customer, which is the next process step. These internal customers have the same requirements as the final customer, to get the products in a certain number, in time and with the right quality. Therefore, the awareness of the customer needs is an essential part of reducing waste in the process. Different to production, the customer in PD is often the management of the enterprise itself, leading to the fact that the management has to set the time to market and quality for the product. [9]

### **3.6. SUPPLIER**

The suppliers deliver raw materials, parts and assemblies for the enterprise. In PD, it is possible that specific parts and assemblies are developed by the suppliers, too. Usually, the enterprise develops the main parts of the product itself, so that the supplier has mainly the same function in production as in development.

In summary, the following five main differences of the development process are identified in contrast to the production processes.

1. The uncertainty regarding the result of the development process
2. The qualification level varies
3. The process time is much higher
4. The product development is structured as a project organization
5. Seeing the value stream is more difficult, as information flows along the process

These discovered differences cannot be handled with the original value stream method, so value stream methods for PD have to deal with these criteria. Therefore, value stream methods are analyzed regarding their handling of the criteria. Thus, it can be determined whether the authors have taken these criteria into account in their concepts.

## **4. BRIEF LITERATURE REVIEW ON CONCEPTS FOR VALUE STREAM MAPPING**

In the following, six main value stream methods are analyzed. The aim of the literature research is to identify, if the concepts have addressed the identified criteria. Furthermore, possible solutions for handling the criteria are examined.

### **4.1. LEARNING TO SEE - VALUE-STREAM MAPPING TO CREATE VALUE AND ELIMINATE MUDA, ROTHER AND SHOOK [2]; VALUE STREAM DESIGN – THE WAY TOWARDS A LEAN FACTORY, ERLACH [4]**

Rother and Shook described the value stream method based on observations in Toyota plants. They explained the method in production. Erlach describes in his book an enhancement of the original value stream method. The main focus is also on production, whereas the requirements of PD are not considered. The authors do not address the issue of uncertainty regarding the outcome, however briefly describes the iteration principle in the context of planning of value stream oriented factory planning. With the iteration principle, the project can revise completed project steps in order to take into account new conditions. Moreover, due to factory planning in a project-organization, it is mentioned the importance of project milestones.

### **4.2. VALUE STREAM MAPPING FOR LEAN DEVELOPMENT, LOCHER [7]**

In his book, Locher presents a how-to guide for mapping the value stream of development processes. He discussed the differences of the development process and points out, that development employees usually work on multiple tasks with a high variability. Due to this, Locher insert shared resources in the value stream map. The uncertainty in the planning process is described generally. Therefore iteration loops are recommended. He illustrates the principle, as well as the difference between "good" and "bad" iteration loops. Furthermore, the method of Swim Lanes is described as a method by which the level of detail can be increased. The milestone planning is briefly explained and illustrated with examples.

### **4.3. THE COMPLETE LEAN ENTERPRISE - VALUE STREAM MAPPING FOR ADMINISTRATIVE AND OFFICE PROCESSES, KEYTE AND LOCHER [10]**

This approach adapts value stream mapping for the whole enterprise. Besides the production value stream, they expand the value stream method with information flows in the office. The pre-production flows complement the production flow. The current state is created on a site level, revealing the big picture. With this procedure, the overview for the entire value stream can be retained. However, detailed problems cannot be processed due to the high level of abstraction. For the detailed analysis, the authors suggest questions to evaluate the detailed problems. With the help of questions specific problems, for example in order processing or inventory control are addressed. The other requirements are not discussed.

#### 4.4. PRODUCT DEVELOPMENT - VALUE STREAM MAPPING (PDVSM), MCMANUS [9], MILLARD [6]

McManus and Millard describe the differences of the value stream mapping of the product in comparison to production. Thereby, the authors refer to the increased uncertainty about the results as well as the greater variability in the level of qualification of the employees. In conclusion, the importance and functionality of iterations is highlighted. In addition to iterations, the authors advise concurrent engineering processes, so that the internal customers, e.g. the production, can take part in the PD. The advice is to use additional methods to consider the differences, like Gantt-Chart or the value stream map according to Ward [11]. The principle of milestone planning is also briefly mentioned in the research.

#### 4.5. LEAN PRODUCT DEVELOPMENT FLOW, OPPENHEIMER [12]

Oppenheimer gives details of uncertainties in the value stream map and proposes opportunities to deal with these uncertainties. These include, for example, the set-based design, as well as iterations. The long process of an entire PD program solves the author by dividing the long process into lean PD flows. The subdivisions should be based on milestones, so that a value stream could be mapped for each subdivision separately. Due to the problem of seeing the value stream in PD, Oppenheimer recommends, similar to the Kanban system in production, a regular and defined communication in form of emails, phone calls, or formal documents and meetings.

The results of the analysis are summarized in table 1. The table shows that no concept covers all criteria.

