Exploring manufacturing solutions for SMEs

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Abstract

This exploratory study provides an overview over current state of manufacturing solutions in small and medium sized enterprises (SMEs) in region of Southern Denmark. Building on manufacturing paradigms, this paper reveals relevant aspects for the development and implementation of improving SMEs' automation processes. The paper presents an embedded case study based on 10 low- and medium-tech Danish companies. Based on the development of production paradigms and the presented study, this research helps to understand key determinants and processes for SMEs' exploration of future directions of manufacturing solutions, which are required to increase their competitiveness and assure sustainable growth.

Keywords: SMEs, automation solutions, case study research

Introduction

The European economy critically depends on the development on manufacturing systems, with a particularly important role for small and medium sized enterprises (SMEs). In fact, while SMEs account for 99,8% of all business in the European Union (EU), the particular segment of manufacturing SMEs provide 20% of jobs, and generate 21% of the GDP (Gagliardi-Main et al. 2013; Wadhwa 2012). The main goal of this paper is to investigate a particular element of manufacturing systems, namely how modern automation solutions can be embedded within in SMEs.

Automation as a mean for productivity, speed and increase of responsiveness is a key factor in contemporary production. Even though the literature provides evidence of various manufacturing solutions, for both small (Koc & Bozdag 2009; Dora et al. 2013) and large enterprises (Bhasin 2012; Inman et al. 2011), the research describing development and implementation of automation solutions in SMEs is sparse (Wadhwa 2012; Ribeiro & Cabral 2006). Following this dearth, this paper explores SMEs' needs in terms of automation as well as possible solutions in a regional case of Danish manufacturing companies.

Theoretical background

Production systems and manufacturing outputs

Miltenburg (2005) delimits the production system to a focused factory, which is "a well-defined production system that produces most, or all, products in a product family". Hon (2005), describes manufacturing systems, on more levels, when dividing them into five levels: single machine, manufacturing cell, flow line, factory, and production network. Even though both terms Manufacturing systems and Production systems are used interchangeably, depending on the authors, there is an agreement concerning the relation between product and processes. Schuh et al. (2011) describe the production system in relation to a product program (a range of products offered to the customer), Bruccoleri et al. (2006) mention "products of same part family", Hu (2013) discusses part families in combination with a series of processes and finally ElMaraghy et al. (2009) examine manufacturing systems and the relation between product and process in relation to variation. Depending on the production system, it is possible to obtain different manufacturing out, such as delivery, cost, quality, performance, flexibility and innovativeness, which will support the competitive advantage (Miltenburg 2008). The level of obtained manufacturing output is determent of a set of manufacturing levers, (human resource, organization structure, production planning, sourcing, process technology and facilities) (Miltenburg 2008) .The way how we define a manufacturing system in this paper is: *one, or a series of processes that produces most, or all, of the products in a product family*. SMEs within manufacturing will consist of a manufacturing facility, which will be able to hold different manufacturing systems, depending on e.g. product families.

Manufacturing systems have been developed throughout history according the development in paradigms, such as Craft Production, Mass Production, Flexible Production and Mass Customization (Jovane et al. 2003). The Craft Production has generated the job shop and batch flow productions systems, which are characterized by very high product-to-product variation, and with a relatively low volume. Job shop and batch flow systems provide high flexibility and innovativeness due to their capabilities steam from skilled workers, such as welders, carpenters and machinists.

Throughout the mass production paradigm, the line-flow production systems were developed: operator-paced (OPL), equipment-paced (EPL) and the continuous flow (CF). OPL, EPL and CF work with increasingly higher volumes, and lower the product-to-product variation. Due to the pursuit of obtaining economy of scale, the provided outputs are: delivery, cost and quality. As we move into mass customization concepts, Lean and Quick Response Manufacturing QRM are introduced, followed by Just-in-Time (JIT) and Flexible Manufacturing systems (FMS). JIT and FMS are more complex, than the more traditional production systems and demand a higher level of capabilities, especially within HR (e.g. cross training), Planning (e.g. Kanban systems), and Process Technology (e.g. automation) (Miltenburg 2008)

Due to an increasing demand for high degree of customization (mass customization), in combination with a dynamic environment (high variations of demand), new production systems emerge. (Jovane et al. 2003) points to Reconfigurable Manufacturing Systems (RMS) as a mean to fulfill requirements of rapid production capacity adaption to market demand. RMS provides a high level of scalability (flexibility within capacity) and cost efficiency. Flexibility, modularity and reconfigurability (Putnik et al. 2013; Wang et al. 2012) are the main characteristics of this approach.

