Realizing a Factory-in-a-Box Solution in a SME Environment

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Abstract
Meeting customer demands require highly flexible manufacturing systems in the same time as the use of automation is becoming critical for competition. This is challenging, especially for small and medium-sized enterprises (SMEs) with their limited resources. This paper presents a possible support to SMEs where the Factory-in-a-Box concept has been realized for a small manufacturing company with a profile of craftsmanship and small production volumes. The objective of this paper is to discuss the possibility for SMEs to use automation and the Factory-in-a-box concept to stay competitive. It also proposes the Factory-in-a-Box concept as means for realizing a Product-Service System.

Keywords:
Automation, Manufacturing, Factory-in-a-Box

1 INTRODUCTION
Emerging economies, social and political transitions, and new ways of doing business are changing the world dramatically. These trends suggest that the competitive environment for manufacturing enterprises will be significantly different than it ever has been earlier [1]. Globalization makes competitiveness within manufacturing industry more difficult to sustain, and it is recognized that low cost and high quality is not enough to guarantee a firm’s competitive position in the market place. Companies in all lines of businesses need to focus on attaining high utilization of their available resources, reduced investments, as well as having a high degree of flexibility to meet fluctuating customer demands.

One way to handle the competitive challenges and improve a company’s efficiency could be to invest in automation and industrial robotics [2]. However, automation investments are in many cases a big investment that many, especially small and medium sized, companies have difficulties to economically motivate and manage for a short period of time.

Thus, there is need for automated systems with an acceptable investment, high efficiency, high adaptability, and with such flexibility that it may produce several different products and adapt to future product variants without large additional investments [2].

One way to meet these needs especially for small and medium sized enterprises (SMEs), would be to temporarily rent or lease the type of automation or production capacity needed during a limited amount of time.

In January 2005, the Swedish Foundation for Strategic Research initiated a research project called ‘Factory-in-a-Box’. The main objective of the project was to demonstrate mobile and flexible production capacity on demand. The Factory-in-a-Box concept was, before the project ended in December 2007, developed, exemplified and realized through five industrial demonstrators developed by researchers together with competitive manufacturing companies in Sweden. [3]

The objective of this paper is to discuss the possibility for SMEs to use automation and the Factory-in-a-Box concept in order to stay competitive. The Factory-in-a-Box concept as means for realizing a Product-Service System (PSS) for SMEs is also discussed together with the results from a case study.

The case study which forms the basis for this paper was conducted at a small Swedish manufacturer with a profile of craftsmanship and small production volumes. The aim of the study was to investigate the possibility of using automation in combination with the Factory-in-a-Box concept in order to ramp-up production in short time and at the same time increase the flexibility of the manufacturing system. The study resulted in a Factory-in-a-Box demonstrator presented in December 2008 in Eskilstuna, Sweden. The development of the demonstrator and the resulting solution will be described in the paper.

2 BACKGROUND
SMEs represent the main part of companies in Sweden as well as in the whole of Europe. SMEs also often have special needs and inferior conditions in relation to larger companies and therefore needs help and tools in order to stay competitive on today’s market.

2.1 Current situation for SMEs
The research presented in this paper has focused on the need of the small and medium-sized enterprises (SMEs). The reasoning behind focusing on the SMEs is evident when looking at the demographics of current business in Europe. In the European marketplace, 93% of the enterprises have less than 10 employees, and only 0.2% has over 250 employees [4].

As the marketplace is becoming increasingly global and technology-driven, the traditional problems many SMEs are facing increase, as for example: lack of financing and difficulties in exploiting technology [5]. In a survey 2007, 60% of the managers stated that competition had increased over the last two years [6]. The SMEs in Europe reported that the availability of human resources and cost of human resources are some of the most important business constrains. As many as 35% of the SMEs reported that the availability of human resources was a problem and 93% reported that they experienced
that the cost of human resources are an important issue [6]. Over half (51%) of the SMEs stated that the problem with lack of skilled labor had increased during the last two years, while 57% stated that the problem with a too expensive labor force had increased during the same time period.

Even though smaller companies may in some ways have difficulties adapting to globalization they are becoming increasingly international. Approximately one-third of all European SMEs reported an increasing number of international business contacts over the last five years [7].

