Operational Business Intelligence Meets Manufacturing

Completed Research Paper

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ABSTRACT

Industrial organizations design manufacturing processes to compete in dynamic environments so that their products incorporate a maximum value for the customers. This enforces the analysis and control of the corresponding product feature creation and implicates a coincidence of logistical and engineering processes. However, the existing information systems in manufacturing do not provide adequate decision making capabilities for a determination of a specific product feature’s value. The paper explores therefore certain advantages of Operational Business Intelligence (OpBI) in this context to give practical insights by a case study oriented approach. The results demonstrate requirements for a decision support in order to analyze and control manufacturing processes of three different industrial organizations. The insights confirm the benefits and advantageous of OpBI in manufacturing.

Keywords
Operational Business Intelligence, Manufacturing, Value creation, Process oriented decision support.

INTRODUCTION

The capability to design and control manufacturing processes is a determining competitive factor of industrial organizations. Dynamic market conditions enforce flexibility and readiness for changes in order to maintain a durable product excellence. (Rogalski, 2011) A product’s value depends on specific product features embodying a particularly attractiveness for the customer. The design of those features is engineering driven, but logistical processes accomplish a customer oriented provision of the corresponding products. These two different points of view coincide during a manufacturing process, where the actual feature creation happens. The manufacturing process design has to be aligned and adjusted so that a created product feature merits to the customer requirements. However, there is a lack of decision support systems for an appropriate control of manufacturing processes in consideration of engineering design data and logistical key figures, yet (Lasi, 2012). Therefore, the paper’s goal is to investigate the need and benefits of a dynamic decision support strategy, which allows an analysis of manufacturing processes in its logistical and engineering perspective. This is pursued to control and improve the value contribution of a specific product feature created during a manufacturing process activity.

Separate IT systems differing in their area of responsibility characterize the decision support in manufacturing. Product Data Management (PDM) systems manage engineering design features e.g. technical drawings or machine tool specifications throughout the whole product life cycle (Liu and Xu, 2001). Enterprise Resource Planning (ERP) systems support an operational planning in manufacturing and its adjacent management areas. They focus in particular on managerial key figures for a comprehensive market and resource oriented planning of e.g. sales, production and inventory volumes (Monk and Wagner, 2007). This spanning view of ERP systems does not allow a control or an analysis of manufacturing process activities on an execution level. Manufacturing Execution Systems (MES) bridge the gap between the planning and the execution layer (Kletti, 2007). These systems maintain and improve the performance and quality of manufacturing processes using contemporary information (MESA, 1997). MES support the intersection of PDM and ERP responsibilities, but they show shortcomings for decisions about adaption strategies especially to address a customer’s changing value perceptions (Saenz de Ugarte et al., 2009). An approach to overcome these obstacles in manufacturing decision making is Operational Business Intelligence (OpBI) (Koch et al., 2010). OpBI is defined as the provisioning of analytical capabilities in order to control the organizational value creation in favor of a continuous improvement of process design and execution (Hänel and Felden, 2012). It refers to established BI techniques and builds up a closed loop to analyze contemporary relations between the process performance and the status of goal achievement (Davis et al., 2009). This research contributes to the discussion about dynamic decision making in manufacturing and delivers practical insights regarding to motives and benefits of OpBI applications. It demonstrates an OpBI’s suitability to jointly analyze the logistical and engineering perspective on a product’s feature creation. This enables a value driven control and improvement of manufacturing processes.
The status quo chapter discusses reasons for the specificity of currently existing IS in manufacturing. The exposition of certain advantages regarding to an OpBI oriented integration of these systems follows this discussion. The paper adopts a case study approach for a profound exploration of reasons and benefits of OpBI in three different industrial organizations. The results chapter presents each case in detail and analyzes replications for an OpBI oriented decision support in manufacturing. A conclusion summarizes the paper’s insights and provides further research directions.

STATUS QUO

Over the last decades, information systems (IS) are discussed to plan and realize manufacturing processes. Computer integrated manufacturing (CIM) introduced an integration of data and processes for economic and technical activities in the 1980’s (Scheer, 1988). CIM could not become prevalent e.g. due to insufficient standardization or a marketing driven use (Klettli, 2007), but IS still support manufacturing processes. Banker et al. (2006) classify electronic data interchange (EDI) to share information with customers or suppliers, operations management systems (OMS) to control and monitor manufacturing processes, and resource planning systems (RPS) for a spanning management of business processes. RPS and OMS support a control and disposition of value-added activities on different organizational hierarchy levels. The nature of the decisions differs with respect to the time horizon of the corresponding level and the integration reach of the supporting systems.