Together with further development of manufacturing, a number of new systems emerge with origin in the low volume high mix market or variation e.g. Intelligent Manufacturing Systems (IMS) focusing on flexibility, adaptability and autonomy, Focused Flexible manufacturing systems (FFMS) (flexibility, productivity and adaptability to new technology) and Self-Reconfigurable Robotics Systems (SRRS) (Adaptability, Cost and Scalability/Flexibility) (Bilberg & Hadar 2012). Especially, few of the newest emerging paradigms: Personalized Production (Hu 2013) and the future Sustainable Production (Jovane et al. 2003) will increase the attention towards building manufacturing systems that are able to cope with demanded objectives. Some scholars (Wang & Koren 2012) highlight that manufacturing systems have to cope with large demand fluctuations, and still be able to produce high-quality products at low cost.

The manufacturing outputs evolve as the manufacturing systems develop. Known manufacturing outputs, such as delivery, cost, quality, performance, flexibility and innovativeness (Miltenburg 2005), will not be sufficient when describing the new manufacturing systems such as RMS. When a market develops towards a competitive environment of continually and unpredictably changing customer opportunities (Hon 2005), outputs like adaptability, agility, responsiveness, dependability, integrality and scalability become important (Al-Zaher et al. 2013; Azab et al. 2013; Bruccoleri et al. 2006).

Focus on manufacturing outputs when deciding on both manufacturing systems and degree of automation will be directly correlated with the ability to obtain competitive advantage.

An SME perspective on manufacturing

Due to the position that SMEs hold in the EU — both direct economic impact and as suppliers to larger companies — the future potential will be discussed. The Manufacturing Academy of Denmark (MADE) points towards a future manufacturing setup that has to be able to adopt and adapt to innovative ideas, being agile towards changes in the market and build a sustainable profile (Statistik 2012). Moreover, Johansen et al. (2010), highlight some future scenarios of Danish manufacturing. In accordance with the input from MADE, it is foreseen that technology development and implementation is crucial in order to increase competitiveness. In the report "Manufacturing 2025", Johansen et al. (2010) propose that this development should be handled through industrial power centers, that should coordinate the development and knowledge resources within the industry, universities and other knowledge centers. The innovative factory is described as a potential "launch pad" for innovative product and combined with a more virtual business approach, where SMEs should be able to reach out to a more global network and more flexible supply chains (ibid.).

Five indicators that Christensen et al. (2012) have identified in their report as common for successful manufacturing SMEs are: holistic orientation, deep customer relations, a lean production, high level of specialization, and an integrated R&D organization. The report points to the following focus areas important for the future manufacturing:

- Highly flexible manufacturing setup is needed to be more agile toward small and frequent orders,
- High complexity is part of the future orders, which also drives the need for close integration between manufacturing and R&D,

- Need of a highly effective manufacturing in order to make investments in new technology possible.

Across the three contributions concerning the future of Danish SMEs our perception of SMEs future developments in the area of manufacturing could be then summarized to the following points:

- There is a need for a strong focus on the customer demand, and the potential lies within striving for a manufacturing setup, that can adapt and operate within an agile and dynamic environment
- Innovation needs to be an integrated part of the manufacturing setup, shortening the introduction time and implementation of technologies, products and processes
- Technology is a driver to assure the right manufacturing setup
- SMEs have a central place in the industry

Method

Research design

In this inductive case study (Yin 2009), the involved researchers focused on the company level (as a unit of analysis), and analysed 10 Danish manufacturing SMEs, which perform customized production to orders. Empirical data based on research in three companies employing less than 20 people, four companies employing between 20 and 50 and three bigger ones. People, that researchers interacted with, were mainly managing directors or production and supply chain managers, which were considered the most knowledgeable to inquiry about the company and its manufacturing facility.

