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A CHANGEABILITY APPROACH FOR PROCESS MANAGEMENT AND DECISION SUPPORT ON THE SHOP FLOOR

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Abstract

This document contains an approach to map the changeability possibilities of machine tools used on the shop floor onto line management understandable business processes. The identified gap is a lack of information transparency on the line management level due to constraints, complexity and speed of a production process on the shop floor. Especially medium-sized enterprises in the supplier sector are forced to operate under strong time restrictions which are predetermined by original equipment manufacturers. Due to competitors and shareholders these enterprises often use a lean management approach which allows them on the one hand to produce under low costs but on the other hand handicaps them to react on disruptive events on the shop floor. We argue that nowadays industrial small and medium sized industrial enterprises have to have a fast reaction on changes and events. It is seen by the authors that changeability of production processes is an essential success factor in this globalized world. Because of the fact that more and more responsibility is handed over to the lower line management, the information support has to be improved in order to make them capable for choosing the best decision. In this paper a concept is shown how the lower management can reallocate production process steps in order to avoid penalty costs if a just in time production is requested by an original equipment manufacturer. To be able to do this, an information support concept for the lower management has to be established within the company to meet the requirements for choosing the best fitting reaction to a disruptive event. The future research concept is described after the analysis of an example production process scenario which is illustrated within this paper.

Keywords: information transparency; management support; changeability of production and process, Business Intelligence.

Introduction

Many enterprises react to the upcoming challenge of globalization and low cost products from abroad with differentiation in their own product range. Especially medium-sized businesses which are in one corner of the market and have to face a new foreign competitor got to decide quickly whether they want to compete with the new products from abroad or leave the hitherto existing market. Due to the strategy of large companies which increase their global activities and try to enter local markets in order to gain shares by offering low-price products, sedentary medium-sized enterprises are forced to react quickly to avoid being placed in a difficult position (Berndt, 2010). Especially during difficult times like the actual economical crisis the fast changeability of a production process can become essential. In order to take advantage of even the smallest margins or cost-saving opportunities, processes which don't produce additional value for the enterprise or idle production devices have to be stopped or quitted.

Only with the flexibility to take influence on the ongoing production and processes an enterprise is able to survive economically hard times for a longer period of time (Jovane et al. 2009, Westkämper et al. 2008). The cost of production if products are only produced to lay in the stock is immense. To obviate such a scenario an enterprise has to collect all necessary information about the actual production process and compare it with the planned process and react to changes on the shop floor which were not planned. Not planned events have different characteristics. On the one hand there are a lot interrupts due to maintenance or die changes. These are more or less normal activities which have an influence on the production process. But these events are somehow planable and already scheduled as estimated. On the other hand there are larger breakdowns which cannot be repaired in a certain period of time. These kinds of events are not to be estimated and probably last for a long time. Therefore they can have a high influence on the production process. In most of the times the production has to be stopped until the broken machine is repaired. Especially if the enterprise follows a lean management approach and is bounded to time restrictions due to just in time production such a breakdown may lead to contractually problems and costs. In order to avoid such a scenario an enterprise has to keep backup machines which are too expensive for medium-sized businesses (Hopp 1996).

Besides the internal events more and more external events forces businesses to be able to react fast in production. One characterisitc of the crises was, that for example orders for parts for the car-manufacturing were canceled, while parts in other businesses were still ordered. Therefore the capabillity to rapidly change production processes was a successfactor for industrial small and medium sized enterprises (SME). The question thereby is how can an enterprise be made capable of reacting to these mentioned events on the shop floor?

The upcoming question how can be dealt with these challenges under consideration of cost-pressure will be discussed in the following pages. This research paper focuses on a possible way to solve this issue with the help of an effective use of the business process management abilities.

1 RESEARCH ISSUE

An actual approach to handle this issue is to use existing enterprise resource planning (ERP) or manufacturing execution systems (MES) for rescheduling the production process. Nowadays many enterprises in the production sector use information systems for calculating their processes. The ERP systems are used for the high level planning which is weeks or months ahead of the production schedule and considers for example human resource planning or sequence planning (Vollmann et al. 1997). Beneath the ERP system the MES systems are residing. The MES systems operate in the near-time environment and are used for planning the production of a day or a single shift. As illustrated in figure 1 the shop floor systems like the control systems are used for the real-time communication with the machines on the shop floor (Schutten 1998, Kletti 2007).

