Facing the Change
Towards a Dynamic Decision Making in Manufacturing Environments

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Keywords: Manufacturing Flexibility, Manufacturing Execution System, Operational Business Intelligence, Dynamic Decision Support.

Abstract: Globalization and increased informal networks lead to a dynamic competitive environment in manufacturing, where uncertainties arise from consistently changing customer demands. Their management is a key challenge for growth and sustainability, while there is evidence that organizations cannot achieve an adequate manufacturing flexibility. Therefore, the paper`s goal is to investigate the benefits of a closed loop dynamic decision making in manufacturing. A qualitative approach using case study research and expert interviews explores the contribution of Manufacturing Execution Systems (MES) and Operational Business Intelligence (OpBI) in this area. The results indicate that manufacturing flexibility challenges organizations, while the issue is supportable by MES and OpBI in order to face the changing customer requirements. In conclusion a case-specific awareness level of flexibility becomes apparent motivating further research to contribute to a dynamic decision making and its IT support in manufacturing.

1 INTRODUCTION

Manufacturing is essential for the value creation especially in industrial organizations. Globalization and increased informal networks have created highly dynamic competitive environments in this area. As a consequence, organizations focus on customer orientation forcing them to align and adjust their product and process design accordingly. Hence, a manufacturing has to consider varying demands, which are consistently changing. In order to address such uncertainties, dynamic planning and decision making processes are essential for a successful organizational existence (Rogalski, 2011). However, an adequate manufacturing flexibility is not achieved (Rodriguez, 2007), while the management of such volatilities challenges the growth and the sustainability of the organizations (KPMG, 2011). Therefore, the paper investigates the phenomenon of manufacturing flexibility in changing competitive environments aiming to detect a strategy for a conjoint process oriented and dynamic decision support.

The range of conformable concepts allowing a dynamic decision support is manifold. Currently, MES and OpBI are discussed, because they promise improvements of process flexibility. Both are integration approaches dealing with analysis and control of operations, but they address either an engineering or a decision oriented point of view. A combined consideration of MES and OpBI is advantageous, because cross linked analyses are possible to coordinate and improve business processes (Koch, Lasi, Baars and Kemper, 2010). Organizations are able to recognize weaknesses, failures, and business interruptions to respond in a flexible manner. However, a literature review reveals that a dynamic decision making capability of the concepts named above is limited, yet. Especially the complementary integration potential of MES and OpBI is not tapped to support the flexibility demands of industrial organizations (Hänel and Felden, 2011). The refinement of complementarities and its affirmation in an organizational context give implications how far a combined consideration of MES and OpBI is necessary and beneficial for an industrial organization to compete in challenging environments. Therefore, the paper contributes to an initial discussion in providing empirical insights on reasons and support strategies for a dynamic decision making based on a comprehensive process analysis in favour of a manufacturing flexibility.

Section 2 discusses the beneficial effect of MES and OpBI for a dynamic decision making to achieve

Hänel T. and Felden C..
Facing the Change - Towards a Dynamic Decision Making in Manufacturing Environments.
DOI: 10.5220/0004107601070112
In *Proceedings of the International Conference on Knowledge Management and Information Sharing* (KMIS-2012), pages 107-112
ISBN: 978-989-8565-31-0

a comprehensive manufacturing flexibility. A methodological structure to affirm the illustrated support potential is explained in Section 3 and the results of its application are presented in Section 4. Finally, the paper is summarized giving conclusions and further research perspectives.

2 STATUS QUO

Manufacturing flexibility has been intensively discussed in the 1980s and 1990s (Beach et al., 2000). Incorporating a strong influence on organizational competiveness (Hayes and Wheelwright, 1984), it deals with uncertainties in multiple dimensions (Browne et al., 1984) and refers to the ability of change without lost in performance, time, cost, or effort (Upton, 1994). Manufacturing flexibility improves firm performance in dynamic markets depending on strategy, environmental factors, organizational attributes, and existing technology (Vokurka and O'Leary-Kelly, 2000).

Despite of the numerous findings, a renewed discussion is identifiable. According to Aberdeen Group in 2007, 85 percent of surveyed companies do not provide an adequate flexibility and especially manufacturing applications are not designed to handle rapid business changes (Rodriguez, 2007). The lack of flexibility implies high cost due to delayed decisions and low productivity associated with negative effects in terms of customer satisfaction and service orientation. Recent surveys confirm this relevance of aligning flexibility to manufacturing operations to face steady changing customer demands (Barrett and Barger, 2010). The ability of managing volatilities is discussed to grow and sustain in dynamic market environments (KPMG, 2011). Manufacturers are faced by an increased complexity, so that they need innovation capabilities to achieve a constant manufacturing performance (Patel et al., 2011). Therefore, flexible planning and decision processes are essential to assure the existence of an organization in competitive environments. This is challenged by the multi-dimensional character of manufacturing flexibility (Rogalski, 2011).