The highest level encompasses a medium and long term enterprise wide planning (ISA95, 2000). ERP systems allow an integrated view of e.g. procurement, production and sales (Hossain et al., 2002). The ERP commits certain target figures to MES for contemporary decisions (Younus et al., 2010). The MES performs a permanent target /actual comparison in terms of volumes, deadlines and quality and reports the achieved results of the shop floor back to the ERP (Klettli, 2007). The shortest time horizon has the actual manufacturing process, which transforms inputs into outputs (EN ISO, 2005). The output results from consecutive occurrences in which specific product features are created, added or changed. PDM defines the corresponding characteristics and is responsible for product engineering and design data during the whole product lifecycle (Peltonen et al., 1996). This includes technical aspects, digital models of products, or even machine data used for simulation and development purposes (Liu and Xu, 2001).

The increasing time horizon redeploy a decision’s subject from the actual creation of a technical feature, to partial product components and finished products. Value considerations are usually performed in terms of manufactured products or its components, because agreed prices and the sum of all costs incurred are taken into account due to ERP integration strategies (Lea, 2007). The value creation is done in the course of adding or modification a product feature by different methods and tools during the manufacturing process. The determination and accounting of the achieved values relates to the resulting product components using the ERP functionalities (Markus et al., 2000). However, it is not possible to amount the value contribution of a specific process activity (add on or modification of product features) and to use it for control purposes of the manufacturing process. The existing systems are not able to give any information about the value proposition of a process activity, if a process activity is worthwhile in certain circumstances, how malfunctions, failures or interruptions influence the value proposition of a process activity, or about the impact of design changes to the value proposition of a process activity.

The missing information limits the flexibility of an industrial organization, because earning capacities are not certain estimable for product or process related changes on the execution level. But, flexibility in a manufacturing context deals with the ability to handle changes in multiple dimensions (Upton, 1994). Table 1 summarizes such dimensions for manufacturing processes according to a literature review of Koste and Malhotra (1999). Decision support capabilities are advantageous to avoid negative influences on the profitability or fatal performance changes.

<table>
<thead>
<tr>
<th>IS</th>
<th>Flexibility dimension</th>
<th>Description</th>
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<tbody>
<tr>
<td>MES</td>
<td>Machine</td>
<td>Machines execute various and heterogeneous operations.</td>
</tr>
<tr>
<td></td>
<td>Labor</td>
<td>Workers execute various and heterogeneous operations.</td>
</tr>
<tr>
<td></td>
<td>Material handling</td>
<td>Various materials are transported along paths between different processing centers.</td>
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<tr>
<td></td>
<td>Routes</td>
<td>Products can have variable routes, if the processing machines are changeable.</td>
</tr>
<tr>
<td></td>
<td>Operations</td>
<td>The sequence of operations can change, if multiple processing plans are possible.</td>
</tr>
<tr>
<td>ERP</td>
<td>Expansion</td>
<td>Expansions increase capacities and capabilities of the manufacturing processes.</td>
</tr>
<tr>
<td></td>
<td>Volumes</td>
<td>Manufacturing processes are exposed to changes or fluctuations of aggregated output levels.</td>
</tr>
<tr>
<td></td>
<td>Mix</td>
<td>Manufacturing processes create various products categorized to different product groups.</td>
</tr>
<tr>
<td>PDM</td>
<td>New products</td>
<td>Innovativeness is characterized by the number and variety of new products.</td>
</tr>
<tr>
<td></td>
<td>Modifications</td>
<td>Product modifications represent changes of the product design and its features.</td>
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Table1. Manufacturing flexibility dimensions

All dimensions are relevant to manufacturing flexibility (Koste and Malhotra, 1999), but an IT support refers to different systems. An advantageousness of BI is subject of a discussion in order to support a conjoint decision making of industrial organizations (Hänel and Felden, 2012). BI provides a multidimensional analysis environment using established techniques of data provision, storage, and presentation (Sahay and Ranjan, 2008). External sources or internal operational systems provide the relevant data (Gangadharan and Swamy, 2004). The ETL process extracts, transforms, and loads these data into the data warehouse (Berson et al., 2002), which is persistent database decoupled from operational systems to support multidimensional reporting and analyses (Kimball and Ross 2002). Techniques like online analytical processing or data mining can advance a data analysis (Han and Kamber, 2001).