Especially at the University of Stuttgart the changeability of a production line is an actual and highly important research field in these days. As mentioned in the introduction a fast reaction on changed environments like the competitive situation is essential for enterprises which are strongly focused on niche products. Therefore an IT based conceptual framework is in research which is combining the previous mentioned existing approaches on shop floor level with analytical decision support environments called Business Intelligence (BI) (cf Figure 1).

1.1 Research design

The research design is related to design science following the paradigms of Hevner (Hevner et al. 2004). The environments of the research are small and medium sized businesses which are focused on industrial production. Major points in this environment are the particular production strategy of the enterprise and the ability to change the production processes on the shop floor. On the knowledge side a production scenario is used exemplarily. With the identified needs of the companies a concept is shown in this paper.

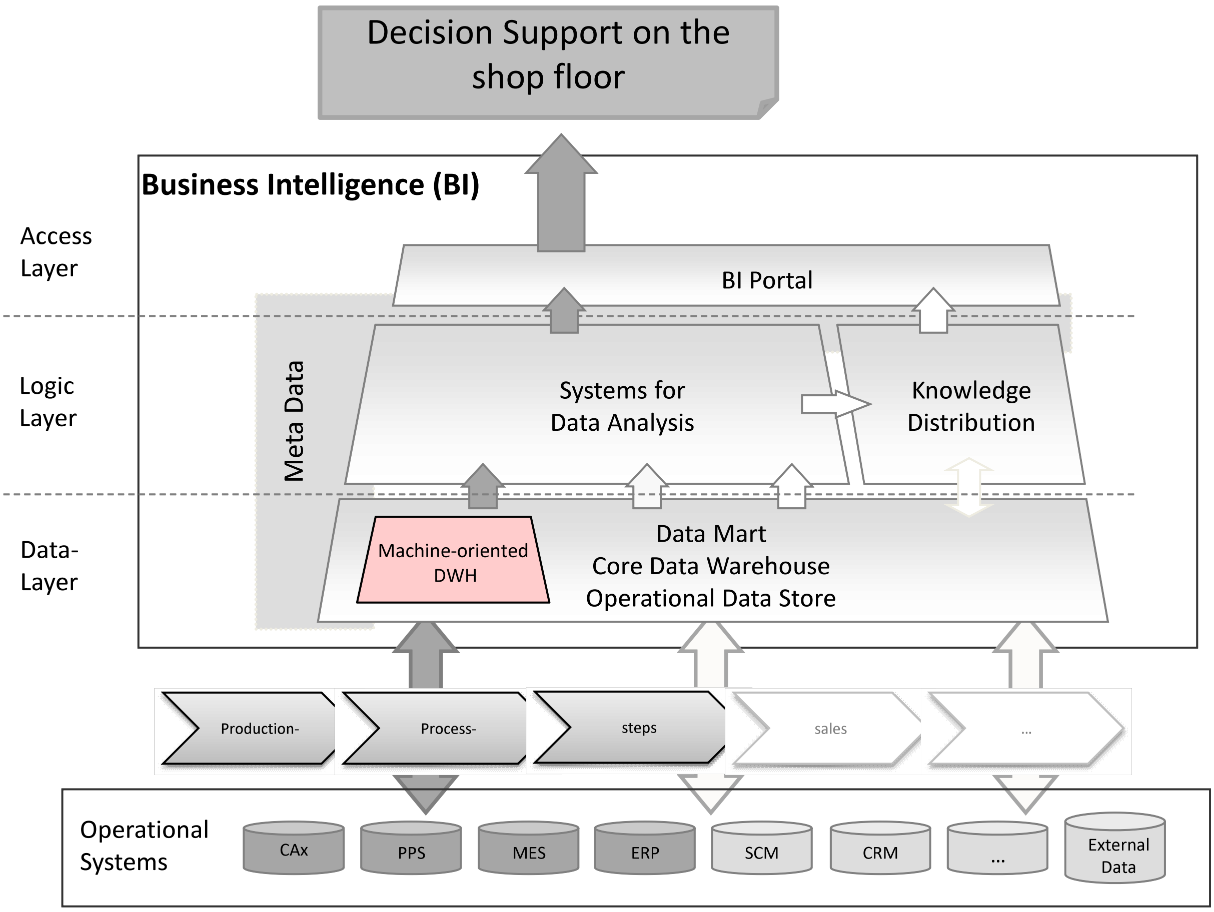

Figure 1. Framework of the research (based on Kemper et al. 2010)

