Manufacturing system design for business value, a holistic design approach

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Abstract

When designing and developing manufacturing systems, many aspects need to be considered. Typically, the manufacturing design objectives are specified to achieve certain operational requirements around quality, capacity, cost etc. They are also specified with the intention to ensure efficient processes related to manufacturing, such as maintenance, logistics, not to mention the main process of manufacturing the actual part. This study proposes that a wider company perspective should be considered during manufacturing system design, to achieve a greater business value. The manufacturing system should be designed to create value to other core business processes, such as product development, marketing, sales and services. This paper also presents examples on value perspectives to consider and how this approach can be implemented.

Keywords: process; manufacturing; design; business; value

1. Introduction

When developing and designing any form of system there will always be certain requirements and constraints that set the frame for the designer. During manufacturing development, operational targets such as quality, capacity and cost are used to specify the development goals. Looking at manufacturing development literature, different authors have different focus areas \cite{1, 2}. One reason for this might be because different industries have different foci, as for example high volume manufacturing must focus their attention to flow, reliable and predictable systems, whereas low volume manufacturing with expensive products instead focus on high quality and handling to prevent damage. Whichever manufacturing industry looked at, the traditional functional organisation is still strong \cite{3}. Typically, functions like research and development, marketing, sales, manufacturing engineering, operations, aftermarket, human resources etc. all have their individual strategies and goals of which aim to optimise and trim that specific function \cite{3}. Therefore, when the manufacturing engineering department initiates a development project, naturally the requirements for this project will dominantly focus on the operational characteristics to which these individuals can relate. The risk is that these operational requirements become sub-optimised if looked from a company perspective, and might even be counter-productive to the goals and targets of other functions within the company. For a company to be competitive, performance of the company consists of more than just the financial aspect and simplified models based on one department’s view \cite{4}. Other areas that are not directly related to a financial transaction, or at least difficult to evaluate in financial terms, are often left out from the formal decision point. Common decision models like Net present value (NPV), Return of Investment (ROI), or Life Cycle Cost (LCC) are only based on a few aspects, and do not really support a value oriented view point. So decisions based on these traditional financial evaluations fall short.

The organisational structure itself is also affecting how these decisions can be made and what viewpoint to use when investing in new equipment. The challenges and downfalls with functional organisations have been covered extensively since the Business Process Orientation (BPO) emerged in the eighties \cite{5}. The concept of BPO originated from Porter in 1985 and was further developed by Deming, but many other authors have contributed to the collective framework that has been reached today \cite{6, 7, 8, 9}. Kohlbacher (2010) has done a
literature review of the effects of structuring organisations into process orientation, which shows that there are links to improved product quality, reduced lead-time and improved customer satisfaction [10].

The most widely used standard today that deals with process orientation is ISO 9001, Quality Management System. Even though many companies today are ISO 9001 certified with the clear process orientation as a requirement, the companies are still often functionally organised. To overcome some of the challenges with this functional orientation, additional temporary cross-functional teams and projects are introduced rather than completely reengineer the whole company structure.

The purpose of this study is to investigate how a focus on business value and process orientation can affect the design of manufacturing systems, within functional orientated companies. The intention is also to give concrete examples of how these value chains between core processes can look like.

2. Methods

The approach in this study has been divided into three steps. In the first step, potential core business processes were identified and established. During the second step, examples of value delivered by the manufacturing system were discussed. Finally, the last step focused on how to practically introduce this approach during manufacturing system investment projects at companies.

The companies selected for this study consist of a selection of the 100 largest companies by revenue in Sweden [11]. Companies within the manufacturing segment have been shortlisted, and out of these, the 15 largest companies were included in the survey.

2.1. Establishing core business processes

The first step of this study was to establish the core business processes. When a process is described and modelled at different companies there will be different approaches and areas of interest. The perspective, scope, annotation and level of details are just a few aspects, which will affect the final models and make them rather unique. Furthermore, the competence of the process modeller will have a big impact on the result, which Rosemann (2006) suggests is one of the biggest issues in the field of business process modelling [12]. Therefore, rather than looking within the companies to establish core business processes, an external study has been conducted to obtain high-level generic processes, easier to compare.