Since in EU SMEs in the manufacturing sector have a modest level of technology, and 88% of all SMEs in this sector has either low-tech or medium-low-tech status (Gagliardi-Main et al. 2013), the researchers chose low and medium-low tech companies as representative sample. Additionally, the scope of activities cover wide selection of industrial branches e.g. furniture, machine building, electrical solutions. As Denmark has one of the highest wage levels in EU, the manufacturing sector may have a future challenge in being profitable. That is why, in this respect, Denmark as a country could be seen as an extreme case, where, as a response to these conditions, a number of improvements in the manufacturing sector have to follow.

Due to a relative dearth in the literature on how SMEs perform manufacturing, including their biggest challenges, we conducted an exploratory study in order to understand how production is undertaken conducted in this group. The case study method with embedded action research elements (Coughlan & Coghlan 2008) was chosen due to increasing importance of a field based practice-oriented research contribution in operations management theory building (DeHoratius & Rabinovich 2011). During the initial inquiry, the researchers undertook an approach, which intended to match theory and reality in a circular process (Van de Ven & Poole 2002), and to engage research participants and encourage them for active contribution for potential improvements (Coughlan & Coghlan 2008). The researchers have employed a systematic iteration between literature review and case study evidence based on surveys, company interviews, factory visits, and observations (McCutcheon & Meredith 1993).

Data collection

The empirical data was collected by 8 researchers during 27 internal (strategy and planning) and 36 external (consulting at 3rd party) project meetings, over a period of 8 months. Each one of 10 involved companies was visited at least 2 times and meeting duration ranged between 1 and 2 hours for the introductory meeting and between 3 and 5 hours for the second meeting.

The first meeting was usually an introduction meeting, where the general discussion about company’s products and ways of producing was discussed and the scope of the project was presented. It was also the first change for the project team to have an insight into the manufacturing facility and to make the first observations. After the introduction each company filled out an online survey, which helped the team to gather some more in-depth information about the level of automation in the company, their products, as well as areas where the company consider potential improvements.

Topics addressed at the second meeting were based both on the online survey, as well as on the observations from the first visit in the facility. During the second meeting, researchers would do a scrutinized analysis of the manufacturing area. This meeting was followed by one or two internal meetings, planned to discuss observations as well as to point out suggested focus areas and recommendations for further improvements to present on the third meeting with a company. In case when the company was eager to obtain further analysis of a particular issue, an iterative process of internal and external meetings took place. Meetings were conducted until the company got sufficient amount of information to proceed with the improvements. In case of some companies, it has happened that the researchers were ready to present recommendations during first two meetings and no follow ups were necessary.

In order to achieve a triangulation (Eisenhardt 1989), the researchers used several sources of data including: notes and minutes from the internal and external visits, e-mail correspondence with the company, survey filled out after the first meeting, pictures and short movies taken in the facility, sketches, drawings and presentations of proposed solutions and recommendations, secondary data about the company gathered from publicly available sources. Since the collaboration within this research project was based on the data confidentiality agreement, the reported results hide the SME identification data.

Data analysis and validation

The investigated SMEs represent a wide range of products not only due to different branches that they represent, but also due to the portfolio of products that they manufacture, which vary from 3 to 12 000 units. Additionally, their products on average have medium or low dependence on seasonality. The products that SMEs would typically like to focus on for potential improvements vary a lot in terms of the size of the product groups that they belong to. However, motivation for improving them is usually similar. Most of them are perceived as having the highest potential, which is either combined with the highest turnover or higher cost. In most of the cases, chosen product represents a high value to the customer due to their: quality (manufacturing according to customer specification), delivery time, performance (the ability to add standard and extra features) and flexibility (the ability to make a fast change of the production capacity).

In terms of the expectations towards automation implementation as well as the project participation, SMEs pointed out productivity increase and cost and waste reduction. However, some of them were also interested in quality, as well as knowledge increase. During the investigation researchers took a holistic point of view with the special focus on areas pointed out by companies as problematic. All the findings and recommendations were discussed with the companies, and through this process researchers’ understanding of each case was verified. The analysis of the data usually started during the first meeting and was later on carried on through internal meetings to final presentation for the company. Each case was closed and additionally summarized through a short closure report.