In figure 3 the framework of the research is shown. The information from the shop floor is usually collected via ERP, MES or other operational systems for reporting or controlling (Golfarelli et al. 2004, DeFee et al. 2004). There are already existing approaches which focus on active, analytical or real-time data warehousing (Akbay 2006, Brobst 2002, Inmon 2005, Raden 2003) but an approach for handling and storing structured information to support changeability can't be found in literature yet. The information from the shop floor's production processes are reproduced via the production example scenario. With the theoretical framework of the production and processes the required information can be gained and a concept can be developed in order to use the gathered data for decision support for the lower management. The rough concept can be seen in figure 3 on the right side. The information for the machine-oriented data warehouse concept would be collected, filtered, harmonized, aggregated and enriched via existent information systems (Kemper 2000) and could provide the required information in a structured and user friendly manner.

In general business process management is understood as an approach to handle, monitor, optimize and change the processes in order to improve them (Hung 2006, Davenport 1997, Breyfogle 2003, Becker 2003, Schmelzer 2008). The holistic view to business process management was first introduced by Hammer (Hammer 1990) in the end of the nineteen eighties. In his work he described the necessity of process re-engineering in order to improve the ability of reaching a goal. The holistic view is shared by many authors like Powell (Powell 1995) who sees business process management as a total quality management approach. Rosemann (Rosemann 2006) includes the information technology resources into business process management and sets the basis for a holistic IT- supported approach. This enterprise wide approach still matches with the need of nowadays enterprises. The medium-sized businesses could also make use of business process management as an overall information and configuration system. A manager from Diebold said that his enterprise wants complete visibility to their order fulfillment process from the time an order is received through the process until delivery (Lamont 2010). In addition to integration concepts to close the gap between product-oriented and business-oriented data (Lasi et al. 2010), new approaches to deal with shop floor data are necessary.

In the following, close to the work of Gudehus (Gudehus 1999), only intra-organizational events will be contemplated. This has two main reasons which will be explained shortly. The first reason is the impossibility to have any influence on other companies' practices or processes. In such a case only phoning for updating information about the other companies' problem is feasible. The second and major important reason is the accountability.

Especially for medium-sized suppliers which are dependent on the correct fulfillment of OEM treaties the assurance of time and quality of their products is essential. Many treaties between an OEM and a supplier pay special attention to the date which has been agreed for delivery. In normal case a delay at the supplied OEM is most expensive, because the OEM production processes are often organized in the lean management principle. A not in time delivered part could cause a stop of the whole production line (National Chamber Foundation 2008).

The suppliers are on the other hand not able to produce their parts in advance because this would lead to immense costs for stock-keeping. These costs must be avoided in order to compete with other potential suppliers for the market shares. It can be seen that a supplier who wants to produce at a maximum performance has to fulfill the balancing act between lean management and changeability. Figure 2 illustrates the problem for the company.

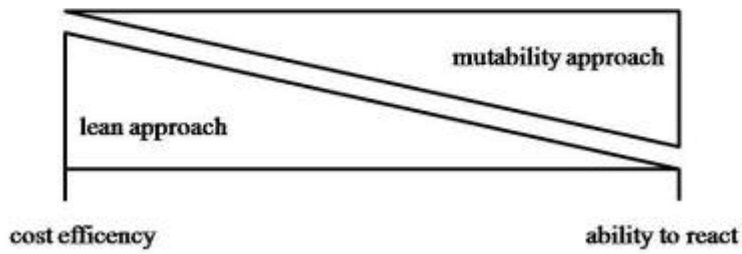

Figure 2. The lemma between lean and changeability approaches.

