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ITERATION MANAGEMENT BY IDENTIFICATION OF VALUE STREAM IN PRODUCT DEVELOPMENT PROCESSES

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ABSTRACT

This paper explores the possibilities of improving Product Development (PD) processes by reducing rework as it has been defined in lean thinking and by managing iterations based on how they contribute to the creation of value. To conduct this broad objective, two main tools are used: the Kano Model and the Multiple-Domain Matrix (MDM). The Kano Model classifies customer requirements into different groups according to their importance for customers, while the MDM provides the possibility of an inter-domain tracing to establish the connection between the customer requirement categories and the process tasks. These activities are performed in order to identify the role of certain iterations in the creation of value. Based on this information, decisions on how to support PD process improvements are made. These decisions are aimed at reducing the number of iterations and should help developers to minimize rework in PD processes.

Keywords: Product development, lean thinking, Multiple-Domain Matrix, Kano model

1 INTRODUCTION

Innovative product development processes have an iterative nature. Iteration in Product Development (PD) is defined as "the repetition of activities to improve an evolving design" (Eppinger et al., 1997). As Browning stated (Browning, 1998), iteration is a fundamental characteristic of product design and development. According to Leong and Smith (Leong and Smith, 1996), the quality of a product design can theoretically be improved with successive iterations. In development of complex high-tech products, where specialists from several domains have to be involved at the same time, iteration is not a negative word (Cronemyr et al, 2001). Iterations in these projects help in achieving the customer desired product specification.

However, iteration draws a negative connotation since it means rework and as such represents waste according to lean thinking. Iterations are characterized with expanding the cycle time in PD and add uncertainty in PD processes (Browning, 1998) – hence a lean perspective on iterations represents a potential improvement possibility in reducing the cycle time.

Most authors that have analyzed iterations in PD (e.g. Unger and Eppinger, 2002; Browning, 1998) agree that there are two general types of iterations:

- Intentional iterations (sometimes in literature referred to as planned, anticipated or expected iterations), and
- Unintentional iterations (also referred to as unplanned, unanticipated or unexpected iterations)

The first type refers to iterations that are planned and expected to occur in PD. Usually this type of iteration emerges as some tasks need to be performed although the input information is not precisely known. As this information becomes known in the downstream activities, the upstream task is repeated and the product information converges to meet specifications.

The second type of iteration is unexpected and results from unplanned failure of the product to meet specifications. This type of iteration occurs from mistakes in upstream activities, wrong sequence of tasks, changes in requirements, test failures, etc.

Lean thinking entails that all activities that do not add value in the process are waste. This approach has been followed by some authors to analyze iterations as waste drivers (Bauch, 2004; Kato, 2005, Graebsch 2005). Kato (Kato, 2005) first defined rework as a waste driver caused by planned and unplanned iterations. Then, by applying root-cause analysis he identified the relationship between wasted time on rework and the corresponding causes.

Browning (Browning, 1998) suggests two steps for reducing PD cycle time and variation. The first step is to minimize the unintentional iteration by ensuring that the right information is available at the right place at the right time; appropriate activity sequencing given the relevant constraints is performed; resources are available; requirements are stable and mistakes are minimized.

The second step according to Browning involves managing the intentional iterations in such a way that the following is achieved:

- *Faster iterations*, and
- *Fewer iterations*

Faster iterations are realized by improving communication between teams. This is achieved by increasing the frequency and speed of information transfer (Graebsch, 2005), utilization of appropriate software to speed up or automate specific tasks, usage of simulation and analysis tools to reduce test cycles, standardization of analyzing tools between different engineering departments and removal of extraneous activities from the processes (Browning, 1998).

Fewer iterations are achieved by elimination of iterations. However, as iterations also add value to the PD process, they cannot be eliminated by blind selection as it might negatively affect the outcome of the PD project. Therefore, the main challenge is to identify which iterations are unnecessary and should be eliminated.

This paper proposes a new prescriptive systematic methodology that would allow early identification of the iterations that do not add value to the process. This is achieved by identifying the value stream in the PD process.

2 METHODOLOGY

The ultimate goal to be achieved by applying this methodology is to improve PD processes by reducing rework as well as by supporting value-adding activities, based on how the customer requirements (value) propagate(s) through the PD process. To conduct this objective, two main tools are used: the Kano model and the MDM. The Kano model is used to classify customer requirements based on their importance for customers while MDM provides the possibility of an inter-domain view and analysis. In this section, a methodology which leads to the identification of the value stream and the identification of the iterations that add value to the process will be presented. The proposed methodology consists of the following steps.

