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Implementing an Internal Development Process Benchmark Using PDM-Data

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Abstract
This paper introduces the concept for an internal development process benchmark using PDM-data. The analysis of the PDM-data at a company is used to compare development work at three different locations across Europe. The concept of a tool implemented at the company is shown as well as exemplary analyses carried out by this tool. The interpretation portfolio provided to support the interpretation of the generated charts is explained and different types of reports derived from the analyses described.

Keywords:
Process Benchmark, Product Development Process

1 INTRODUCTION

Today's development-process is mainly driven by three factors: time, quality and costs. High quality products need to be brought to the market in as little time as possible at competitive costs. In addition to this, flexibility and creativity have further important impact on the development-process. With these influences competing, ways need to be found for an optimal product development process.

One way to identify potentials for development process improvement is carrying out a process benchmark. In this paper the concept of a tool to support an internal process benchmark is introduced. This tool is implemented at a company using data derived from its Product Data Management System (PDM-system). Three different development locations are compared this way.

To do so, qualified characteristics for process analysis are discussed in this paper. Furthermore practical methods of analysing business processes based on data-collection from digital data-sources are introduced. Also, a general concept of an analysis-tool based on Microsoft Excel and a PDM-system is introduced. In order to support the interpretation of the results of the development-process-analyses and to draw conclusions for corrective or investigative actions, a portfolio is provided. An international automotive supplier company serves for the practical application of the theoretically planned analyses.

2 PROCESS CHARACTERISTICS

In this chapter the development- and change-process in particular are characterised. Dettmering [1] defines as characteristics of a development-process the required information and the required organisational departments. In addition to this, the goal and the result of a process are named as important characteristics, as well as the development-phase and the current state of process and product.

In the context of product-information, Dettmering [1] gives the following list of characteristics:

- identification data (owner, revision, date, name, ID-number)
- structural data (technical classification, standard name, kind of product)
- constructive data (function, material, weight, size, tolerances)
- production data (procedure, alternative procedures, processing time)
- controlling data (material costs, machine costs, stock costs)
- purchase data (price, source)

When dealing with processes within the development of products, however, the relationship between product and process can be seen as so tight that product-information can also be used for a characterisation of the development process.

Gaul [2] mentions some characteristics in the context of distributed development-processes as well. He gives the following, mainly qualitative aspects for a description of the development-process. By naming specific values for these characteristics, in some cases a quantitative evaluation is seen as possible, so that these aspects can be taken into consideration for an objective process-description and analysis. Some examples are given in the following:

- number of partners (two, more than two, not clear)
- distribution of locations (local, regional, international)
- time order (parallel, sequential, mixture)
- intensity of cooperation (integrated, loosely linked)
- data access (possible, not possible)

In addition to this, the different functions of PDM-systems can serve as characteristics and therefore as a source for analyses. With products and documents passing through these functions within the development-process, their main attributes are changed and therefore can be used for the characterization of the development-process.
But it has to be warned against the wrong conclusion that the PDM-functions are a complete digital implementation of the development-process. The PDM-system it is not an exhaustive documentation of the development-process, only certain process steps can be seen and analysed by its data.

Derszteler [3] provides a further set of variables that describe processes. He specifies seven groups of variables, which are: time, information, resources, costs, human resources, quality and flexibility. For this paper six different kinds of information are derived from these literature sources, as can be seen in figure 1.

In order to be able to analyse these characteristics they need to be implemented and used in the PDM-system.

The question arises, which characteristics should and can be taken into consideration. This is discussed next.