Lean management on the one hand tries to avoid costs for processes which don't add value to the product (Jones et al. 1999). In this case stock-keeping for example is seen as a non-profit generating process. Such processes should be avoided in order to get a certain production performance at a low level of costs. On the other hand changeability is also a key to keep high priority parts in time for delivery. But changeability, especially on the shop floor layer is associated with costs for additional tools, machines or stock. It is obvious that both approaches have their assets and drawbacks but have to be considered in every production plan. Additionally, if an event takes place and the flexibility of a production process should be used or triggered, the worker at a machine is generally left more or less alone to handle the problem himself or seek help from the corresponding line manager. In general the worker at the shop floor hasn't got the information about the whole production process where he or she is involved in (Boreham et al. 2004). This means that the responsibility of reacting correctly to an event has to lay somewhere else in the enterprise. So the lowest level of management which has complete information about the production process has the responsibility. If the management is asked how to keep the production running the answer would be that they have no idea about the constraints in the production process. Figure 3 illustrates the constraints problem between management and shop floor in a production process (Deming 1982). The time needed to inform the management about the processes and their interdependencies would be longer than the time for repair or organization of a new machine. So this is also a not satisfying alternative.

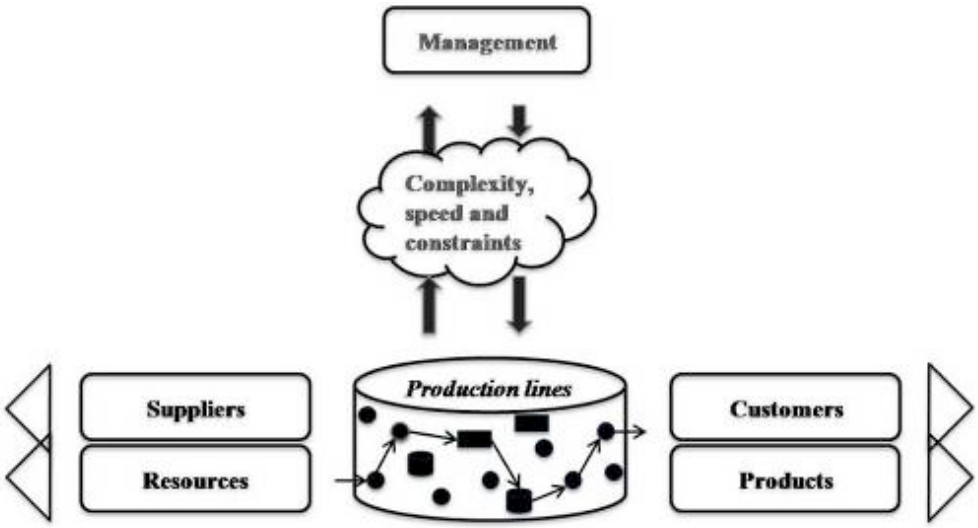

Figure 3. The constraints of a production process.

Changeability itself doesn't give any benefit to the enterprise as long as it is not used or known within the company. How can changeability be used within an enterprise due to lean management restrictions and flexibility? In this paper a concept will be presented and explained with the help of a scenario analysis. An approach to handle this problem is to make the management capable of choosing between alternative reactions possibilities with the help of changeability information mapped onto business processes.

1.2 Production example

In order to give an overview of a production line and to illustrate possible impacts and reactions a production example is set up and described in detail. With the help of that example it is much easier to understand the information needed for a change in the production process. This production example is related to a case study which focuses on artificial intelligence on the operational shop floor (Nau et al. 1999).

At first the term changeability of processes will be defined in the following and the selection criterion is discussed subsequently. To explain the possibilities of process changeability a simple production example will be used in the following.

Figure 4 shows a simplified example of production process for plungers. This process is developed from the minimal requirements to accomplish the production task. In this case neither all process fragments can be swapped nor can machine tools process all steps of the process.