Since the process approach is one of the ISO 9001 quality management principle (QMP), it is required by the company to specify which processes they intend to certify [13]. Once the certifying body grants the certificate, the scope of the certificate specifies these "main processes for its product realisation or service delivery activities" [14]. Therefore, the scope was used as a main source of data to establish what core processes the company considered having. As there are different certifying bodies for the ISO 9001, there is not one location for where the certificates can be found. However, most companies openly publish their certificates on the public domain, which made it available for this study.

Another source to identify the companies’ core processes, is the annual financial report. It sometimes specifically specifies the business models and processes around it, while at other times it can be rather ambiguously found in the text if read carefully. The company structure can also reveal the core processes, because the processes have been used to dictate the organisation. These companies are good examples of truly process-orientated organisations. The annual report has also been used to find the ISO 9001 certificate that represents the larger part of the company, as smaller individual business areas within the company also have their own certificates.

The next step of the study was to organise and sort the collected data, to be able to define core processes. Different criteria for what to look for and how to sort the documentation was established, and their core processes were identified and documented.

2.2. Analyses of business value through manufacturing systems

The second step in this study was to discuss, reason and elaborate how the manufacturing systems can contribute with value to the other identified core business processes. Each process identified within the companies was analysed from the basis on how the manufacturing system can provide value. The analysis is based on semi-structured interviews with representatives from some of the selected business processes. In addition, observations from industry, where examples can be found, were used as input together with the authors’ combined experience in the field of manufacturing engineering.

2.3. Implementation of manufacturing system design for business value

The last step in this study gives examples on how to practically start incorporating manufacturing system design for business value (DFBV) into development projects. This is not intended to be an exclusive method proven to be the best, but rather based on a general approach, observation and experiences of the authors.

3. Results and analyses

Based on the ISO 9001 certificates and the annual reports of the selected companies, a number of core business processes could be identified. There is a large proportion of the studied companies that all have the same core business processes. These are predominantly (1) Design, (2) Development, (3) Purchasing, (4) Manufacturing, (5) Sales and (6) Marketing. A number of companies also included (7) Service, but only one interesting company has (8) Recycling of their own products as a core business processes (see figure 1). This shows, perhaps
not surprisingly, that large Swedish manufacturing companies have multiple core business processes, and that there are many similarities between the companies. All processes are equally important for business success, similar to links of a chain. However, even though the importance of process orientation is recognised as beneficial in both industry and academia, it often still appears that companies’ internal organisation is structured functionally. Additionally, experience shows that organisation and people only stretch their main scope of responsibility to the boarder of their function or sub-organisation. A functional structured organisation creates functionally optimised departments. However, what might be optimised for one function might give a negative effect on another function, causing sub-optimisation. The phenomenon of sub-optimisation is well recognised, but still it seems difficult to counteract. Particularly within large and complex organisations with many specialised departments or even individuals. If a company wants to maintain a functional structure, individuals within the function must look beyond the natural scope of responsibility for the overall business to become more profitable and competitive. However, without the processes clearly documented, long experience is required or in other ways a good understanding and insight on how different functions relate and interact.

During manufacturing development, the objectives are to achieve certain targets mainly associated to the manufacturing organisation, i.e. cost, quality and capacity. However, if other processes’ objectives also were included, an even greater company-wide benefit could be achieved, sometimes with no extra effort. The following chapters will elaborate on these value chains.

3.1. Improved product design

The first core business process, (1) Design, can definitely benefit directly from a closer collaboration with the manufacturing related functions. Two important and valuable aspects of having accessible manufacturing facilities, are the possibilities to better facilitate internal visits and other forms of collaboration. Design engineers located away from the manufacturing facility, can increase their manufacturing awareness. By doing so, they can improve and adapt the new product design to better fit current manufacturing systems, shortening time to market and cost.

Furthermore, if the design engineers and the developers collaborate with the manufacturing functions, a quicker feedback loop can be established. New concepts can be discussed with the manufacturing engineers and potential problems identified earlier. The earlier a problem is identified the lower the cost is for change in the development product. This is a well-established phenomenon, at least within software development, but many kind of development projects follow the same trend, see figure 2 [15].