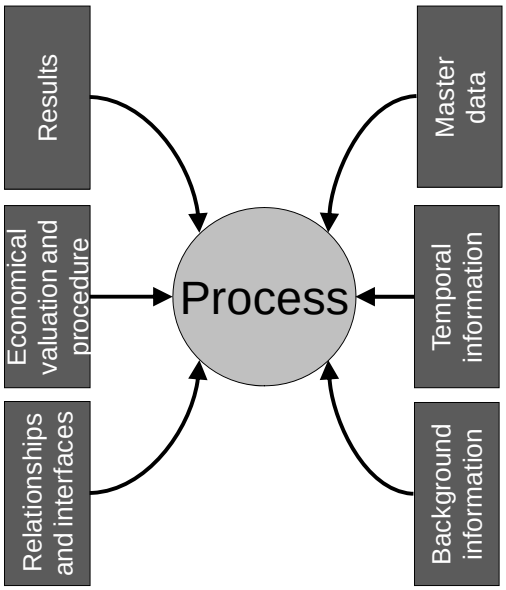

Figure 1: six kinds of characteristics for process description

In order to adapt process characteristics to the kind of process analysis proposed in this paper, these characteristics have to be implemented and administered in a software system, in this context a PDM-system.

As far as implementation of characteristics is concerned, the following three kinds of implementation can be distinguished in the context of PDM-systems:

- characteristics that are directly implemented in attributes (e. g. name)
- characteristics that are summarised in the history (e. g. any modification)
- characteristics that are not implemented in any attributes (e. g. development time)

Besides the form of implementation also the form of administration can vary. On the one hand, an attribute can be administered by the PDM-system; on the other hand, an engineer might be responsible for the administration and by that can cause inconsistencies and gaps within the documentation. The different forms of implementation and administration are discussed more detailed in the following.

The first group of characteristics are directly implemented in form of attributes, so they can be collected directly and their analysis is simple. They are administered automatically by the PDM-system or manually by the development engineers.

However, the second group of characteristics are documented in the history of an object and therefore can only be analysed indirectly. These data are subject to supervision of the PDM-system. Moreover, these characteristics document different kinds of events related to an object (e. g. check in, check out, modification or promotion).
Histories have a common content, even if there are different ways of notation. So, the recorded events are mainly documented with name, date, and application-specific information. The history can include information like the ones listed below:

- kind of event
- person
- date
- status
- access-specific information

Having described the second group of implemented characteristics, the last group of characteristics can be addressed: the non-implemented ones. These characteristics might be interesting for the description of the change- and development-process, but they are not implemented and thus not applicable for process analysis.

3 OBJECTS OF ANALYSES

The aim of this paper is to analyse change- and development-processes. Focused on workflows according to zur Muehlen [4], these processes can be analysed by five kinds of data:

- events (processes with irregular operations, such as aborted processes)
- activities (comparison of similar activities for analysis of efficiency)
- processes (analyses of distribution and required resources)
- resources (identification of organisational ratios or learning curves)
- business objects (analyse of performance of processes)

In this paper, all of these are needed. But from the PDM-perspective, all of these data can be seen as objects administered by the PDM-system. Due to this, they can all be summarised to a single group named “PDM-objects”. As in this case one single group of objects is not sufficient and five are too many, the objects of analysis are grouped into process and product specific objects

The grouping into process and product leads to two ways of analysing a process:

- direct analysis analysing the process (process, activity, event)
- indirect analysis analysing the product (resource, business object, event)

3.1 Description of the tool

The approach on the analyses-tool in this paper bases on the management-information-systems introduced in Best and Weth [5].

In contrast to the original concept the semi-automated tool in this paper only uses a single data-source: the PDM-system. Furthermore, the update of the data and the modification of analyses-algorithms are carried out manually instead of the automation that is originally described by Best and Weth [5]. But the main difference between the two systems can be found in the inclusion of a support for interpretation. While the management-information-system-approach only presents variables, the semi-automated process-analyses-tool in this paper is accompanied by an interpretation portfolio to support the interpretation and therefore facilitate the handling of this system.

At the beginning, the data are collected, and several table reports are generated. Based on these files from the PDM-system, the information is summarised into two analysis-files, one for the background information and another one for the actual analyses. The first one, the general data, includes general information that is universally valid, such as a list of persons and the location they work at or a list of customers. The latter contains the

information on the object for the actual analyses.
After the generation of these two files, the information is analysed and specific values are calculated with by formulas and Visual-Basic-for Application-macros. Based on these values, charts are generated and the most important variables are integrated into the summary-sheet. From both, charts and summary-sheet, a specific report is generated for presenting the results to the management.