Table 1. Analysis of product development value stream concepts.

criteria \ value stream concepts	1. Uncertainties related to the process result	2. Variability of the qualification level of the employees	3. A longer process time	4. Organizational project character	5. Difficulty to see the value stream
1. Rother and Shook [2]; Erlach [4]	○			○	
2. Keyte and Locher [10]			○		○
3. Locher [7]	●	●		●	
4. McManus [9] and Millard [6]	●	○	○		○
5. Oppenheimer [12]	●		●		●

legend: ● approach for solution ○ problem addressed

## 5. MODIFICATIONS FOR A VALUE STREAM IN PRODUCT DEVELOPMENT

On the basis of the literature analysis, an expansion of the value stream method is necessary to cover the described criteria of the development. In the following five modifications are described.

### 5.1. UNCERTAINTY OF THE PROCESS RESULT

The uncertainties related to the process results require short cyclic feedback loops. This iterative approach is supported by the lean development method Scrum, which is initially an agile software development method. Starting with a planning meeting to define the requirements of the “voice of customer” in different product backlog items, the development team selects product backlog items for the next development phase, so called sprint. These sprint meetings can vary in length. Poppendieck and Poppendieck recommend that the cycle is short enough to get the feedback from the voice of the customer that the development is on track. On the other hand the team must have enough time to run through a design-build-test cycle. [13] In a daily scrum meeting the team coordinates the tasks for the day, so that problems and barriers could be addressed very fast to the scrum master. [14]

For the implementation of this criterion in the value stream method, it is necessary that iterations or sprint meetings and feedback loops have been scheduled.

### 5.2. VARIABILITY OF THE QUALIFICATION LEVEL

Due to the variability of the qualification level, it is necessary that the tasks fit to the qualification level of the employee. The more complexity and knowledge the task demands the more expertise and qualification is needed by the employee. Otherwise employees with expertise and a specific qualification should be exempt from other tasks. It is important to distinguish between the qualification level and the broadness of qualification. The qualification level could be documented in the value stream map. Similar to the value stream of administrative processes [15], the modification with swim lanes realize the transparency of different roles. In this way different roles visualize different qualification levels. The broadness of qualification could not make transparent by this modification. An additional tool, like the qualification matrix has to be used to visualize the qualification broadness.

### 5.3. LONG PROCESS TIME

The long process time makes it difficult to watch the whole activities of the employees in the everyday business. Therefore, the mapping of the value stream has to be carried out in two steps. The first step is the rough value stream map with the entire PD process. In this map, problems especially at the interfaces could be identified. The second step are detailed value stream maps for the main tasks, like order processing, design of the product, generating the bill of material, work plan preparation etc. The detailed value stream maps identify problems in the processes. The interactions of the detailed value stream maps should be integrated in the rough value stream map to understand the interactions between the separated process steps. In the detailed value stream maps, process times could be estimated in a range from the employees. According to the complexity of the project a task could take different duration. Another method to measure the process time is the multi-moment recording. With this method, random samples of process times are recorded to make statistical statements. [16]

### 5.4. ORGANIZATIONAL PROJECT CHARACTER

The PD is organized in a project. Regarding the project structure, it is important to have deadlines with milestones for the main tasks, so that the status of the project can be measured. Moreover, milestone meetings give the chance to coordinate and verify the consistency of the development project. Oppenheimer recommends that the whole PD should work in equal Takt periods between milestone meetings. [12] In the value stream map, milestones could easily be provided shown in figure 3. Iterations are visualized with arrows in opposite direction. The percentage describes the frequency of the questions and the time specify the duration for the rework.

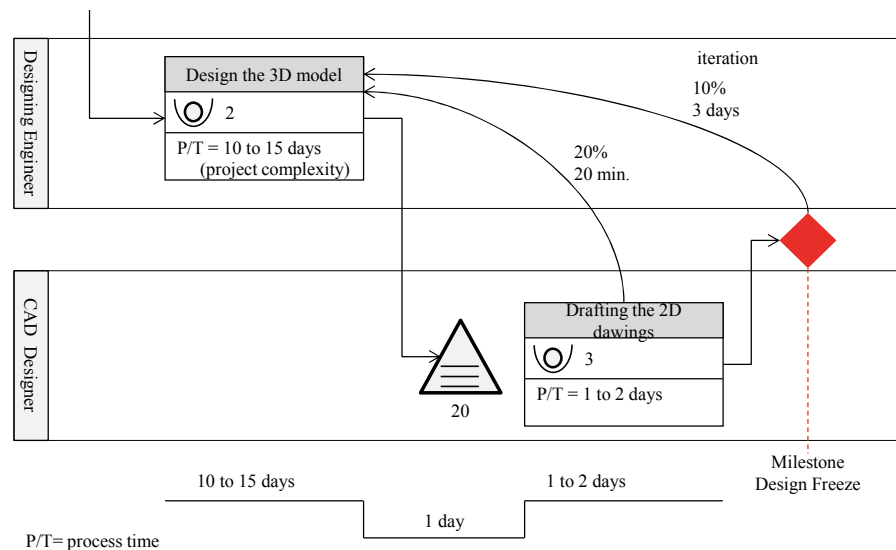


Figure 3. Example of the modifications in the value stream map.

