SOFTWARE SUPPORT FOR MANUFACTURING OPERATIONS IN BELGIAN SMEs: ONE SIZE FITS ALL?

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Abstract:

Manufacturing companies face a big challenge to bridge the gap between their business and manufacturing processes. The urge to increase efficiency makes it necessary to align the business and manufacturing processes. Small and Medium-sized Enterprises (SMEs) experience several barriers to adopt software support for manufacturing operations. This paper gives an overview of a research study conducted in Belgian SMEs. The research studied the current adoption of software support for manufacturing operations and the barriers that SMEs experience to invest in this type of software. The study is concluded with a number of considerations to enable the adoption of software support for manufacturing operations by SMEs.

Keywords:

Manufacturing operations, SME, MOMS, ISA 95.

INTRODUCTION

Computer Integrated Manufacturing (CIM)

In the mid 1970s Harrington (1973) introduced for the first time the term Computer Integrated Manufacturing (CIM). His work described CIM as a structure to integrate different manufacturing systems. The development of different systems led to so called '*islands of automation*'. In the 1980s the CIM pyramid model was developed and this model defined five hierarchical levels within a company (Unger, 2001). The lowest level of the pyramid, level zero, represents the sensors and the actuators. These devices are connected to level one control systems like Programmable Logic Controllers (PLC) and Distributed Control Systems (DCS). Level two represents the supervisory systems that communicate with the level one control systems. The systems on these three levels are closely related to the manufacturing process and can be referred to as Production Control Systems (PCS). The Manufacturing Operations Management Systems (MOMS), situated on level three, manage the different control systems. A first example of MOMS are systems that support production operations. This software is commonly referred to as Manufacturing Execution Systems (MES) (MESA International,1997). Other examples of MOMS are Warehouse Management Systems (WMS), Laboratory Information Management Systems (LIMS), Maintenance Management Systems (MMS), Logistics Execution System (LES), … . The highest level in the pyramid, level four, represents the business management systems. These systems manage business processes like order processing, procurement, … . Typical examples of this kind of software are Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM), … . The CIM pyramid is depicted in figure 1.

The distinction between each level can be made based on the time frame and the quantity of data. As indicated in figure 1, the time frame and quantity of data are larger at the top of the pyramid. ERP systems for example, process large quantity of data and the decisions made

on this level are long term decisions (Months, weeks and days). MOMS operate on a shorter time period (Days, hours and minutes). The Process Control Systems interact with the manufacturing process in real time, so the time frame is even smaller (Minutes and seconds).

The interpretation of the definition of Dr. Harrington has changed over the past decades. CIM has evolved to an effort to integrate the different software systems (Foston, Smith and Au, 1991). This type of integration is commonly referred to as vertical integration.