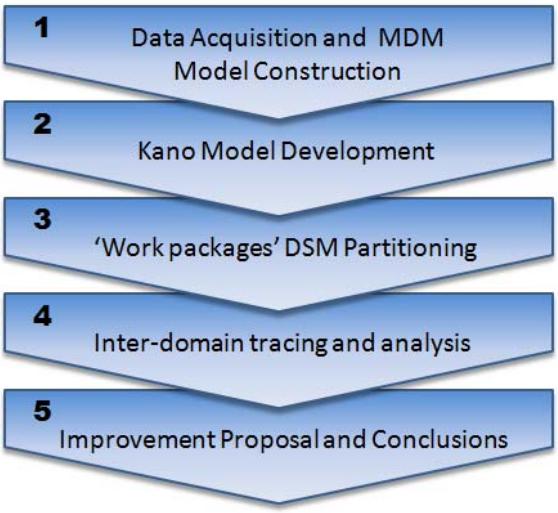

Figure 1. Proposed methodology

2.1 Data acquisition and MDM model construction

The first step consists of the acquisition of the essential information, required to carry out the process improvement proposed in this methodology. This data will be used to build the MDM model of the PD project to be improved. The MDM model needs to have 4 core domains.

- Customer requirements: this domain comprises a detailed breakdown of the customer's expectations for the product, coupled with the technical response about how the product will meet those needs.
- Customer functions: is composed of all the functions the product to be improved should contain. These functions are derived from the customer's requirements.
- System elements: comprises all product components such as software, controllers, electrical connections or mechanical parts. "System elements" is linked to the "Customer functions" domain, which contains the functions that the system parts have to perform.
- Work packages: includes all the tasks to be completed in order to develop the product. This domain represents the process of the PD.

Based on the information above, the appropriate Design Structure Matrices (DSM) and the Domain Mapping Matrices of the MDM are obtained. For more information how the MDM is obtained, please refer to (Lindemann at al. 2008).

2.2 Kano model development

This step consists of the classification of the customer requirements obtained in the previous step of this methodology. The tool that is used to conduct this classification is the Kano questionnaire. Through the application of Kano's model, customer requirements are divided into 4 different groups:

- *Attractive requirements*: include those requirements which are critical for the creation of customer satisfaction. These types of requirements exceed customer's expectations and therefore are highly appreciated by the customer.
- *One-dimensional requirements*: in this group are classified those requirements which lead to a proportional increase or decrease of customer satisfaction according to their level of fulfilment.
- *Must-be requirements*: if these requirements are not met, the customer will be very dissatisfied but on the other hand, their fulfilment does not increase the level of satisfaction.
- *Indifferent requirements*: the requirements in this group are not taken into account by customers, therefore their fulfilment is irrelevant.

2.3 'Work Packages' DSM partitioning

This third step consists of applying the partitioning algorithm to the "Work packages" DSM, with the purpose of minimizing the number of iterations, through the reordering (re-sequencing) of the DSM's rows and columns. The partitioning, also known as sequencing, or triangularization, is the algorithm used in time-based DSMs to lower-triangularize the dependency marks, in such a way that a better process sequence is achieved.

It is important to remark that after applying the partitioning, tasks' order has to be manually revised. The reason is that the partitioning algorithms are context-free algorithms. These limitations emerge from the fact that in a time-based DSM the order of some process tasks might depend on some other previous tasks (or resources are not available at the right time) and thus, the sequence generated by a partitioning algorithm may not be executable in a real process.

2.4 MDM Inter-domain tracing and analysis

This step consists of the inter-domain tracing of information across the different MDM domains. The goal of this step is to connect each customer requirement with the final "Work packages" DSM and make an analysis of the data obtained from this process.