The following figure illustrates the concept of the analyses-tool in a flowchart.

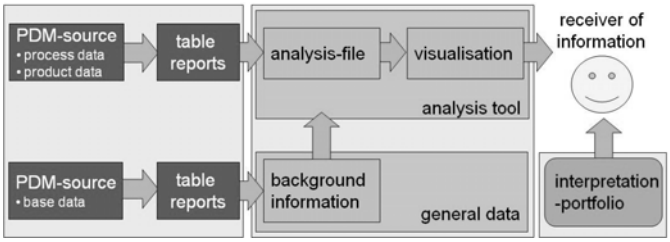

Figure 2: Concept of analysis-tool

3.2 Analysis of products

As far as the analysis of product-change- and -development processes is concerned, some information has to be taken into consideration, as stated before. Mainly the product that passes the processes can serve as a source for this information. Thus, the relevant objects and the analyses of their characteristics are presented. In this respect, the following PDM-objects are analysed more detailed:

- persons
- drawings
- notify- and responsibility-lists

Based on these objects, the analyses described below have been performed.

Persons and their locations and departments

The persons involved in a change- or development-process play an important role. On the one hand they have strategic functions such as planning or deciding about change requests or other processes, on the other hand they fulfil operative functions like giving estimation-statements or realising the decided changes.

Additionally, the analysis of persons and their locations and departments can serve as background-information and reference for further analyses. Thus, persons and their organisational and regional impact on processes are interesting to analyse. There are mainly two aspects worth investigation: the location and the department a person is located at. As an example the analysis of departments is described in the following.

Although person-related analyses have a rather statistical character they can serve as background information and reference for the interpretation of further analyses. Moreover, the persons have strategic and operative influence on the processes. These are the main reasons for the importance of this investigation.

The analyses are based on attributes that can be taken from the PDM-system. The relevant attributes are:

- login-name and full name of the persons
- location and department of the persons
- availability of the persons (active / inactive)

Persons per departments

One analysis in the context of persons is the analysis of the number of persons per department. This analysis can serve as statistical background, as possible reason of a certain level of influence and as reference variable for further analyses.

The company's structure of organisation is observed more detailed in order to acquire knowledge about the real impact of departments.

3.3 Drawings as object of investigation

In development processes, the main object of communication and documentation concerning geometrical information are drawings [6]. Furthermore, they contain functional information and are therefore important representations of the product. Moreover, drawings include information that cannot be taken directly from the digital product models such as tolerances, materials or methods of production. Thus there are a few aspects that have to be analysed in more detail in order to gain information about the development process:

- number of drawings per development-phase
- number of approvals and rejections of drawings
- number of drawings generated per person
- current number of drawings per state
- number of drawings per state in trends
- relative number of revisions per drawing
- average development duration per drawing
- number of drawings with a certain duration in statistical overview

These aspects have been selected for mainly two reasons. The first one is the availability of data. Not every kind of information is implemented and administered in the PDM-system, thus only available information can be considered. The second reason why these analyses have been selected is that they focus on topics that are tightly connected to the development process such as development duration or releases. Therefore, the selected information is suitable for a process analysis based on PDM-data.

As well as persons, drawings are objects that are documented with by the PDM-system. In order to carry out the analysis of the aspects named above, the following characteristics have to be taken into consideration:

- name of the drawings and the related parts
- current revision and all revisions of the drawings
- rejections and approvals of the drawings
- current state and policy of the drawings
- date of origination and all states of the drawings

Number of drawings per development-phase

The number of drawings per development-phase can be used as a general overview of the activities of every location. Additionally, the absolute number of drawings per development-phase can be identified. Also the ratio of these numbers is important for the strategic orientation of the company. These numbers can help to identify weaknesses concerning the company`s future. There need to be enough activities in development in order to guarantee future success.

In order to enable a more specified analysis, it is not the absolute numbers of all locations which are plotted, but the values for the three main development-locations.