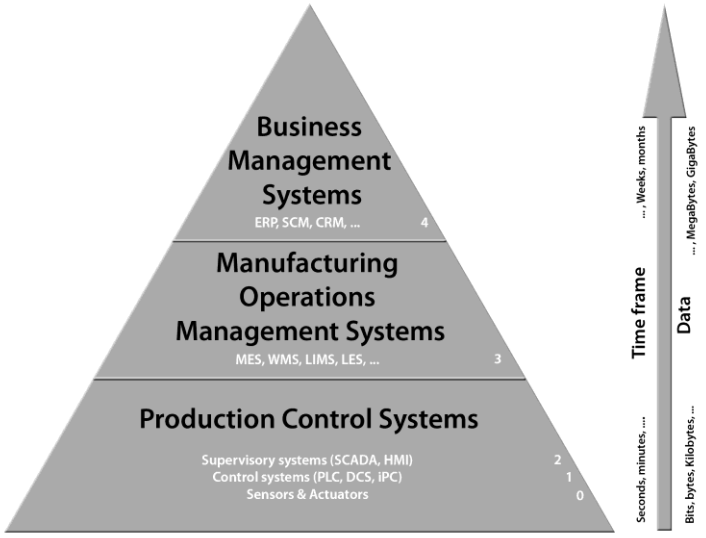

Figure 1:The CIM pyramid

Bridging the gap

With the emergence of computers and ICT in the past decades industrial companies invested in ERP systems to increase efficiency by automating their business processes. On the other hand industrial companies also invested in the automation of their manufacturing processes. This leads to a gap between the business management systems and the production control systems. Companies face a big challenge to increase efficiency even more by bridging this gap. Manufacturing companies, especially Small and Medium-sized Enterprises (SMEs), still manually exchange information between both levels. It is obvious that the use of MOMS, that automates the information flows, leverages important strategic advantages (Scholten, 2007).

Literature about the adoption of MOMS in large companies is available (MESA International, 2008). International organizations like the Manufacturing Enterprise Solutions Association (MESA) and the International Society of Automation (ISA) publish papers concerning MOMS. However literature lacks sufficient attention on software support for manufacturing operations in SMEs. This paper will discuss a research study conducted in Belgian SMEs to investigate the current adoption of MOMS and the barriers that SMEs experience to adopt MOMS. A comparison will be made between the barriers discussed in literature on technology adoption in general and barriers encountered during the research study.

TECHNOLOGY ADOPTION AMONG SMEs

In the perspective of the adoption of MOMS in SMEs and the lack of literature about this topic, a literature study was conducted to investigate technology adoption among SMEs. The purpose of this literature study is to identify the barriers that also could apply to the adoption of MOMS.

Literature about ICT adoption in SMEs frequently treats a phenomenon called the '*digital divide*'. The digital divide can be described from many viewpoints (Wielicki and Cavalcantie, 2006). From an ICT point of view, Arendt (2006) stated that a digital divide exists between SMEs and large companies. Large companies are more capable to adopt ICT than SMEs. This leads to a segregation between large companies and SMEs and this phenomenon is described as the digital divide. The digital divide is even larger when the complexity of the applications increase. SMEs encounter more barriers to adopt ICT than large companies. Many studies were conducted to get insight in these barriers and the results of the studies were similar. The EU ICT task force (2006) has conducted a research to increase the competitiveness of the European ICT industry. Their report made it clear that SMEs experience several barriers to invest in ICT. The most important barriers, which are related to the topic of this paper, are lack of innovation culture, lack of financial resources, lack of flexibility of the production environment and lack of awareness/skills. These barriers form the origin of the digital divide from an ICT point of view.

Estrin et al. (2003) studied the technology adoption in SMEs. The research study discusses similar barriers as stated above. In addition to the already formulated barriers, the pressure to be productive and the lack of technologies that are suited for SMEs are common barriers experienced when adopting new technologies.

It can be concluded that the barriers can be divided into three categories: social, financial and technical. The categories and the different barriers are shown in table 1. MOMS relate to both ICT and new technologies. The barriers experienced when adopting new technologies or ICT can be similar to the barriers experienced when adopting MOMS. The research study will point out of if this statement is correct or not.

Economic	Social	Technical
The lack of financial resources	The lack of innovation culture	The lack of suited technology
The pressure to be productive	The lack of awareness / skills	

Table 1: Common experienced barriers when adopting new technologies or ICT

RESEARCH STUDY

The ever-increasing urge to maximize profit drives companies to optimize and improve their manufacturing processes. A key element in this perspective is software support for manufacturing operations. Large manufacturing companies with highly automated manufacturing processes adopted MOMS (MESA International, 2008). The adoption of MOMS among SMEs however is not common. The purpose of the research study is threefold. The study has to give insight in the current adoption of MOMS in Belgian SMEs and how to overcome the barriers to adopt MOMS. The study will also verify if the barriers depicted in table 1 apply to the adoption of MOMS or not.

Target group

Since 01/01/2005 the EU has introduced a new SME definition. As a member of the EU, Belgium applies the same definition. Table 2 shows the different thresholds to determine the Enterprise category. The research study was restricted to SMEs, so the micro enterprises were not included in the study.