MES contribute to the success of manufacturing flexibility (Rolón and Martínez, 2012) improving a decision making based on the measurement of production key figures (Younus et al., 2010). Placed between the layer of Enterprise Resource Planning (ERP) and process execution, a vertical integration of shop-floor information is realized (Kletti, 2007). The MES allows a decision making by detailed scheduling, dispatching, resource management, definition management, execution management, tracking, data collection, and analysis in the subareas of production, quality, maintenance as well as inventory operations management (ISA, 2000). However, current MES solutions are limited in offering an integrated production support covering all of these subareas. Manufacturing gets more complex due to an increased customer orientation triggering a multiplication of product characteristics (Rogalski, 2011). The existing informal networks in manufacturing environments consider a heterogeneous software application landscape. This forces the MES to process and analyze a higher amount of information. (Saenz de Ugarte et al., 2009) The MES limited analysis capabilities are challenging in this context (Alpar and Louis, 2007).

OpBI provides those analytical capabilities to control the organizational value creation in favour of a continuous improvement of process design and execution (Felden et al., 2010). The focus is on reducing times to collect, report, and analyze data as well as to take appropriate decisions (White, 2006). OpBI is understandable as an integrated business process oriented system approach, supporting time critical decisions during process execution based on process related and historical data using mature traditional BI functions (Gluchowski et al., 2009). These functions are classifiable to decision support, business relevant information, information description, data preparation and data collection (Schrödl, 2006). OpBI and MES have beneficial intersections supporting dynamic decisions in manufacturing (cf. Table 1).

Table 1: Complementation of MES and OpBI.

MES functions/ OpBI functions	Decision support	Business relevant information	Information description	Data preparation	Data collection
Detailed scheduling	MES	MES			
Dispatching	MES	MES			
Resource management	MES	MES			
Definition management	MES	MES			
Execution management	MES	MES			
Tracking			OpBI		
Analysis				OpBI	
Data collection					OpBI

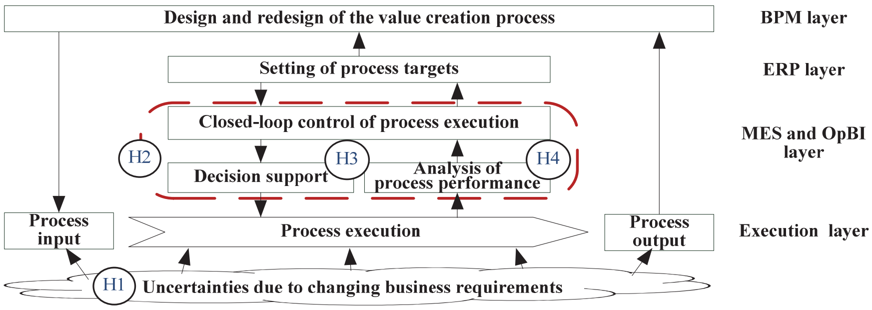

Figure 1: MES and OpBI in context of a process oriented decision support architecture influenced by uncertainties.

The MES provides the background for decision support and business relevant information, while OpBI is able to fulfil tracking, analysis, and data collection. During a process, input is transformed to specified output according to quality and quantity measures (ISO 9000, 2005). This transformation is influenced by uncertainties due to changing basic conditions e.g. demand volatilities or varying customer and supplier relationships. To cope with these indeterminations a closed loop approach is able adjust targets of the corresponding value creation (cf. Figure 1). The following hypotheses summarize the interrelation of MES and OpBI:

- H1: Organizations have a comprehensive flexibility demand in manufacturing due to consistently changing basic conditions.
- H2: Organizations need comprehensive analysis functions and dynamic decision making capabilities to fulfill the complex manufacturing flexibility requirements.
- H3: MES provide dynamic decision making capabilities to achieve manufacturing flexibility.
- H4: OpBI is able to strengthen a MES in context of comprehensive analysis functions.

3 METHODOLOGY

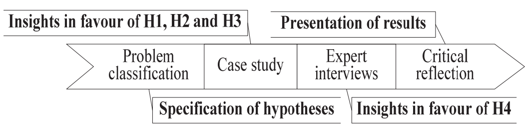

Figure 2: Research phases.