Number of drawings originated per person

The number of drawings originated per person can be seen as an index for productivity. For enabling the

comparability between the different locations, this variable is referenced to the number of persons working at the location. Thus the formal definition is similar to the following productivity factor named by Burghardt [7]:

$$Factor\ of\ \ productivity = \frac{Expense\ on\ product}{Number\ of\ \ persons} \qquad (1)$$

Moreover Burghardt [7] hints that this index describes a business economical variable, but in this paper's context, it can also be interpreted as indicator for the quality of work in a process. Furthermore, this variable can indicate the workload at a location or special events in the development-process such as a request-for-quotation-phase.
While the number of persons can be collected easily, the expense on the product is hard to evaluate. In this paper, the number of generated drawings has been selected to represent the expense. Thus, the analysis of drawings originated per person can be seen as an analysis of productivity and events in the development-process.

For a better overview not only the value of a single location is plotted, but the values of the three main development-locations as well as the average value. By that a more detailed analysis is enabled. Still it has to be regarded that the amount of work necessary to complete a drawing is related to the complexity of the part or product in question. So not only the number of drawings is taken into account but also the complexity of the products generated over a period of time as it is done in the following type of analysis.

Average development duration per drawing and part-class

In this paper, the average development duration is analysed in relation to the complexity of the related part. These two variables are described in more detail next.

According to van der Aalst [8] and Derszteler [3], the average development duration can be used as a process-indicator. It is mainly used for performance-analysis in the context of workflows. Heinz [9] warns against the wrong conclusion that the duration between two states is identical to the work time. This wrong interpretation would imply that the developing engineer is exclusively working at this single product, which is not a realistic assumption.

The average duration in this context means the arithmetic mean of all durations between the date of origination and the date of releasing the drawing.

In order to quantify the complexity of a part and its drawing, part-classes are assigned to the standardised part-names in the PDM-system. This provides the advantage that the products are generalised and comparable. The following six part-classes are used for the analysis:

- class A combined assembly
- class B complex assembly
- class C simple assembly, complex component
- class D simple component
- class E small or standardised part
- class X not assignable

The analysis is then carried out regarding the average development time for the different part-classes and the numbers of parts developed per class.

3.4 Notify- and responsibility-lists

Notify- and responsibility-lists can be seen as automatic documentation of information-distribution and responsibilities. While the notify-lists include all persons who need to be informed automatically about important news concerning a development project, the responsibility-lists include all persons who take a role of responsibility in a process like the change-process. Additionally, both lists can be used as a source for information about possible contact persons.

These lists are an object of investigation as the information-distribution and responosibilities are documented here. As the analyses for both types of lists are very similar, only one example is given in this paper. The following items are aspects of the analyses:

- number of active persons per list
- number of projects per list
- number of references in lists per location
- number of departments per list

Along the lines of the analyses of drawings, these aspects have been selected because of their availability and their tight connection to the development-process.

As notify- and responsibility-lists are objects in the PDM-system, they can be administered and analysed as described above. To do this, the following relevant attributes can help:

- e-mail-address of persons
- location and department of persons
- availability of persons
- projects and customers of actual list
- date of last modification

Having given the relevant characteristics, one analysis is described in more detail.

Number of active persons per list

As far as the analysis of information-distribution and the responsibilities with the help of notify- and responsibility-lists is concerned, a very interesting point is the number of persons, whose communication is documented in the lists. It is analysed, whether there are enough persons communicating, but no answer can be given whether these are the right persons or not.

For this analysis, the number of active persons in the lists is counted and the number of lists with a certain number of persons is plotted in a bar-chart. Furthermore, ranges of optimal sizes are pointed out by coloured areas. These graphs and an explanation what to do when optimal sizes are missed build up part of the interpretation portfolio described later on.

3.5 Analyses of process

As stated above, along with the analyses of products, information can be collected by the direct analyses of processes. The process analysis adds to the already carried out analyses of development processes via product data. As the development-process was regarded intensively in the analysis carried out by product data, in this part of the contribution the focus is laid on change-processes.