The input of this step is the MDM model constructed in the first step of this methodology, which contains the appropriate matrices to permit the realization of this inter-domain tracing. The tracing path across the MDM is a manual exercise in which it is required to keep track of the information that is revealed as the tracing process goes forward. Process tasks have been classified according to the relation with the fulfilment of each customer requirement, in such a way that this classification determines which tasks are critical for the creation of customer satisfaction (tasks related to "Attractive" requirements), and which tasks can increase customer satisfaction (tasks related to "One-dimensional" requirements). In addition, the classification reveals which tasks do not increase customer satisfaction (tasks related to "Must-be" or "Indifferent" requirements). This will reveal the

value stream through the PD domain. From the tasks classification mentioned above, any iteration that might take place in the development process can be classified based on the type of tasks involved in that iteration. Therefore, iterations can be divided into different categories according to their contribution to customer requirements, respectively contribution to the creation of value.

2.5 Improvement proposal

The final step of this methodology consists of suggesting an improvement strategy for the product development process. The improvement proposal will be based on the results obtained after applying the MDM inter-domain tracing and specifically on the tasks and iteration classification made based on their contribution to the value creation.

Based on lean perspective, the proposed improvement strategy should help developers to reduce rework. After conducting the MDM inter-domain tracing steps, parts of the PD development process will have one of the following four hypothetical conditions:

1. *The process has iterations and they have been classified as "Must-be" or "Indifferent"*: in this situation, as the iterations involved with process tasks based on their classification do not contribute to increased customer satisfaction, they can be eliminated. With this elimination of iterations, a reduction of the development time will be achieved, but at the same time it represents a loss of information within the process. To ensure that the improvement process is conducted effectively but without this loss of consistency, the elimination of any iteration has to be followed by the creation of appropriate new tasks. In the case of "Must-be" or "Indifferent" related iterations, the new tasks to be created will be aimed at bridging the gap created in the process by introducing the re-used solutions for the product to be developed.
2. *The process has iterations and they have been classified as "Attractive" or "One-dimensional"*: in this case, as the iterations involved with the process tasks are indispensable for the creation of value, they cannot be removed. Furthermore, these iterations should be closely monitored and supported by the project management. Appropriate resources should be allocated in order to converge these iterations faster.
3. *The process has no iterations*: in this case the improvement strategy should aim to strengthen the process through the creation of tasks which support the existing value-adding tasks (tasks related to "Attractive" or "One-dimensional" requirements). Those tasks related to "Indifferent" requirements should be further analyzed to identify the possibility of shortening or eliminating them.
4. *The process has iterations which comprise tasks belonging to different requirements categories*: in these cases, the iterations that take place in the process are comprised of tasks classified in different requirement groups, so in order to decide which actions have to be applied to improve the process a deep analysis of these iterations has to be conducted. One way of doing this is by breaking down the tasks involved in the iteration and performing an analysis of each one of its sub-tasks in order to see to which requirements group they contribute. This process is repeated until clear iterations of customer groups are obtained.

3 CONCLUDING REMARKS

Through the application of the methodology, customer requirements can be traced in order to identify the tasks responsible for each requirement. This provides several benefits for the developers, which are summarized below:

1. It permits a visualization of the value stream.
2. It provides an overview over the connection of product parts and customer requirements.
3. It provides possibilities for process improvements through a value stream analysis, which defines the iterations that can be eliminated from the process.
4. Parts, tasks and iterations that are responsible for important customer requirements are visualized. Based on this, developers can decide to further analyze particular parts of the process by using traditional VSM tools in order to identify other waste types in the process.
5. The methodology provides a framework for an analysis of important PD domains and sets customer requirements as basis for the improvements of these domains.

A limitation of the methodology is that PD process improvement efforts are only based on customer functional requirements, in such a way that other kinds of requirements such as legal and economical are not taken into account. However, this work represents the first step in using the MDM as a value

stream mapping tool. Further research on how MDM can support the implementation of lean thinking in the PD processes should be conducted. Such efforts include (but are not limited to): extension of the methodology to multi-project environment; incorporation of other lean techniques in the methodology, such as tact time, pull and just in time (JIT); inclusion of other requirements in the analysis, such as legal and economical requirements.