A consideration of ERP, MES, and PDM within a BI environment allows an investigation of flexibility related changes according to technical and economical aspects within different perspectives of manufacturing processes. This provides analysis capabilities in terms of an OpBI in order to analyze and control the value contribution of certain process activities, i.e. the creation, adding and modification of product features. However, there is not much experience about an OpBI’s decision support capabilities in industrial organizations, yet (Hänel and Felden, 2011). The research objective is therefore to investigate reasons and benefits of an OpBI application in a practical context. This leads to the following research questions:

RQ1: Why does an application of OpBI contributes to a decision making in manufacturing processes?

RQ2: How does OpBI analyze the value contribution of process activities for controlling and improvement purposes?

METHOD

The method is based on case study research and follows a multiple structure with a single unit of analysis (Yin, 2009). Planning and design activities develop the research questions, which are derived in the previous section. The selection of the corresponding cases encompasses three industrial organizations. Two organizations have a repeatable manufacturing process design, so that benefits of OpBI are expectable due to theoretical considerations. One organization has in contrast a project oriented structure, where a comparability of the performed projects is not given. These different characteristics are chosen to provide an eclectic input for a detailed investigation about an OpBI’s contribution for a decision making in manufacturing.

The case based method is able to provide tried and tested results in the first place. The insights are necessary to evaluate the advantageousness of subsequent research actions and provide guidance for similar cases. Yin (2009) emphasizes the demand of three or four cases for literal replications. This allows the identification of recurring patterns referring in the present investigation to reasons and benefits of an OpBI application in manufacturing. Figure 1 illustrates the research process.

RESULTS

The result’s chapter presents cases of three industrial organizations, i.e. an IT and communication product manufacturer, a machine tool modernizer and a hydraulics engineering company located in Germany. A discussion of cross-case conclusions follows in order to make a point about the OpBI’s contribution for a decision making in industrial organizations.
Case one: Manufacturing of IT and communication products

The first organization refines IT and communications products including a customizing and a refurbishment. A packaging of shipping finished products happens in course of a blistering and a foliation of item boxes. Blisters allow the buyer to see the packaged item consisting usually of a device and its accessories. The foliation enables the affixing of security chips and the creation of product bundles.

The customizing refers to assembling and remodelling of mobiles e.g. keyboard changes or software updates. Individual configurations and settings are performed according to specific customer requirements. The refurbishment executes the quality assured maintenance, repair and overhaul of returns. A customer orders the service to resale outdated or defective devices. The process includes completeness checks of incoming devices, resets to factory settings and functional checks. External partners repair defective components as the circumstances require. Figure 2 illustrates the refurbishment process.

The monthly throughput is more than 100,000 products of different brands and categories. But, the order situation has seasonal fluctuations. In boom phases like Christmas trade, weekly sales quantities are doubled, while the throughput is marginal in silly seasons. This fluctuating situation determines the number of employees so that the shop floor staff changes accordingly. It is important to maintain a high product quality during boom phases. The processes have to be quick and cost efficient independent who is executing the process. The refurbishment and the customizing process need access to customer order specific and product related data. A joint consideration is advantageous for controlling purposes of the processes, because this provides the opportunity to analyse, if the add-on of a specific product feature has improvement potential regarding to time, quality, or cost.

OpBI facilitates analyses with respect to the changing staff and to the heterogeneity of customer specific product features. Process managers are able to identify, how a specific product feature merits to a customer, which expenses are associated to the creation, and if the processes are well executed by the employees. The customizing needs those capabilities to shift the attention to eminently worthwhile product features of certain customers. The refurbishment process benefits also from an integrated analysis of order and product design data. The first step checks the completeness of devices including an ordering of missing parts or accessories. The purchaser reviews the current product data needed to update old devices for design or functional changes. The reset and test activities are responsible for an early detection of defective devices. The refurbishment board has to decide who is able to repair the respective device, which expenses are associated to it and if it is worthwhile at all. An analysis of defect causes, order information and product data supports the decision making, because this demonstrates the amount of the affected devices across all orders in a refurbishment cycle categorized by the features to be restored. The production control can decide about scrap or repair. Early sharing of those insights with the purchase avoids the order of redundant materials for final packaging and unnecessary expenses.

Case two: Project oriented decision support in machine tool manufacturing

The second organization modernizes gear hobbing machines by reviewing machine components and replacing of worn parts. This happens in different individual projects with fixed budgets and limited time frames in order to restore the desired machine states. The projects passing several phases as illustrated in Figure 3. The employees remove cover panels and disassemble a machine in assemblies and single components. The assemblers list all standard and specific parts. They take pictures of the units, if technical drawings are not available. This input is needed to design necessary adjustments, to purchase standard parts and to reassemble the machines.