Enterprise category	FTE	Annual turnover	Annual balance sheet total
Medium-sized	< 250	≤ €50 million	≤ €43 million
Small	< 50	≤ €10 million	≤ €10 million
Micro	< 10	≤ €2 million	≤ €2 million

Table 2: The European enterprise category thresholds (Enterprise and Industry publications, 2005)

Method

The first step in the research study was finding SMEs that were prepared to participate in the study. Initially a selection was made based on the thresholds in table 2. Each SME that was suited for the study was contacted by e-mail. This approach wasn't successful, there wasn't any company that responded to the mailing. As a result the strategy was altered. A subset of the initial list was created based on the industry and region. Each company from this subset was contacted by phone. This approach was more successful, 10% of the contacted SMEs were prepared to participate. Besides this approach, a great deal of organizations were contacted to promote the research study on their website. This resulted in 8 additional participating SMEs. In total 22 SMEs co-operated with the research study.

22 SMEs might seem a small group to conduct a research study. However this study deviates from classic research studies such as Love et al. (2004). Each SME that participated in the study was submitted to an interview with the researchers. This approach enabled the researchers to get a detailed view of the software support for manufacturing operations in the SMEs. The SMEs that took part in the study were provided with a report with the findings of the interview. Taking this considerations into account it is obvious that this type of study is more time consuming. However there are multiple reasons why this approach was applied. The first and most important was the lack of knowledge in SMEs about MOMS. This could have led to incorrect answers if a classic method with a questionnaire would have been applied. The applied approach also enabled the researchers to create awareness about MOMS among the participating SMEs.

In order to investigate different companies it is necessary to develop a uniform method. The research method used in this study, is based on international ISA 95 standard. ISA 95 standardizes the manufacturing operations management activities and the interface with the business management systems. The ISA 95 models and terminology can be used to perform an analysis of a manufacturing company (Scholten, 2007). The method is based on the functional hierarchy model, the equipment hierarchy model and the functional enterprise control model from the first part of the standard (American National Standards Institute, 2000). There are four important topics in this method. First, the interviewee presents the company (Industry, number of employees, production strategy, …). Second, the complete flow from order to finished product is mapped. This mapping allows the researchers to get insight in the different material and information flows. The next topic is related to the ISA 95 functional enterprise control model. This model represents the different functions and information flows within a company that are related to manufacturing. Fourth and final topic, the interview is completed by a guided tour in the production department of the company.

Results

The research study was conducted in Belgian SMEs from different industries. Figure 2 illustrates the different industries of the participating companies. A great deal of the most important Belgian industries are represented in the figure. The participating SMEs can also

be distinguished based on the enterprise category. The small and medium-sized enterprises were almost equally represented in the research study. 55% of the companies were small enterprises and 45% were medium-sized enterprises. In the greater part of the interviews the interviewees were managing directors (46%) and production managers (45%). The remaining part of the interviewees were IT managers (9%). In 41% of the companies there was a combination of two production strategies. The largest part, 72% of the participating SMEs, practiced a Make to Order (MTO) production strategy. A smaller part of 37% had a Make to Stock (MTS) strategy and 32% had a Engineer to Order (ETO) strategy. Although the research population was relatively small, there was a great variety of production strategies, interviewees, enterprise size and industries. The results presented in the following paragraphs are not final and the research population will be extended in the future.