The change-process

The change-process is tightly connected to the development-process. For this reason, exemplary analyses of this process can be used to get information about the overall development-process. With the change-process being implemented in the PDM-system as a workflow, data about this process are available and the PDM-system can serve as data-source.

In this context several aspects can be taken into consideration. They have been selected because of their relevance for the change-process and for the availability of information in the PDM-system. In order to give an overview of the analyses, the selected aspects are listed below:

- number of affected drawings
- current number of change requests per state
- number of change requests per state in trend
- number of change requests per location
- number of tasks on time

Processes can be implemented as objects in a PDM-system with characteristic attributes. With these attributes being the base of the analyses, they are shortly introduced in the list below.

- involved persons and their roles
- start- and target-date of the change requests
- description of the change requests
- date of initiation and the states of the change requests
- related customer of the change requests

One of the analyses carried out to analyse the change process is described in the following.

Current number of change requests per state

The number of change requests that are currently at a certain state are analysed. This analysis can serve as answer to the question, what the affected engineers are working at currently. This analysis can be completed by a look at the number of drawings generated in the development process. By that a snap-shot of the momentary topics of work can be deduced.
In order to allow a more specified analysis, a distinction for all locations, all customers and all supervisors is integrated.

3.6 Summarising, interpreting and reporting

Having analysed processes and their resulting products, these analyses and their results need to be summarised, interpreted and presented for the initiation of further adequate action. In this respect, zur Muehlen [4] and Derszteler [3] point out the need of different information for different users. The strategic management needs long-time-oriented information, whereas the operative management requires rather short-time-oriented facts [4]. Additionally, a third and maximum detailed level of information is important for the direct controlling by PDM-administrators.

For the supply of information regarding the different needs for information, summary-sheets, the interpretation-portfolio and reporting are used.

Summary-sheets

During the analyses of processes and products in the PDM-system, a great amount of different variables is calculated. But this amount of variables is neither clear, well-structured nor handy. For these reasons, summary-sheets are created within the analyses-tool. These contain the most important variables of the analyses at a glance, such as the number of drawings in a certain state or the number of missing tasks within a process. In addition to this, they contain some organisational information such as the date of data-collection or the name of the analysing person.
Referring to van der Aalst [8], two concepts have to be traded-off in this respect: aggregation and abstraction. While aggregation describes the accumulation of required information, abstraction focuses on the reduction of unnecessary information.

While for strategic and operative management the information displayed in the summary-sheets is integrated into a report at different levels of detail, PDM-administrators can take the required information directly from the summary-sheets and the analyses-tool.

All in all, based on the summary-sheets, the generation of reports is facilitated, different needs of information are considered and a clear, structured and handy overview on relevant process-information is given.

Interpretation-portfolio for analyses

The textual documentation of the interpretations for the analyses as provided by the summary sheets does not fit the need for an easy and fast interpretation. Therefore, the interpretation-portfolio has been developed, which is described in the following.

After having analysed the development-process, the results of the analyses need to be interpreted in order to enable a decision for corrective or investigative measures. Zur Muehlen [4] suggests a procedure of defining hints for predefined results of process-analyses. Here, explanations can be inserted for positive or negative correlations of indicators. In contrast Heinz [9] provides an abstract level of support for interpretation by naming five patterns of problems that can be found analysing the data. While the first concept is not applicable for the specific situation because the hints are given automatically, the second concept is too general and therefore provides no reasonable suggestions for suitable actions.

In order to fill this gap the interpretation-portfolio has been developed. This document contains a list of all analyses carried out, along with the developed chart and its interpretation. Additionally, some restrictions are given that are related to the specific analysis.

The support for interpretation is given by naming possible company-specific reasons or effects for high or low values. Moreover, tasks for further analyses or questions on the process are listed, which can prove the proposed reasons and which support further corrective or investigative actions. The optimal value is documented as well, in order to enable the documentation of process-knowledge and the provision of a reference for the analyses.
The restrictions given in the interpretation-portfolio include information on limitations that are applied for the analyses. They consist mainly of the following content:

- vault for data-collection
- locations that can be analysed
- important hints on the interpretation
- information about the displayed values
- visualisation-specific restrictions

Figure 3 shows an extract from the portfolio.