The methodology follows a phase oriented approach (cf. Figure 2). The first phase classifies the problem of manufacturing flexibility and the contribution of MES and OpBI. The results are further investigated by a case study (Yin, 2009). Subsequently, expert interviews (Flick, 2006) enrich the discussion clarifying an OpBI potential in production environments. Actions to improve the quality are facilitated by a critical reflection.

3.1 Case Study Design

The case study organizations is an IT and communication products distributor. Process-related roles, components and decision relevant information could be acquired in workshops with responsible persons of the manufacturing department and supplemented by observations of the processes. This leads to a consolidation of the information flow illustrating the demand for a manufacturing flexibility. Finally, the benefits of a MES to support a flexible process oriented decision making were discussed.

3.2 Expert Interview Design

22 experts with IT-related leading positions from different industries were asked for participation. The response rate was 63.64 percent. The participants were consultants (8) and professionals of software (3) as well as manufacturing and trade industry (3). All interviews focused on an OpBI classification and application potential. The interviews were conducted in September and October 2011. They lasted typically on hour. Each interview was guided by predefined questions, recorded and transcribed.

4 RESULTS

The subsequent description focuses on a critical reflection of the case study and the expert interviews.

4.1 Exploration of a Need for Flexibility

The following discusses flexibility requirements at

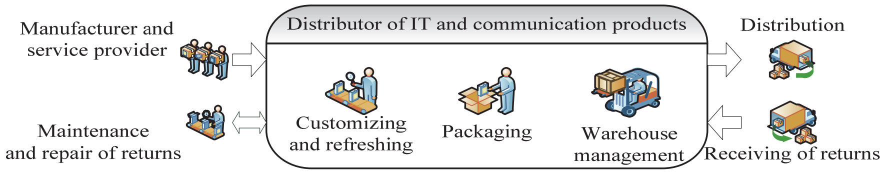

Figure 3: Value creation structure of the case study.

the manufacturing department of the case study organization. The company refines IT and communication products by implementation of software updates, prefabrication of returns and packaging of shipping finished goods. Suppliers are manufacturer and service provider, while a subsidiary performs maintenance and repair of returns. The products are predominantly distributed to specialized trade, wholesale and online retailers. The structure of the value creation is demonstrated in Figure 3:

There are four core processes. The customizing is characterized by assembly and remodelling of mobiles, e.g. a change of keyboards, covers or software updates. The new configuration depends on customer requirements differing in individual orders. A refreshing pursues quality assured maintenance and repair of products. Devices are sent by customers and refreshed for the purpose of resale. This includes a completeness check of the receipts and if necessary an ordering of missing devices. Thereafter, a reset to factory settings, a functional check and a corrective maintenance of defect devices done by the subsidiary is executed. Multiple key accounts are served, while the process scope differs. There are customers passing through the whole process, while others just order reset and test activities. After conditioning the products are finished for shipping. A blistering and a foliation of item boxes are executed for different product sizes. Blisters allow the buyer to see the items consisting usually of a device and its accessories. They are packaged in boxes getting foiled and stacked on pallets. The packaging has to consider multiple peculiarities. Order specific barcode labels and security chips are generated for the items and pallets. Campaign stickers and additional information have to be attached. Intermittent, product bundles must be equipped with extra packaging bands. A warehouse management is responsible for material storage, shipment and assumption of returns.

The processes are characterized by complex requirements regarding to planning, coordination and analysis. This is reinforced by the current order situation. On average, 20,000 products are processed during a week. However, there are enormous seasonal fluctuations. In boom phases like Christmas trade the weekly quantities are reduplicated. The throughput is marginal in silly seasons. It is important to adjust the staff according to the order situation. Due to a perennial growing of the quantities within boom phases, the readiness of delivery has to be increased next to a reduction of throughput time. This is associated with dynamic routing and resource utilization by maintaining of a consistent quality. An intensive tracking of process states and demand situations is necessary to achieve time and cost efficiency. Given to the dynamic market environment and the complex process parameters of the organizational value creation, a comprehensive need for manufacturing flexibility is evident, especially in terms of output volumes and highly customized products.

The case study participants affirmed a need for dynamic decision making in the final consultation. They mentioned that the IT systems should consider order fluctuations especially by a flexible staff planning. Provided that a consistently quality level has to be met, the suitability of a MES was analyzed to support the flexibility demands. The analysis reveals a MES's ability to beneficially complement the existing IT systems in terms of scheduling and dispatching. Furthermore, overarching analysis and reporting capabilities were notably emphasized. The discussion casted doubts, that a MES is able to track to forecast customer behaviour or predict current market developments. These are popular application fields of OpBI (Eckerson, 2007). Hence, the next section investigates its potential to support the MES analysis capabilities.