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INVEST ON VISUALIZATION

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Introduction

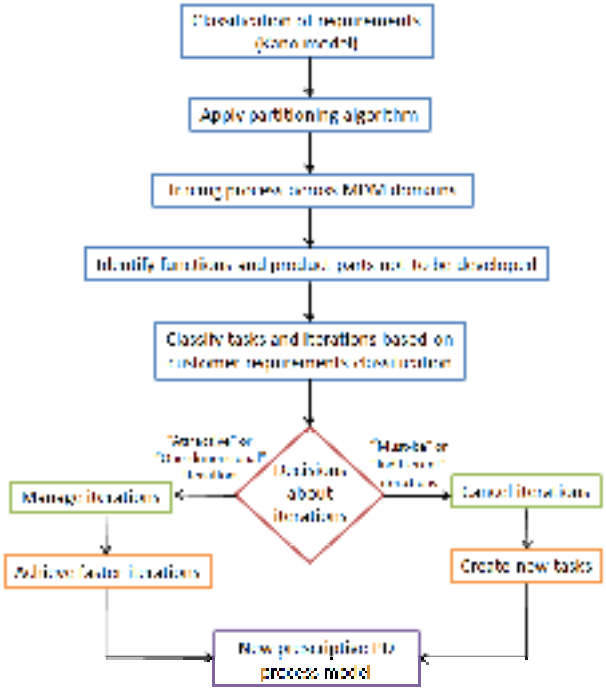
- Product Development (PD) processes are complex because of the branching, iterations and rework.
- Shortening the PD lead time has two main benefits:
  - Faster response to market changes
  - Cost reduction
- Shortening the PD lead time can be achieved by:
  - Faster iterations
  - Elimination of iterations
- The problem: How to identify iterations that can be eliminated (negative iterations)?

INVEST ON VISUALIZATION

Objective and Research Questions

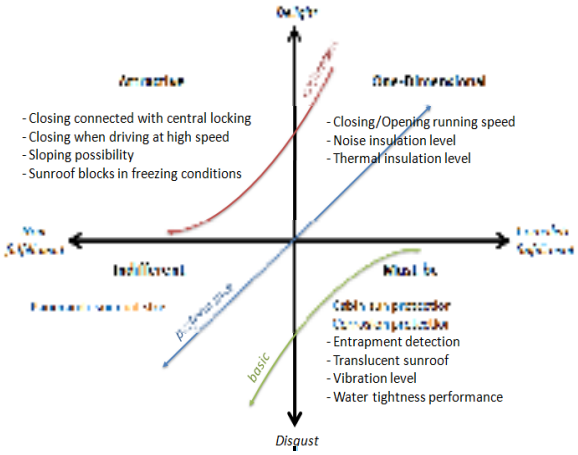
- **The aim of this paper is to explore the possibility of using an MDM methodology for improving PD processes by eliminating iterations that do not add value from customers perspective.**
- Is it possible to trace which process tasks are affected by certain customer requirements?
- Is it possible to classify process tasks and iterations according to value generation, based on customer requirements?
- Based on this value stream information, what kind of process improvements solution are possible to implement?