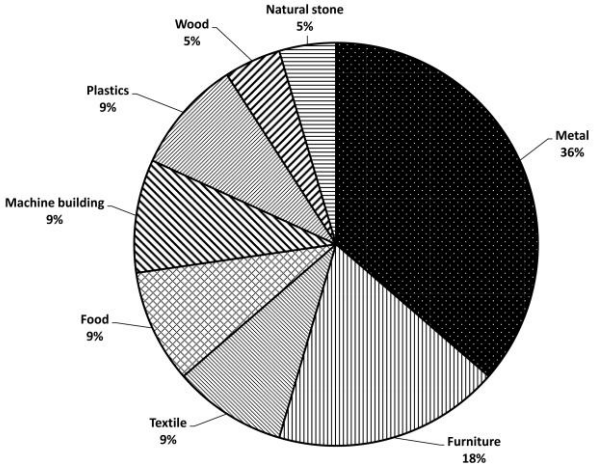

Figure 2: Industry overview of the participating SMEs

The goal of the research study is to get insight in the software support for manufacturing operations in SMEs. A great deal of manufacturing companies have adopted an ERP system to automate their business processes. It is common that a level four software system is also used to support manufacturing operations. However, level four software is not suited for this type of support (Alan, 2006). A first topic is the software support for manufacturing operations in the researched SMEs. An overview of the software support in the participating SMEs is depicted in figure 3. The figure indicates four categories of support. These categories are clarified in table 3.

Category	Description
Exclusively level four support	Level four operations are supported by level four software
Level three and four support (ERP)	Level three and four operations are supported by ERP
Specific level three support (MOMS)	Level three operations are supported by MOMS and level four operations are supported by ERP
No support	No operations are supported by any type of software

Table 3: The four categories of software support

The results of this first topic are divided into four circular diagrams in accordance with the four categories of manufacturing operations management of the ISA 95 standard (American National Standards Institute, 2005).

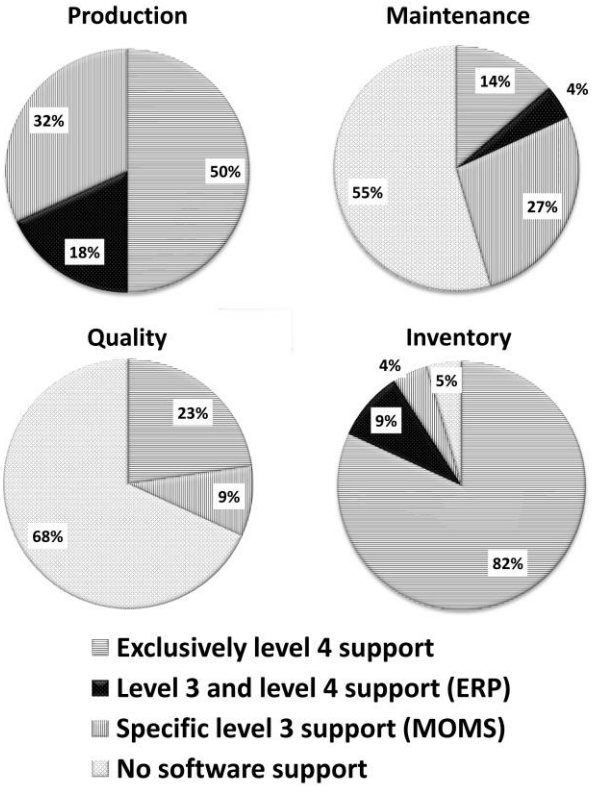

Figure 3: Overview of the software support for manufacturing operations

The production activities were, to a certain extent, always supported by software. In 50% of the cases the SMEs had exclusively level four support. Another 32% of the researched SMEs use specific level three software to support manufacturing operations. All of these companies used MS Excel to manually create a production schedule. It is clear that this working method is inefficient. None of the SMEs had a commercial off-the-shelf MOMS. This is in great contradiction with large companies who have adopted commercial MOMS (MESA International, 2008). The remaining 18% of the companies used their ERP system to support level three and four manufacturing operations.

The software support for inventory activities slightly differs from the production activities. More than three quarter (82%) of the companies supported inventory activities with their ERP system. The software support was often limited to the tracking of the inventory levels. These inventory levels were in all the cases not updated in real time. 9% of the SMEs use a specific inventory module of their ERP system to support level three inventory operations while 4% of the cases used a Warehouse Management Systems (WMS) to support level three inventory operations. The remaining 5% doesn't support any inventory activities with software.