An assessment about the assembly states takes place during dismantling. The project board decides about an overhaul sequence of the components or whether a new production is required. A responsible board analyzes the availability and suitability of in house capabilities and capacities. They have to find out if external organizations offer required services. An overhaul must be cheaper than purchase or new production. The board needs accurate information about the expenses to renew or reproduce the features of a given component. However, the organization process different kinds of gear hobbing machines including various assemblies and components. Expense considerations on part level are difficult due to this.
complexity and multiplicity. The actual features which are added or restored have indeed a high comparability, but their expenses depend on several factors influencing the feature creation e.g. the type of material or the processing equipment.

OpBI is able to point out the expenses of feature creation from these perspectives to a varying level of detail. This is beneficial to plan and manage the different project workflows. The project boards can execute comprehensive cost estimations already during the stocktaking in the course of dismantling. The number and heterogeneity of a gear hobbing machine’s features lead to a determination of cost, duration or quality measures, although this machine type must not necessarily be modernized before. Those planning parameters provide also decision support to control the occurring activities of feature creation. Employees are able to intervene in the overhaul process at concerning points in case of target/actual deviations. Causes can be related to perspectives of feature creation. This leads to continuous process improvements and adjustments of planning parameters.

Case three: Value adding analyses and quality management in hydraulics engineering

The third organization produces various hydraulics cylinders. An engineering department designs new products and customer specific enhancements. Each product consists of several components to be manufactured internally or externally, and purchased parts. An assembly, a possible coloring and a preparation for shipment conclude the value creation. Order withdrawals, missing materials, troubles of external manufacturers, unavailable labors, machine failures or quality reductions constantly disturb the value creation. Malfunctions of e.g. automatic welders or CNC machining centers delay the planning cycles, so that product features cannot be created as scheduled. A continuous planning is associated with large uncertainties and corresponding adjustments imply disproportional expenses. Unfortunately, the process includes many cleaning steps to assure the leakproofness of cylinders. This leads often to impossibility of proposing subsequent activities.

A workaround is the consideration of monthly value creation targets. Alternative outputs have to compensate adverse circumstances if an order fulfillment is impossible. This necessitates a measurement of added values in order to use variations for control purposes. An analysis based on finished products is not favorable, because created values are only measureable during the assembly shortly before delivery. The value contribution of the actual component’s manufacturing remains unclear, although it is usable for a controlling of the process and its influencing perspectives. Figure 4 illustrates the incremental feature creation and the value adding for a cylinder head.

Figure 4. Cylinder head manufacturing

OpBI supports the measurement of the incremental accretion within a component’s manufacturing process. Production manager enrich their decisions by consideration of expenses and benefits regarding to a specific feature creation. This allows an improved allocation of e.g. resources, materials, and available technologies to create a product feature, because an in house production of the product’s components has to be cheaper than an external procurement. The engineering department get also information about the expenses of the specific feature creation e.g. to punch a hole in a certain material. This allows the determination of costs and prices for new products or product enhancements in advance during the design phase based on needed features.

A quality assurance board investigates issues according to costs-by-cause principles using the different process perspectives. OpBI is records the quality related complaints in each process step and calculates the expenses for rework, sorting or scrap. The costs compared to the monthly revenue support decisions for quality assurance measures, e.g. a change of the feature design, the processing equipment or the materials supplier and a mix of it.

Cross-case conclusions

This section analyzes the presented cases in order to identify replications for an OpBI oriented decision support in manufacturing processes. The business scope of the investigated industrial organizations is indeed different, but the explored analysis requirements are quite similar. All cases benefit from an integrated view on logistical and engineering information in order control the organizational value creation.

RQ 1 conclusions – Reasons for an OpBI application to contribute a decision making in manufacturing processes

A product’s value refers not only to the difference between cost and selling price, but rather depends on the underlying product features. This provides the opportunity to design and manufacture the products, so that they incorporate a maximum value for the customer. An appropriate control of the value creation needs to know the expenses that a specific feature causes
during its production. OpBI represents the various perspectives of a product creation. Executives and process managers are able to consider technical and economic information on different detail levels. This supports decisions looking for causes of unnecessary costs in order to increase the value contribution from an explicit product feature up to final products and product groups. Figure 5 illustrates the several perspectives of a manufacturing process addressed by an OpBI concerning and joining different decision support areas.

Figure 5. Perspectives and decision support areas

The middle square of Figure 5 represents the decision support areas, which are representable by fact tables or analysis cubes in a multidimensional data model. They include situational transaction data originating from IT systems of the supply chain, the product engineering and the certain operations of manufacturing control.