Methodology



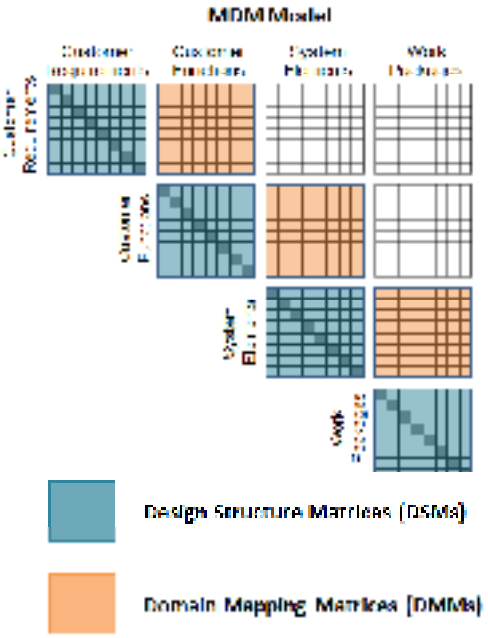
Case Study – Kano Model

Kano Model



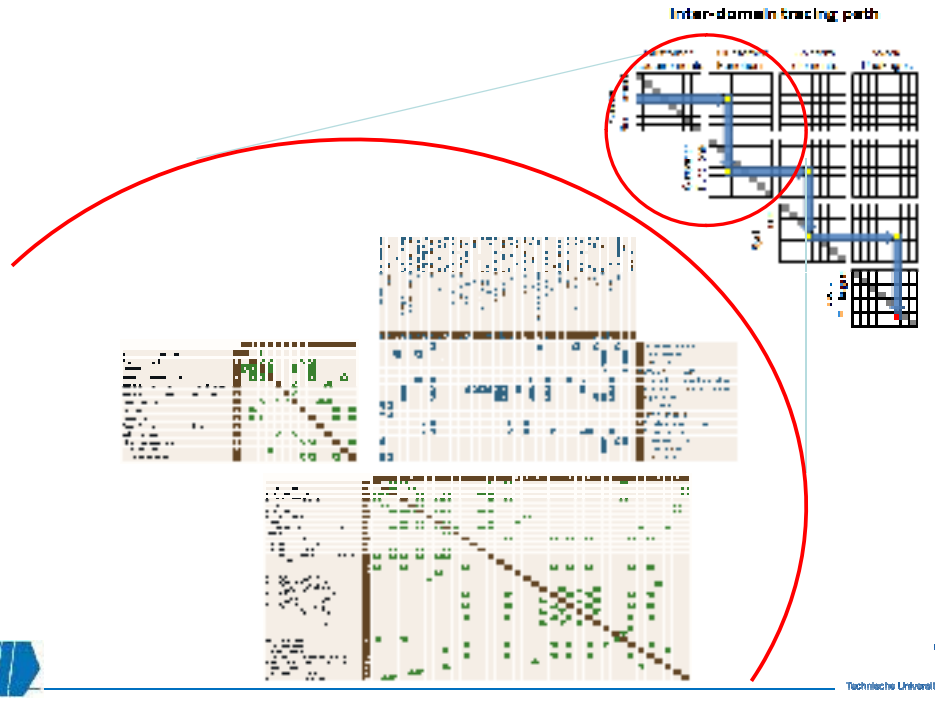
- Car sunroof PD project was taken as a case study for the methodology
- A group of 20 students was interviewed to obtain the list of the customer requirements
- Self-stated importance questionnaire were used.
- 14 customer requirements identified and classified in 4 groups:
  - Attractive
  - One-dimensional
  - Must-be
  - Indifferent