### 5.5. DIFFICULTY TO SEE THE VALUE STREAM

Due to the longer process time in PD, it is imperative that the detailed value stream maps are described in interviews instead of walking the production line. In structured interviews, the process steps can be described and visualized with processing times. To ensure that the whole process is mapped, the employee could be observed in random samples to get an impression of the tasks. The figure 4 illustrates the approach of analyzing and the conception of PD value stream mapping.

### 6. VALIDATION OF THE METHOD

To validate the modification of the PD value stream method, it was validated in the PD of an enterprise of the train industry within a timeframe of half a year. For this purpose, a core team of eight people initially created a rough value stream map. This rough value stream map includes eight value stream sections, which was the basis for detailed process interviews with contact persons for each section. The interviews were then conducted with up to eight contact persons from the enterprise for each section in order to obtain different impressions of a value stream sections. The content of the detailed interviews was to map the value stream section and to identify the problems within the section and with other sections. This procedure has shown that all details could be defined only after repeated consultation. To complete the analysis phase a consolidation workshop was conducted. In that way, problems in later PD phases could discuss and follow up to the root cause. Main problems were found with regard to lack of communication and control meetings, not firmly deadlines, and faulty work distribution as well as an inadequately IT interface for transferring the bill of material. The lack of communication and control meetings were especially between the engineering and the manufacturing of the product. Many problems arise through missing coordination, which lead to many call backs and rework. The faulty work distribution could be discovered by mapping the tasks in swim lanes. After identifying problems in the current state, measures were defined to improve these problems in a future state map.

In the future state map, control meetings and milestones were introduced at certain stages in the map. Especially, a concurrent engineering with fixed milestones for handing over the output of each value stream section was initiated. Moreover, an IT interface for handling the bill of material was recommended. Iterations were scheduled in order to avoid incomplete or erroneous transfer of the information. Moreover, the roles and tasks were reorganized to meet the qualification level of the employees and to avoid the faulty work distribution. In the last step, the future value stream map was detailed. The estimated results of the improvements are 24% lead time reduction and up to 2.300 hours workload. These results are mainly based regarding the benefits of the concurrent engineering, the reorganized roles and tasks as well as the implementation of an adequate IT interface

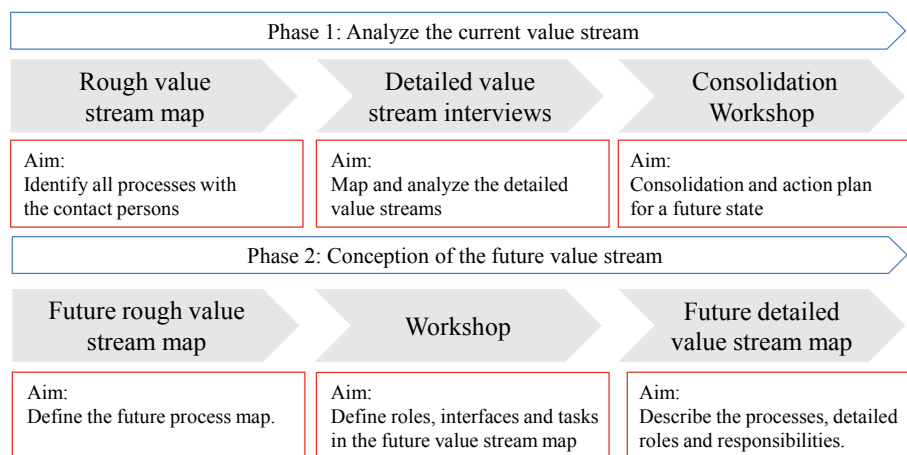


Figure 4. Approach to improve the value stream in product development.

## 7. CONCLUSION

Global competition and increasing customer requirements challenge enterprises to improve their efficiency and effectiveness in PD. The value stream method is often used to identify problems in the current state of the production and to improve it to a future state. The PD has different requirements for this method. Through analysis of six elements of a value stream map, the main differences are summarized from PD to production. The literature review shows that none of the value stream methods covers all differences, so that modifications are necessary to improve the PD value stream. The presented modifications of the value stream method approach the identified differences, so that the paper supports the development of a PD value stream method. The results of the project in an enterprise showed the benefits of the modifications.

In this paper the modifications of the value stream method for PD are based on differences to the production value stream. As the elements of a production value stream serve as classification for differences, it is possible that in PD other elements, which are not part of the production value stream, are needed. Therefore, it is necessary to examine other differences on the basis of circumstances in PD to develop the PD value stream method bottom up. Another further research activity is to test the method in other enterprises to ensure the general practicability.

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