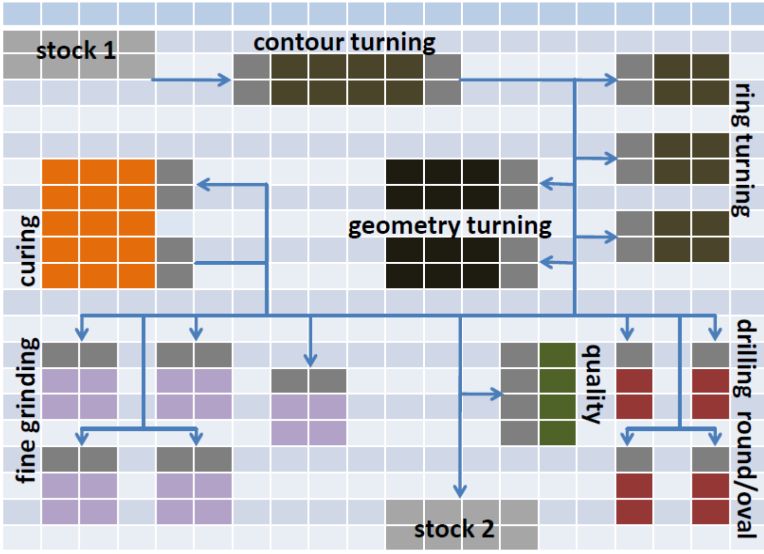

Figure 4. The shop floor layout.

In order to understand production process of the enterprise an overview of the shop floor layout, the used machine tools and process parameters is given in the following. From stock 1 the first production step is the contour turning of the raw part which is done by one contour turning machine. After the contour turning the lean process would be ring and geometry turning, performed by three and two parallel machines. The next process step is the round and oval drilling which is done by four drilling machines. After the conditioning process steps the manufactured part is cured in a curing oven and finally grinded by one of five grinding machines to complete the production process. Every batch is finally spot-checked by the quality. The single process steps are illustrated in figure 5 which shows the possibility of changing the process within the production.

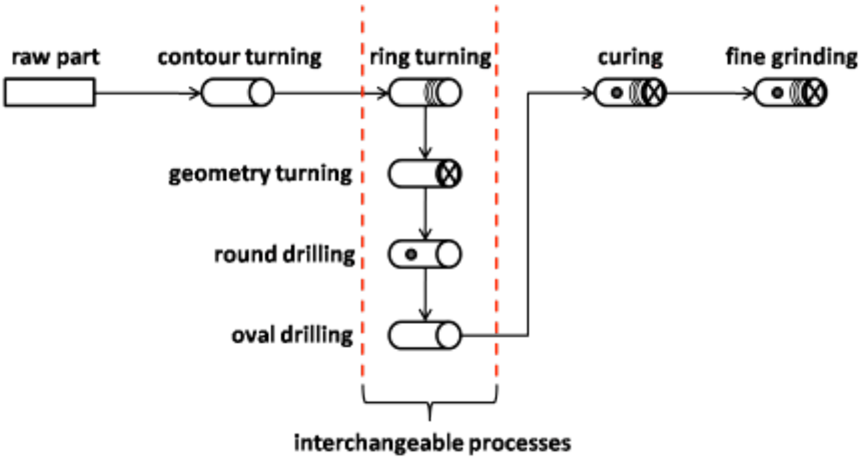

Figure 5. The single steps of the production process.

If a closer look at the process structure is taken, it can be seen that contour turning, curing and fine grinding for example can't be processed by other machine tools. Due to cost restrictions and the high processing speed the enterprise management decided to use only one contour turning machine. The curing oven is also a single device but its probability of failure is close to zero and so it is not seen as a risk factor.

As the factor time can be transformed easily into it is chosen as the main criterion for comparing processes and estimating impacts. Also the choosing of a reaction can be based on time because they are now comparable. In order to define the time-value a closer look onto the single process steps is given in the following. All the time-values used are from the planning of the production example.

An overview is given by table 1 which shows the time needed for each process step.

#parts	contour-turning	ring-turning	geometry-turning	curing	grinding	drilling	quality min/part
25	8,33 min	12,5 min	12,5 min	15 min	17,5 min	5,2 min	10/5
50	16,66 min	25 min	25 min	30 min	35 min	10,4 min	20/10

Table 1. The process time needed for each step.

First the different possibilities of changeability which can be installed on the shop floor have to be discussed. Only if changeability in the production is possible a mapping of this characteristic onto a business process makes sense. How can changeability on the shop floor be expressed? First the flexibility of that machine has to be reviewed. If the machine tool is capable to handle different die heads it is feasible to hold other die heads available. If multiple die heads can be applied on a machine tool it is possible to change a production process faster and easier. Of course it is common to have different die heads in an enterprise but these are often only used as backup. In that case the machine tools haven`t got changeability and are mapped on the business process plans without their changeability.