The other categories of manufacturing activities are less supported by software. Quality is in 68% of the SMEs not supported by software. The employees do *at-line* tests to ensure the quality of the manufactured products. In case of a non conformity, the product is reworked or disposed. The rate of rework is in none of the cases tracked. 23% of the investigated companies use an level four system to support level four quality activities. These SMEs use software to store the quality test results. The remaining 9% of the SMEs use specific

software to support level three quality operations (Managing quality test information, execution of in-line tests, …).

The amount of software support for maintenance activities resembles to the software support for quality activities. 55% of the SMEs don't have any software support. The largest part of these companies perform reactive maintenance and only a small part of these SMEs perform preventive and periodic maintenance. 27% of the SMEs use software to support level three maintenance operations. All of these companies, except one who used commercial maintenance software, use MS Excel to plan maintenance activities. A smaller part (14%) use a level four system to track level four maintenance activities (Spare parts, preventive maintenance, …). 4% of the companies use their ERP system to store level three specific maintenance information.

A second important topic is the information exchange between different software systems and especially between business management systems and process control systems. Figure 4 illustrates the information exchange between level four and level two. There is a distinction between the downward information flow and the upward information flow.

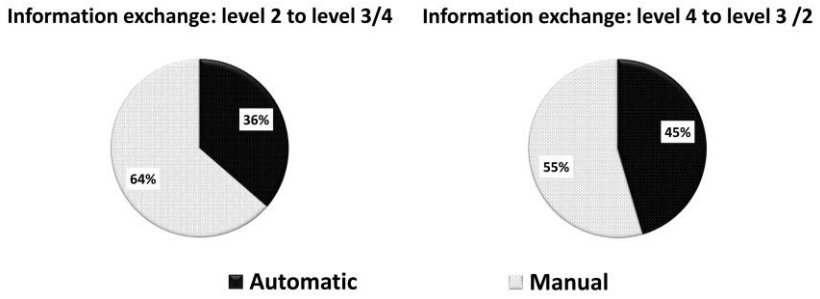

Figure 4:Overview of the information exchange between level two and level four

In 36% of the participating SMEs there is an automated information flow from level two to level four. With exception of two cases, a scanning system provides the ERP system with data. The data consist of the duration of each production activity, the date, the type of production activity and a code to identify the person who performed the activity. In the other two cases, touch screens were used to feed back information to higher level systems. The remaining part of the SMEs did not use any type of automatic information exchange. In all of these cases paper documents are used to feed back information to the administrative level. The necessary information is then manually entered in a level four system by an administrative employee.

The information flow from level four to level two was in 45% of the cases automated. A great deal of these SMEs have an export function in a level four system to extract the necessary information to a MS Excel sheet. A small part of the SMEs apply touch screens to dispatch production information to the shop floor. The touch screens are fed with information from the ERP system. The remaining 55% of the companies do not have automatic information exchange. The greater part of these SMEs distribute printed documents, coming from their ERP system, to the employees on the shop floor.

45% of the researched SMEs had no software support for level three manufacturing operations. This implicates that only level four manufacturing operations are supported by software. 32% of the SMEs use specific level three software to support level three manufacturing activities. All of these companies, except one, use Office tools as software support. Another 14% use a combination of Office tools, commercial MOMS and ERP. The remaining 9% use only their ERP systems to support level three manufacturing operations. These results indicate that SMEs frequently use Office tools to support level three

manufacturing activities. Only 18% of the investigated SMEs use a commercial or customized MOMS. The investigated SMEs experienced multiple barriers to adopt MOMS. The most important barrier is the lack of financial resources. A great deal of the current commercial MOMS are not suited for SMEs due to the large financial investment. A second important barrier is the lack of knowledge about MOMS. Many SMEs confuse MOMS with ERP and aren't aware that MOMS exists. A third important barrier is the lack of awareness. 70% percent of the SMEs experienced problems concerning MOMS. These companies realize that the current working method is not efficient but they struggle to find a contact point due to the lack of skills/awareness. A fourth important barrier is the lack of suited systems for SMEs. Suppliers of MOMS focus on large companies and the current available systems are not fit for SMEs. The above formulated barriers are similar to those formulated in table 1.