Case Study – The MDM

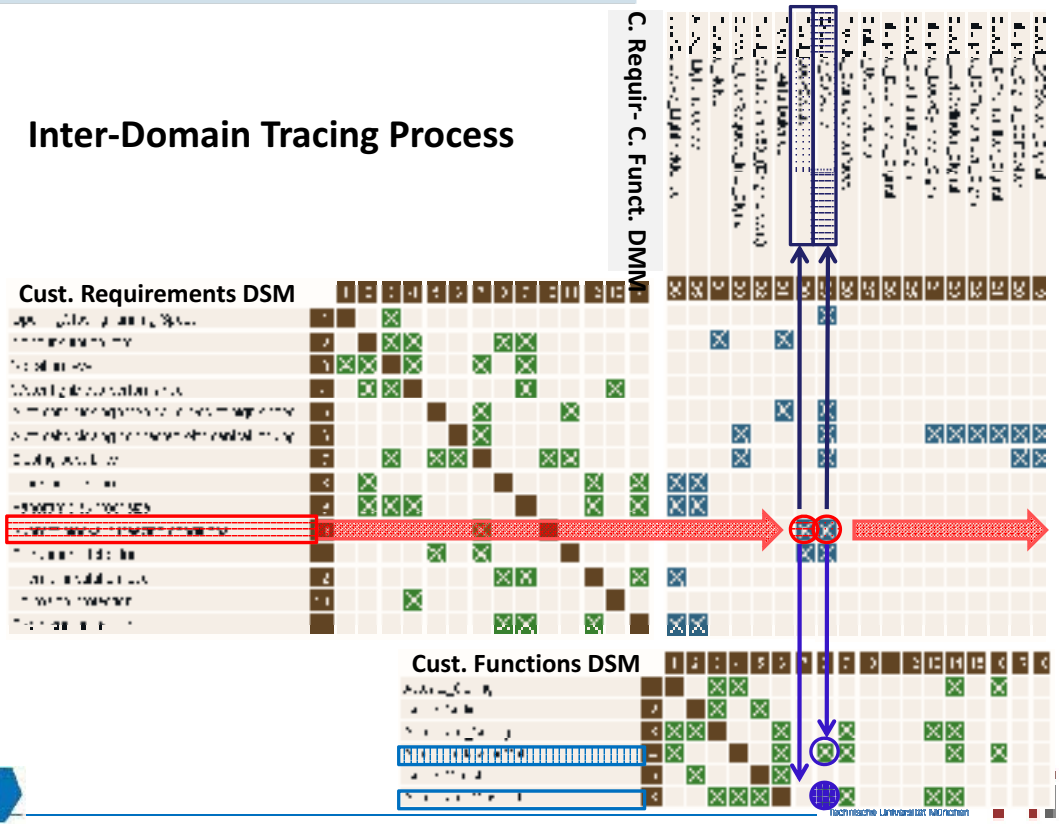


- MDM model of a Sunroof PD project
- 3 domains obtained from an International Car Manufacturer
- 1st domain – Customer Requirements was added after Kano model was developed
- Relationships between customer requirements and customer functions obtained from interviewing the project team members