Analyses	Chart	Restrictions	High values		Ideal	Low values	
			Reason	Task		Reason	Task
Active persons per notify-list		vault: eurasia hint: only active persons	List is too general Too many people are informed	Check if list can be sub-divided Check if notify-list can be actualised	2-5	List is empty List is needed in small projects Persons missing	Check if list is used in active project Check if list can be erased Check if list is complete

Figure 3: Exemplary excerpt from the interpretation portfolio

By using the interpretation-portfolio, a clear interpretation and hints for further analyses are given to the user. In order to ensure its validity, the interpretation-portfolio has been generated in discussions and workshops and therefore documents the process-knowledge of several persons.

Important persons for the creation and maintenance of the portfolio come from management and operative engineering. They all hold certain aspects of process-knowledge that can be summarised in this way. Additionally, their integration into the interpretation of the processes can help to raise both acceptance and motivation for process-analyses.
In the context of maintenance it has to be mentioned, that the interpretation-portfolio is not and possibly never will be exhaustive. Thus, the interpretation needs to be questioned every time applied. The portfolio should be completed and adapted during its use so that more process knowledge can be accumulated.

Table 1 summarizes the strengths and weaknesses of the interpretation-portfolio as it is introduced in this contribution.

Table 1: Strenghts and weaknesses of the interpretation portfolio

strengths	**Weaknesses**
• use of a summary makes interpretation faster, safer, easier and more intuitive • increasing process-understanding • discovering best-practise- and limit-values • documentation of long term knowledge • enabling common interpretations, avoidance of wrong interpretation and wrong measures • used to characterise the process • support for interpretation and for drawing conclusions	• great expense on creation and maintenance • danger of unreflected taking of interpretations • low manageability • not exhaustive

When interpreting a result of a process-analysis, this interpretation has to be seen critically. Management as well as work council might be concerned from the analyses and their results [10]. So both analyses and their interpretations can be dangerous for company politics.

For example, an analysis shows that a development-location seems to be less efficient than the others. A premature interpretation might be that this location is working worse, and the replacement of the bad working engineers is a possible measure. But the lower efficiency can also indicate a lack of manpower. Thus, the interpretations of the analyses need to be done very carefully in order to avoid wrong interpretations. Due to nondisclosure agreements no further detailing of the analysis-results and the measures taken afterwards can be given here.

Reporting

After analysing and interpreting the development-process, the results need to be documented and presented, in order to be able to take measures for process improvement. To do so, reporting is seen as a suitable solution. Based on reports, managers should be able to take strategic or operative decisions for process improvement.

For the generation of the report, the generated summary-sheets and charts as well as the interpretation-portfolio are used. All components have been generated during the analyses and provide actual, available and relevant information without much additional effort.
The summary-sheets give important variables from the relevant analyses. In addition to this, charts are presented to visualise important results. In order to allow a more intuitive understanding, the relevant interpretations from the interpretation-portfolio have been integrated into the charts in form of message-boxes.

A management report adapted for the partner company was generated this way.

4 CONCLUSION AND FUTURE WORK

In this contribution a concept for an internal process benchmark using PDM-data is introduced. The process characteristics used for analysis and the concept of the tool implemented at a partner company is described. Furthermore some exemplary analyses are depicted as e. g. the number of drawings generated per person. The interpretation portfolio that was developed in order to support the interpretation of the generated charts is explained. Different kinds of reports for different kinds of receivers (amongst others, management and PDM-administrator) are created. By this kind of analysis of PDM-data an internal development process benchmark at the company is enabled and suggestions for possible measures or actions for process improvement are derived.

After enabling this benchmark it is now planned to implement a similar kind of analyses for different development projects in order to find characteristic metrics that hint on possible project delays and thus enable taking early measures to prevent these delays.

5 ACKNOLEDGEMENTS

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