The lack of MOMS among SMEs implicates that the information exchange between business administration and manufacturing is problematic. As MOMS form the link between business administration and manufacturing, it plays an important role in the information exchange. On the one hand a MOMS is, among other functionalities, responsible to create a production schedule and to dispatch it to the shop floor. On the other hand it collects data from the shop floor and sends critical information to level four. 41% of the investigated SMEs didn't have any kind of automatic interface. The absence of MOMS creates a gap between level two and level four which is often bridged using inefficient paper based communication. In some cases there is an automatic interface (eg. Scanning system coupled to ERP system) to feed back information. This approach often causes problems because of the absence of a MOMS. In none of the studied SMEs there was a level three software with a connection to level two.

The results of the research study show that the size of the companies has an important influence on the adoption of MOMS. Half of the medium-sized enterprises used commercial or customized MOMS. In general medium-sized companies experience less barriers than small companies to adopt MOMS. These companies dispose of more financial and human resources which make it easier to invest in new technologies like MOMS. Only one of the small enterprises used a commercial or customized MOMS.

Enabling the adoption of MOMS in SMEs

The current available commercial MOMS are elaborate and expensive systems with a great deal of functionalities. This implicates that these systems aren't suited for SMEs. There is an mismatch between the supply side (Suppliers of MOMS) and the demand side (SMEs). As a conclusion to the research study it is important to consider some enabling factors for SMEs to adopt MOMS. First of all SMEs have to be informed on the opportunities and the functions of MOMS. Government supported research can play an important role in this perspective by organizing events to create awareness about MOMS and stimulate investments in new technologies. Second, it is important that suppliers of MOMS have an appropriate approach for SMEs. Suppliers have to take into account that SMEs in most cases don't have employees with the appropriate knowledge and that they dispose of less financial resources than large companies. Third, suppliers must match the demand of the SMEs. SMEs require modular, low cost software that is easy to expand. This would enable the companies to implement MOMS step by step and implement the most critical functions first. It also would enable the companies to spread the financial investment over several years. It is unnecessary to provide MOMS with elaborate functionalities. SMEs only require some typical basic functionalities of MOMS (Production scheduling, shop floor data collection, ...). Standardization is also a key issue in the development of software. If the MOMS is based on the ISA 95 standard, it could be easily integrated with business management systems. Fourth, SMEs struggle with the return on investment calculation of software. In order to calculate the benefits of MOMS, it is necessary that an SME can assess what MOMS will

deliver. This can be achieved by providing SMEs with a method or tool that supports them with the justification of MOMS. Taking these enabling factors into account, the barriers from table 1 can be overcome.

CONCLUSIONS

The literature study made it clear that SMEs experience multiple barriers when adopting new technologies and ICT. The barriers can be divided into three categories and the most common barriers are shown in table 1.

The adoption of commercial or customized MOMS in SMEs is not common. SMEs often use MS Office tools to support manufacturing operations. The absence of commercial or customized MOMS makes it more difficult to exchange information between level four and level two. This implicates that an efficient information exchange between business administration and manufacturing is not common. Even when an automatic information exchange is present SMEs struggle with problems. The research study made it clear that the researched SMEs experience similar barriers as depicted in table 1. The lack of financial and human resources were the most important barriers in the studied SMEs.

In order to overcome the barriers to adopt MOMS, there has to be an appropriate approach for SMEs. This implicates that suppliers of MOMS must match the demand of SMEs. Another important aspect is creating awareness about MOMS among SMEs. The most difficult barrier to overcome is the justification of MOMS. SMEs need a method or tool that supports them with the justification of MOMS.

Further research will be conducted to extend the research population of the conducted research study. In addition, the development of an easy-to-use method for SMEs, to guide the return on investment calculation for MOMS, will be started. The method will enable SMEs to analyse their current situation and guide them to map the future situation. The ISA 95 standard will form the starting point of the method.

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