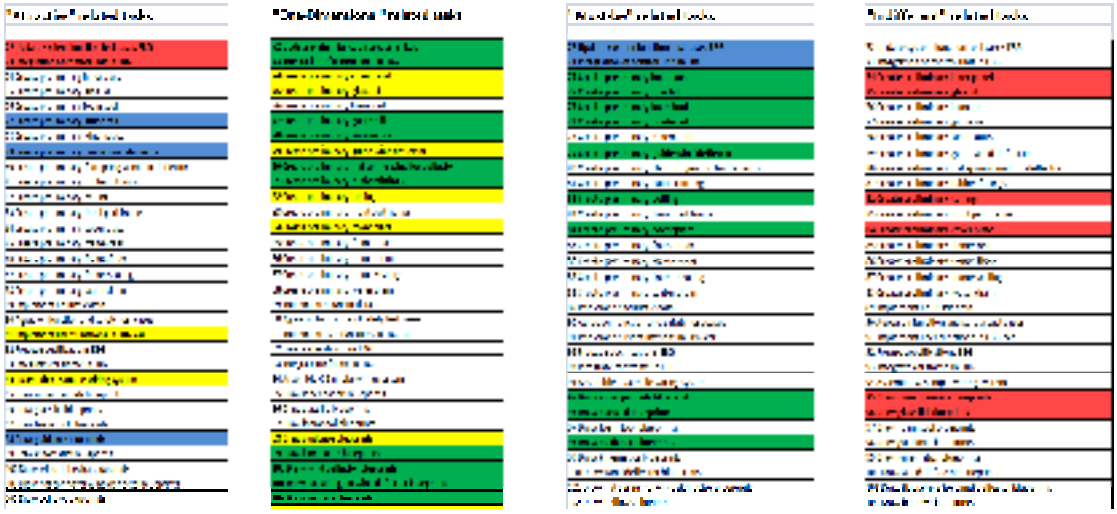
Case Study – Tracing Path



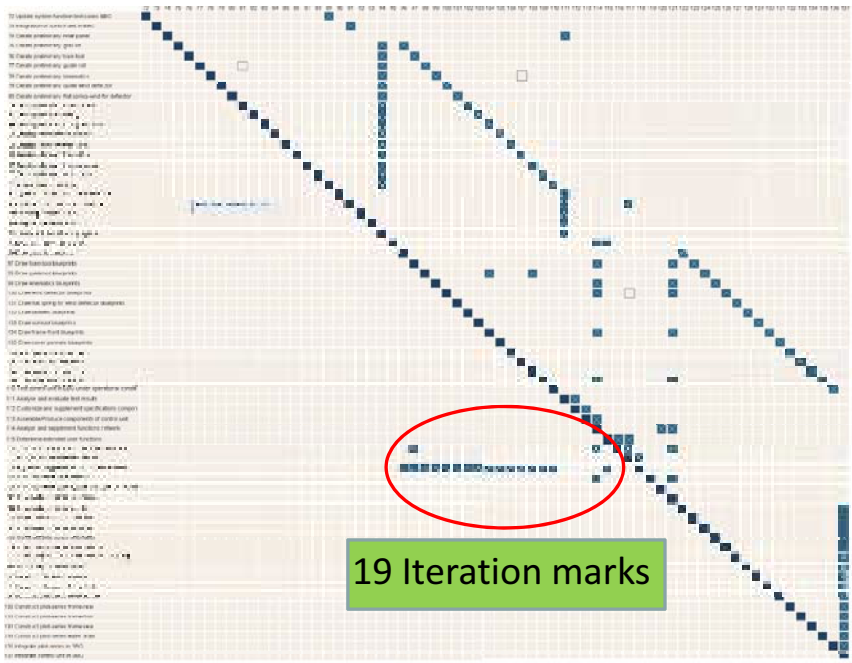
Inter-Domain Tracing Process



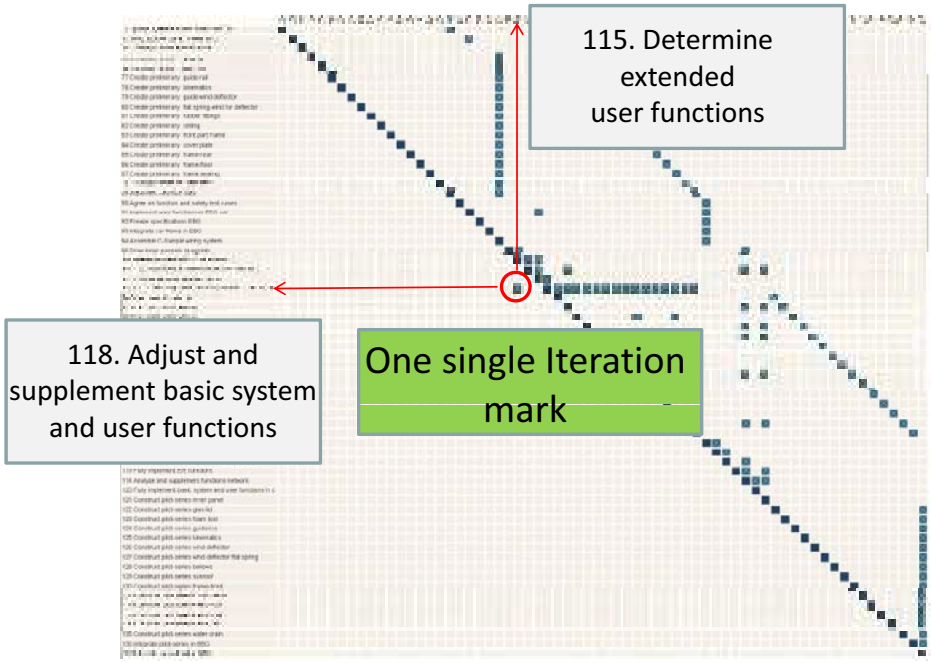
Case Study – Categorization of the Tasks



Case Study – Work Packages DSM

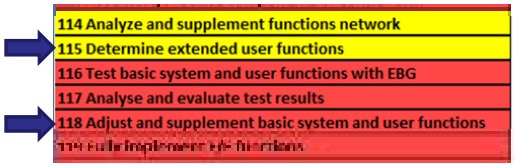


Case Study – Partitioned Work Packages DSM

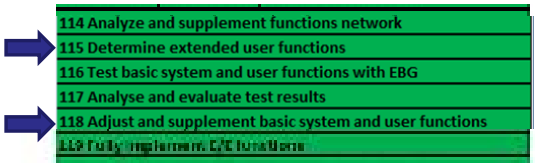


Case Study – Analysis of Iterations

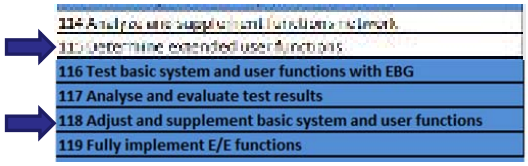
Attractive related tasks



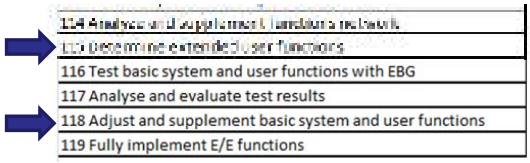
One dimensional related tasks



Must-be related tasks



Indifferent related tasks



Iteration mark relates to attractive and one-dimensional requirements, therefore should not be eliminated.

Conclusion

- The MDM domain tracing process revealed the relation between process tasks and customer requirements. Process tasks were classified according to their responsibility in adding value to the process.
- The PD process can be improved by supporting these value-adding activities, and by elimination of the iterations that do not add value to the process.
- In the case study presented, the classification of tasks revealed one iteration mark connected to “Attractive” and “One-dimensional” requirements therefore its elimination was not possible.
- One of the main limitations of this methodology is that it is focused only in customer requirements.