**RQ 2 conclusions – OpBI benefits to analyze the value contribution of process activities**

An OpBI solution is able to analyze information jointly within the various perspectives surrounding the decision support areas in Figure 5. The characteristics of the perspectives to control the organizational value creation of manufacturing processes result from the similarities of the presented case studies.

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Characteristics explored due to replications of the case studies</th>
</tr>
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<tbody>
<tr>
<td>Stakeholder</td>
<td>customer, supplier, and external manufacturers</td>
</tr>
<tr>
<td>Materials</td>
<td>raw materials and supplies, purchased parts, and external manufactured features or components</td>
</tr>
<tr>
<td>Products</td>
<td>sales items produced categorized to product groups</td>
</tr>
<tr>
<td>Feature</td>
<td>geometric and qualitative properties of products added in the course of a manufacturing process</td>
</tr>
<tr>
<td>Human resources</td>
<td>executives, responsible persons, operators distinguishable into departments</td>
</tr>
<tr>
<td>Processing equipment</td>
<td>machines, tools, plants, or IT systems applied during a manufacturing process</td>
</tr>
<tr>
<td>Key figures</td>
<td>metrics and calculation rules determining the value contribution of manufacturing process activities</td>
</tr>
<tr>
<td>Time</td>
<td>calendar hierarchy to track the chronology of manufacturing process activities</td>
</tr>
</tbody>
</table>

Table 2. Characteristics of manufacturing process perspectives

The basic objects of the analysis are the features that are created for a specific product using materials and the appropriate processing equipment. The chronology of the corresponding occurrences describes the manufacturing process in its actual behavior. Responsible boards controlling the process behavior are able to consider the expenses of a specific feature, the situational most efficient manufacturing alternative and the value a feature merits to the customer. These capabilities of OpBI beneficially complement the existing decision support concepts in manufacturing. Table 3 compares the effects of OpBI to ERP, MES and PDM systems with respect to the value contribution assessment of manufacturing process activities.
OpBI is not a new software application or system approach, which replaces the existing systems for decision making in manufacturing. To a greater degree, OpBI facilitates an integration effect regarding to flexibility dimensions, product characterization, reach of decisions as well as perspective, scope and focus of the manufacturing process activities. This integration effect is demonstrated by certain examples of industrial organizations confirming theoretical considerations of OpBI. This is especially expectable for case one and three due to the underlying standardized and repeatable manufacturing processes. However, case two reveals this integration effect also for a project oriented context. OpBI processes according to that the corresponding information allowing a comparability of tasks and activities, where standardization and repeatability is not given at a first glance. This novel capability is particularly advantageous for industrial organizations, because the existing systems have not been able to respond dynamically to uncertainties during the performance execution.

**CONCLUSIONS**

OpBI is able to provide beneficial decision support capabilities in industrial organizations. An application contributes to a decision making in manufacturing, because OpBI enables a conjoint analysis of the concerned process perspectives in context of managerial, engineering and manufacturing operation information. A product value is described, measured, and managed according to conspicuous features from a customer’s point of view. OpBI investigates the expenses for each feature creation within the manufacturing process perspectives. Executives and responsible persons get decision support capabilities to justify corresponding efforts. Industrial organizations are able to face dynamic market conditions by adaptations of their product design and manufacturing, so that a customer perceives durable excellent products.

The raison d'être of OpBI for a decision support in manufacturing results from the insufficiency of the existing IT systems to combine logistical and engineering information of a product’s feature creation. OpBI debuts a multidimensional understanding about the value relations between the corresponding manufacturing process activities and the influencing factors. Features and activities that do not contribute to the creation of a customer value can be redesigned or modified. The necessary interaction of product engineering design, manufacturing operations and logistics gets transparent. This is particularly interesting for managers deciding about changes or redesigns in manufacturing as OpBI provides input for profitability analyses of new and existing products. However, care must be taken in consequence to the number of case studies restricted only to industrial organizations. Three cases represent not a large share of industrial organizations, but they are sufficient for literal replications. Despite an indeed different scope of the concerned organizations, the case studies provide resilient congruencies to explore the advantageousness of OpBI for a decision support in manufacturing.

There are opportunities for further research based on these qualitative insights about an OpBI’s decision support in manufacturing. Further qualitative or quantitative analyzes are able to achieve a broader level of knowledge in favor of a result’s generalizability. A value orientation is also discussed in context of service provision and e-Business activities (Gordijn, 2004) next to the creation of physical products. The achieved insights of this paper provide therefore also starting points for further research within the scope of services.
REFERENCES