Especially the line management of the enterprise which has to deal with a breakdown or similar event on the shop floor often doesn't know about the alternatives which could be chosen. So a mapping of additional information such as changeability of a production process makes sense in order to enable the line management to react on an event in the best possible way.

1.3 Placement of changeability information in a business process

In order to give information about alternative constellations of the production process the normal additional information has to be added to the single process steps. This information should support the management in choosing or discussing alternative options. In the mentioned example process changeability information would include possibilities to mount a machine tool with different die heads. With that information it is possible for the management to find a fast reaction on an event.

How has the information for a business process to be structured and stored in order to enable the management to understand the alternatives which can be chosen? At first it has to be thought about the additional information which has to be added to a process step. Changeability can be used in different ways. A first possibility is to swap single process steps which each other. In this case time can be saved if a tool is broken and needs to be replaced. So this possibility of process swapping information is one relevant parameter for business processes in the production. In this example it can be seen, that there are the ring and geometry turning and drilling processes which can be swapped without any problems in quality or time. The time needed for transportation of one batch to another machine tool is considered as minimal in contrast to the time needed if a batch would have to wait until a machine tool is repaired. In order to keep the example simple the additional time needed for transportation is set to zero.

It can be seen that the first changeability factor is the swapping feasibility which can be added to a business process. This factor can be realized as a parameter which includes the identification of all swappable processes and the overall time which can be obtained. In the following figure the interchangeable processes are named "group A". The time saved can be described as costs in order to keep this parameter comparable to other values. How important or how expensive in this case time is, is highly dependent on the priority of each batch and has to be defined by each enterprise and each batch individually. In this example the priority is calculated as priority factor divided through time left to the deadline and eventually multiplied with the additional penalty costs if the deadline is exceeded. With this approach the priority can be calculated dynamically at each point of time.

2 CONCLUSION AND FUTURE RESEARCH CONCEPT

With the ability to use this changeability information mapped to production processes an enterprise management is able to react on events or breakdowns on the shop floor directly and can take the responsibility from the worker in the production who generally hasn't got knowledge of the whole production process or the constraints of a product which is manufactured. With a faster and due to more information transparency the management is able find better solutions to each event on the shop floor which can't be managed by local workers or management. Each better solution leads to higher process performance and furthermore to reduced costs.

The only necessity is to establish a changeability concept on the shop floor and to calculate the variables for each production and each enterprise. With the mapped information from the production processes it is possible to keep a high priority project running at a minimum of additional costs. The only difficulty examined is the mapping process because information has to be gathered from the machines and workers. Modern machine tools have standardized interfaces to communicate with the production control centre. Obviously older machines which are still quite common in medium-sized production businesses don't have an interface for communication. In this case the information and transparency is dependent on each worker in a production process.

It can be seen that there is a lack of information support for the management as well as for the worker on the production line. The identified need of a commonly used tool or database for information exchange between the single working places and the management is not solved properly in the producing industry. In order to close this informational gap a future research concept is a machine-oriented data warehouse which is capable of storing and reproducing the required data from the shop floor. Such a data warehouse solution would have to fulfill the following criteria:

- storing all relevant machine oriented data
- possibility of adding features
- ability of gathering real-time process data from the shop floor
- visualizing the stored information

Existing data warehouses are capable of storing all necessary machine data which is given by the machine tool manufacturer. The second point is not yet implemented in the producing industry so the person in charge for the production line has the overview which machine tools are in the factory hall. But the information which is needed at the moment a reaction on an event on the shop floor is necessary lies hidden in the experience and knowledge of the different workers at the machine tools. Due to constraint of a fast reaction all relevant machinery information has to be accessible and integrated into one data warehouse.

We argue that with the help of IT support and in this case with a machine oriented data warehouse the changeability on the shop floor can be increased significantly. This means that the person in charge of the product line is supplied with all relevant information to find the best fitting alternative to each occurring problem. The benefit of such an IT support is a shorter machine and process down time and an optimized use of available resources. Within the future research in this topic a concept for this machine oriented data warehouse will be designed and described. The integration of decision support with the help of information supply to the lower management level is seen as a major possibility for optimizing processes on the shop floor.

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