It is also beneficial to be able to make the prototypes directly in the actual manufacturing line instead of investing in dedicated prototype systems or even at an external supplier specialised on prototypes. If it is possible to iterate the prototypes internally and obtain input from actual manufacturing system, it would give much more feedback into the further development on how to improve design for manufacturing (DFM) and design for assembly (DFA). This would result in reduced cost and the design time should be possible to decrease. Costs for alterations and updates of the current manufacturing lines could also be avoided or minimised. However, to be able to make development parts in the operational manufacturing systems, a surplus of capacity, flexibility in tools, fixtures as well as in the programming will be required. This would perhaps also disturb the manufacturing line through stops and introduce risks of different kinds, but holistically on a business level, it would likely contribute to increased total value if managed correctly. As seen during the study, it seems easier to manage prototypes in assembly lines where the work is predominantly carried out through manual labour, compared with automated systems configured for the known serial products. It seems also common to use dedicated prototype lines to reduce risk for disruption, but by doing so certain serial line aspects will be missed.

There is potentially much more that the manufacturing functions can contribute with to improve the product design and development process. However, if manufacturing developers are asked if they work together with the product designers, the answer will most likely be yes. As part of the today common cross-functional teams, there will be...
collaboration across the functional borders. For example, the product designer will already work with methodologies like DFM and DFA. Similarly, when designing manufacturing systems, a degree of flexibility will likely be introduced to manage future product changes. However, even if the manufacturing system is designed to reduce product design constrains through flexibility, the driving force during manufacturing development still often seems to be from a self-orientated perspective. The incurred cost (time and money) on the manufacturing organisation by introducing new products, is perhaps one of the key aspects that drives investments in flexibility. If the mind-set was more holistic or focused on the business value, different types of flexibility would be introduced. Seen at one of the studied companies is that the complete flexibility that standard machining centres provide, gives the design engineers better possibilities to be innovative.

3.2. New technology and product development

There are other examples on how the manufacturing functions can contribute to the development of the company’s products. With the development of new manufacturing technologies, new approaches to product development can be reached. One example of this is the increasingly discussed technology of additive manufacturing (3D printing). In many industries this is still perceived as difficult to justify financially [16]. As the existing product portfolio has been designed over many years with more conventional manufacturing methods in mind, there is little extra value to start producing them with this new additive technology. However, for prototyping and building up knowledge in-house it might still be valuable to invest in this type of new technology. In addition, through the investment, it could open up for new ways of producing parts and allow for new types of design. One example seen is in aerospace industry, where standard designs have been developed for a family of parts, to then make them unique through additive manufacturing that adds specific features.

Even though the manufacturing return on investment (ROI) calculation gives little incentive to invest, the additive machines could still create intangible values. For example, the additive machine would be a base for building competence and knowledge, and completely new innovative products could emerge. This in turn could open up to new markets, which would not be reached without the technology. The perceived opinion on being a market leader in technological development can also have several benefits. A strong brand value can create new customers and increased sales. Moreover, being an attractive employer will attract technology-interested engineers resulting in an increased and improved recruitment base.

3.3. Value for sales and marketing

To help both the sales and marketing processes, the manufacturing system can be designed with the intention of bringing new and existing customers straight into the making of their products. With the right design, the customers can safely be brought into the factories and shown how, for example, the quality is assured and technology used. Moreover, the detail and effort that go into making their products can be demonstrated rather than just promised with words. As long as the company actually is good at manufacturing, this ought to generate an increase in trust and confidence between the company and the customer, and thereby increase future sales.

Factory visits is nothing new and has been used for different purposes over the last century, perhaps starting with Kellogg in 1912 [17]. However, with new technology and concepts from Industry 4.0, the customer could be provided with interactive information in new ways, about the manufacturing cycles or the machines they are observing [18]. During the tour they could for example also get video and other marketing material directly to their smart phones. This type of direct access to the manufacturing information could lead to new customers, but also give other functions within the company better and easier access to understand the manufacturing processes.

In addition to these videos, with a safe and available access to the manufacturing facilities, it would be possible to also invite children, students, teachers and other individuals with an interest, to safely enter this normally restricted industrial environment. This could contribute to an increasing collaboration with schools and universities, leading to an increased industrial awareness. Moreover, with increased awareness that the industrial environment is an interesting workplace, the recruitment base could improve and indirectly bring value to the core processes. Collaboration with universities can also contribute to research projects, which would also support multiple business processes with knowledge and competence.