Findings

Despite of the fact that only six companies out of the visited admitted sustainable increase in production during the period of last 5 years and only four plan to expand their production facilities. All of the companies claimed to be familiar with Lean principles, and seven claimed to follow them. However, based on the researchers' observations, SMEs are very selective in terms of how do they understand and implement Lean methods. In cases when the current production manager has previous experience from manufacturing facilities of larger firms where Lean was practiced, investigated SMEs tend to benefit from his/her tacit knowledge a lot. In such a case, not only the selection of applied principles is very much tailored to needs and capabilities of the SME, but also a lot of attention is put at the day-to-day management e.g. proper work sequence, timing and outcome or limiting various types of waste. In other cases application of Lean methods is very limited.

In some cases manufacturing facilities reveal the reminiscences of previous manager's influence. This could be observed by left overs of Kanban system, or double labelling of goods and raw materials.

Reduce spill

Some of the companies had difficulties with waste management and measurement. This had to do with the production process, particularly vibrations and wireframe in which big amount of dust created as a side effect. This has its roots in usage of a relatively old machinery and lack of process control. Unfortunately simple 'cleaning' would not solve the problem due to a large amount of dust, which is constantly created along the manufacturing process. In the long run horizon, the improvement should be connected with implementation of new machines, which should be well consolidated

In some other cases due to an old type of machinery a lot of energy was wasted for e.g. vacuum lift. In this case newer types of vacuum lifts significantly reduces energy consumption

Changeovers &recycling trap

Another observed difficulty was related to many changeovers, which create additional scrap. Theoretically there is always recycling opportunity; however it is been noticed that some companies run into a 'recycling trap'. Instead of reusing the raw materials left from changeovers, they created a relatively large stock of materials intended for later use. Since it is usually easier and more convenient to use a new batch, use of changeover materials does not occur. One of the recommended solutions was to consider product lines dedicated towards fewer products. However, this may require increase in production volume, in order to cover investments and will increase the overall transportation in the facility and dedicated production lines would also require increase in production volume, in order to cover investments. Changeover time could also be reduced by applying the SMED (Single-Minute Exchange of Die) technique on the process, which would make the process more flexible towards change in production mix and order production.

The 'recycling trap' does not necessarily have to be related with leftovers from processed materials - it could also happen due to the minimal required size of a material order. In this case, manufacturing companies are being left with oversized inventory, often unregistered. In case this inventory consists of special parts the company could run into difficulties like build-up of unregistered stock materials. This issue could be solved by Standard Operation Procedures (SOP) and immediate disposal of scrap.

Transportation & inventory
In relatively many SMEs, the researchers observed a lot of excessive transportation. This usually was connected with order handling, where many intermediate inventories (Work in Progress) were created. The problem emerged from poor design of the production flow. In some cases, in order to manufacture the batch, prior assembling a product all the parts had to be collected (i.e. temporarily stored), and after assembly, products were temporally kept at place before the whole batch was transported to dispatch. In such cases, SMEs were recommended transport improvements e.g. conveyor belts, which could be customized for them to eliminate transportation and inventories between processes, reduce repetitive work as well as decrease the overall lead time for the product.

Assembly
In many visited SMEs, both assembly and material handling processes are still done manually. In some cases those processes could be easily automated, but this depends very much on complexity of the product as well as the recourses that the company would potentially like to invest in automation. Nevertheless, in case of limited resources, a good starting point would be at implement at least some small semi-automatic solutions, like automatic screw feeders to the drilling machines, which in a long time horizon could be replaced by mechanical "Co-workers". Mechanical "Co-workers" are especially appropriate for simple packaging operations, e.g. packing products into boxes, filling pallets and the like. Another option, useful in case of bigger or heavier parts would be a crane to load/unload at the assembly stations, which would help avoiding heavy lifting. Last, but not least in some cases, a very simple movable and height adjustable tables could prevent wrong working positions and increase the efficiency of assembly workers. Additional advantage of implementing such a solutions (both in short and long run) would be a gradual work environment improvement. If the assembly process is value-adding in relation to customization, it can be hard to automate, as the value can be tied into the assembly operator. In these cases the automation focus could be on increasing the OEE on the assembly stations instead.