4.2 Results from Expert Interviews

The analysis of the interview transcriptions reveals main characteristics of OpBI. The concept integrates process data on an instance level to determine primarily non-financial key figures in regular report cycles during process execution. A control effect of organizational core processes is pursued by a short dated time reference of the decisions. This is similar to the MES definition and focuses on an event-oriented analysis. The identified drivers for OpBI support this aspect (cf. Table 2).

Table 2: Drivers of OpBI.

Enhancement of process analysis solutions	Improvement of process performance
• Comprehensive process analyses • High transparency requirements • Support of core processes • Broader range of users • Handling of increasing data volumes • Fast provision of current information • Tapping the integration potential through cross-linked structures	• Flexible process control • Adaptiveness to changing basic conditions • Achieving higher process and product quality • Acceleration of production times and process cycles • Increasing of output rates • Realizing cost savings • Obtaining of new insights regarding interrelations between process structures and performance

Current application fields named by the participants are customer relations or marketing. Certain examples with respect to the analysis of customer behaviour were provided. Offers can be displayed and adjusted according their impact on customer behaviour to manage marketing campaigns. A further example is a flexible staffing in case of new product placing. Often, there is a high usage of customer services and in terms of capacity overload the staff can be expanded.

Furthermore, the participants were asked for the use of OpBI in manufacturing. The quintessence across the interviews is that the short-dated time reference of decision making in context of OpBI leads to a big potential. Examples are the processing of production data using dashboards. This allows a monitoring and reporting of process performance in terms of operational control. Manufacturers are able to identify quality deviations, weaknesses or machine failures to facilitate time savings and to accelerate the production. Particularly industries with manufacturing bands, such as the automotive or the packaging industry were called as appropriate areas. Further applications like staffs work time logging, maintenance and surveillance of the production equipment, inventory management for raw materials and supplies, or product lifecycle management came in mind of the interview participants. The potential to use the gathered information for improvement of logistics processes was also mentioned, e.g. the timing of loading cycles to reach optimal transport capacity utilization.

4.3 Discussion of Results

The case study reveals that customer oriented value creation leads to planning and decision making uncertainties in manufacturing. Flexibility is required to react accordingly, while the management of tremendously changing order quantities is important. However, it has to be noted that the focus on the respective flexibility depends on the specific value creation. This differs according to specialist fields of industrial organizations.

Nevertheless, a universal valid need for comprehensive analysis functions and dynamic decision making capabilities in manufacturing is evident. Since flexibility is defined as the ability to change by a constant performance level (Upton, 1994), counteracting adjustments necessitate an awareness of the current situations to execute adequate control mechanisms. The case study confirms that actuating interventions are supportable by a MES to support a dynamic decision making. The functional design will vary depending on the requirements of the respective value creation. Such an asking for a case dependent alignment is also true for analysis capabilities, which are required for a closed loop process control. Therefore, the expert interviews affirm a supporting potential of OpBI enabling comprehensive descriptions of information, data preparation and collection in manufacturing.

Summing up, MES and OpBI are jointly able to support a manufacturing flexibility. However, they have to be aligned to the value creation to achieve a closed loop control approach. Considering that a lack and an excessive flexibility are discussed as reducing effect of process performance (Gebauer and Fei, 2005), a case specific awareness of flexibility becomes beneficial for dynamic decision making and the IT support in manufacturing.

5 CONCLUSIONS

The paper investigates the demand of manufacturing flexibility in competitive environments and explores the benefits of a closed loop approach using MES and OpBI in a conjoint manner. This facilitates a dynamic decision making to face steady changing customer requirements. These are uncertainties for a manufacturing, while their successful handling cast a positive light on growth and sustainability especially in industrial organizations. A closed loop approach of MES and OpBI is able to achieve these benefits, because the decision making is directly attached on the execution of the value creation process. The MES provides control mechanisms for production, quality, maintenance and inventory operations management, while OpBI complements by providing capabilities for a customer oriented analysis of the process performance.

The lessons learned from the paper reflect the complex and multidimensional characteristics of manufacturing flexibility. Its achievement challenges especially industrial organizations to establish a dynamic decision making based on comprehensive performance analyses. The issue is supportable by MES and OpBI, but there is no unisonous and abstract procedure universally valid across all manufacturing industries. This sheds an ambiguous light on flexibility, because of its presence regarding to the manufacturing itself as well as for the underlying decision support.

Considering subsequent research actions, the paper gives an impulse for case specific implementations and for benchmarking studies of all-embracing industries. Thereby, the initial discussion gets enriched by further insights including comprehensive statistical evaluations with respect to a particular and a global view on manufacturing flexibility in context of a dynamic decision making.

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