Individuals who do not work in the industry can have a rather stereotypical view of the working life in a factory. Dirty and noisy factories with monotonous repetitive work seem to be a common perception. This view is unintentionally transferred to our children through parents and teachers, but also through other means. However, looking at the studied company Volvo Cars and their new commercial “Made by People” [19], it shows how the manufacturing system and the people within this, can convey a strong marketing message but also give an insight into the modern industry. During most of the four minute commercial, the viewer is taken into the factory to demonstrate the importance of diversity, as well as the technology and craftsmanship that goes into making their products.

3.4. Increased sales through flexibility

Manufacturing flexibility outside the normal perceived necessity could also bring value to the business processes sales and marketing. Even though many modern companies of today offer customised products, it is still often from a specific product portfolio, to which the manufacturing systems are already designed. However, to be able to satisfy the customers with extra special requirements that is not offered through the normal portfolio, the manufacturing system must be flexible enough to make these special orders to a reasonable cost. Seen at some of the companies is that analyses of this are reactively
when the customer request has been received. Even though it will be difficult to predict what special requirements future customers might have, it is possible to be proactive when designing the manufacturing system. By using the sales and marketing experience during manufacturing systems design, at least chances increases to understand what features can help in satisfying these customers in a cost efficient manner.

Another form of flexibility is to be able to meet the uncertainty that comes with changes in sales volume throughout the business cycles. In earlier work, an index has been identified for how to define change sensitivity over a business cycle [20]. If critical systems would be more cost flexible to meet changes in market demand, the cash flow could be better managed in times of low demand. This will give value to the financial controlling function who are looking after the solidity of the company.

4. Implementation of design for business value

The arguments and examples of this study are to some degree on a general level and require more specific details if to be implemented in a company. The approach to implement design for business value (DFBV) would be similar to this study, but focus would be within the company.

The first step would be to identify the specific internal core processes and key stakeholder to consider. The result of this study, in particular figure 1, can be used as a general guideline, but an internal investigation should be conducted to find the company unique internal processes. The second step would be to understand the objectives of these processes and discuss with responsible individuals how the manufacturing system and the manufacturing competence can contribute to create value.

To ensure that each manufacturing development project takes the whole business value into consideration, the business value aspects must be embedded into the development process. However, rather than specific requirements, areas to investigate and explorative questions should be included in the process. This will ensure that new project specific answers and investigation will be conducted for each project. Another way to ensure that the project takes these additional aspects into consideration and investigate how they affect the project, clear and simple channels for finding the information is required. Details of which processes to consider, departments responsible and perhaps even contact details to individuals, ensures that the project will quickly and without frustration find the additional requirements.

5. Discussion

Except for the business process review, this study is rather hypothetical in how the manufacturing function and manufacturing system can create value for other core processes. Further work to deep dive into specific value analysis between processes is required. However, the examples given can easily be found in isolated cases. Many car manufacturers have for example dedicated webpages for factory tours to strengthen their brand and products [21, 22, 23, 24, 25]. At one of the studied companies, the factories have lately been modified to become more easily available to facilitate visits. If this had been in mind while designing the system to start with, the cost could have been kept down and better solutions made. There are also examples of manufacturing development where other business processes have been kept in mind. Extra capacity has been planned for, to support development projects and prototype manufacturing, but also to ensure that time is available for training of both operators and engineers. The difference is that in these cases, certain individuals have been the innovative drivers and thought outside the box to create more value for others than the manufacturing function. Furthermore, it might also just have become a happening through coincidence, rather than with the intention of creating additional value.

6. Conclusion

Most companies studied have the same or similar core processes to realise their products and services. Furthermore, to ensure that manufacturing development projects do not become sub-optimised, there should be a focus on designing for business value (DFBV), looking beyond the functional boards. Manufacturing systems should be designed with additional functions and features that do not directly contribute to the operational targets in a factory, but to other core business processes as well.

To convince the decision makers that creating values across processes is good for business, it might be required to estimate the additional value in financial terms to justify any extra costs. This could potentially be difficult as some of these effects are intangible and not only related to the efforts made through the manufacturing system design. The decision models of today do not always account for such values. There has to be other business decision models that take these more intangible values into account as well, which is a big challenge for future work.

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