Documentation
Many of the visited SMEs have automated only the administration processes e.g. computer aided data collection and additionally use few machines, what indicates a big space for improvements in this respect. In some cases researchers observed that when workload is high, documentation steps are skipped, in this case companies could consider implementing a software solution. Task boards with instructions and dedicated tools for these tasks could be also very helpful in improving efficiency of workers especially if the people on the work station are changing.

Discussion and implications

An attempt to implement a new adaptive and flexible manufacturing solutions in SMEs should allow the manufacturing of several different products at the same time, increase the degree of machine utilization, reduce in-process inventory (Eroglu & Hofer 2011) as well as decrease response time (ElMaraghy 2005) in order to meet customer preferences (Aitken et al. 2002). Furthermore, in the terms of this case study, it could also be a great help in the process of increasing their competitiveness and productivity through new production technology.

Our exploratory research conducted among manufacturers in the region of Southern Denmark concluded that despite of familiarity with different manufacturing concepts (e.g. Lean) and standards (e.g. ISO), SMEs still encounter difficulties with their implementation. In almost half of the cases, the only implementation of automation was realized by purchasing different types of machines (e.g. CNC). In some cases, companies also used computer aided automatic data collection system linked to production. Besides, most of the processes in the manufacturing area were done manually. In this respect, automation pyramid concept, which takes into consideration multiple layers of automation, is also very relevant. Each level focuses on different areas of the application, starting with sensors, actuators, and then devices, followed by control systems to enterprise level. Additionally, it is very important to take into consideration Rother's (2001) levels of automation, which indicates in what order automation should be implemented in the company. According to Rother (2001), if a company would like to shift from manual to automate process execution, it should start with machine cycle followed by loading and unloading processes to automate transportation at the very end.

The main reasons why involved companies would like to implement more automation solutions in their facilities are: increasing productivity, quality and waste reduction, and lowering the costs. Despite of a big value and potential improvements that automation could bring to the company, the biggest issue in case of SMEs, is usually related to financial concerns (Nieto & Santamaria 2010) as well as access to required resources (Sharifi et al. 2013), which in many cases could be just a proper advice. Moreover, in some cases additional motivation for improvements implementation could be concerns about the work environment, which have a direct impact on workers' efficiency.

Processes that have the highest potential for automation are material handling and inventory management. However, during the analyses of the facilities, the researchers found that in many cases the biggest impact could be automation of the data management system, which could help companies to assure efficient information flow as well as integrity of the data on a various stage of product development and production process. Additionally implementation of those systems could be way cheaper than purchasing a dedicated machine.

According to the literature, the future focus points in terms of automation would be related to adaptability (Putnik & Sluga 2007; Martin et al. 1990; Maffei et al. 2010), responsiveness (Jovane et al. 2003; Jämsä-Jounela 2007; Samad et al. 2007), and innovativeness (Müller & Horbach 2012; Sharifi et al. 2013), however the investigated SMEs see automation and technology as a mean to optimize toward cost (productivity), quality and delivery, which indicates a gap between the understanding of the market, purpose and potential of the technology. Nevertheless, one of the possible explanations of this discrepancy could be an overall focus on large companies and as an implication, an extrapolation of their objectives into the whole manufacturing industry.

Conclusion

Our intention in this research was to explore the current knowledge and understanding of manufacturing paradigms as well as to find out what kind of processes have to be taken into consideration in the first place for further automation solutions investigation in SMEs. Unfortunately there is still a relatively big gap between all the known paradigms and their implementation in SMEs. Our study showed that in the investigated cases the starting point for improvement could be a proper Lean implementation, which could be good base for better identification of the most potential areas for automating. Based on our observations so far, the biggest potential for implementing automated or semi-automated solutions could be related to the data management system, transportation and assembly and replacement of old machinery

The paper adds to a deeper understanding of local SMEs' manufacturing facilities and their challenges, which contribute to a better understanding of the development of automation solutions. However, future research expansion to more countries as well as different groups of SMEs (in terms of size and scope of their operation), is necessary to develop more systematic improvement framework.

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