As the SMEs are facing this new and more competitive business environment they will have to adopt by, for example, start utilizing new and more advanced manufacturing technologies. For SMEs, automation could be a prerequisite in order to survive in a market that requires high flexibility, intelligent manufacturing systems and robots [8]. It was concluded in a report compiled by EURON that [9, p. 15]: ‘New robot development should not neglect the new pay equipment by the hour’ and leasing mentality, driving the need for low-cost robots, especially for small and medium enterprises (SMEs).’

2.2 The Factory-in-a-Box concept

The Factory-in-a-Box concept was developed as part of a three years research project started in 2005. The overall vision of the project was to realize the concept of “mobile production capacity on demand” [10]. The concept of mobility of equipment and production facilities has been used for quite some time within, for example, military application and construction. Also, looking at primary industries, such as agriculture or petroleum industries, it is common to move the manufacturing equipment closer to the resources. In contrast, when looking at tertiary industries, such as medical services and repairs and maintenance, mobile equipment is used to get closer to the end user. However, the concept of mobility within traditional manufacturing industries is rather new and can provide competitive advantage [11].

There are several potential applications of mobility within manufacturing systems. For example to [12]:
- cover occasional production volume peaks,
- reach new markets,
- perform maintenance close to customer,
- train, for example, operators,
- share investments in equipment between plants or companies,
- quickly facilitate prototype development,
- demonstrate equipment,
- cover temporary disturbances in supply chains, and
- lease out equipment to 3rd parties.

The Factory-in-a-Box concept is an approach to enable mobility within manufacturing systems in order to realize one or more of the above mentioned applications to strengthen the.

During the Factory-in-a-Box project, standardized production modules was developed with the overall objective of providing means for easy re-configuration of manufacturing systems and supply-chains. The modules can be used for different applications and re-used when no longer needed at the original site. In order to realize these kinds of manufacturing modules, different enablers of flexibility and mobility where developed and incorporated into the modules.

Demonstrators
Five demonstrators where developed in cooperation with industrial partners during the Factory-in-a-Box project: (1) a reconfigurable solution for assembly operations using industrial robots, (2) a mobile platform for semi-automatic welding, (3) a mobile and automatic solution for deburring of casted products, (4) a concept for functional sales of mobile equipment, and (5) a mobile facility for manual assembly. The demonstrators are described in the following five paragraphs respectively, followed by some conclusions from the project.

Demonstrator 1 was developed as a reconfigurable robotic working cell used for assembly of metal sheet cabinets. The Factory-in-a-Box concept was here important since the case company had a stepwise automation integration strategy, meaning that they wanted to be able to introduce some automation at first and then increase the level of automation as they felt comfortable with the current automation equipment. Further, the flexibility aspect of the concept was appealing since the design of the product produced at the plant is changing frequently and thus the manufacturing system has to change accordingly. This demonstrator was developed in a laboratory environment, evaluated, and then introduced in operational production during the fall of 2006.

Demonstrator 2 was developed as a response to a manufactory company’s need of having a welding facility available at three different sites. The company could not financially motivate the purchase of the equipment for one production site alone, but if the investment was spread over three sites it was financially sound to invest. A mobile platform was designed with a flexible fixturing system that allowed for a wide range of products being produced in the same piece of equipment. This demonstrator is fully designed but the investment is on hold until a feasible customer project is available for the industrial partner.

The development of Demonstrator 3 started based on the company’s needs of an automated solution for how to deburr casted products. The company had three production sites in a geographically close area and wanted to be able to move the purchased equipment between the sites. This demonstrator project resulted in the design of an industrial robot solution, integrated in a container for mobility and containment of the ergonomically unsound application. The demonstrator was partly realized in a lab environment and was delivered to the industrial partner for further decision on investment.

Demonstrator 4 did not include any technology development, but focused on the business concept of being able to lease out mobile manufacturing equipment. The industrial partner in this demonstrator project used the Factory-in-a-Box project as a model for new business opportunities and the research interest in this demonstrator was to participate in quoting phases where the concept of leasing manufacturing equipment was introduced. As of now, no real business case has gone through all the way in this demonstrator project.

Demonstrator 5 was not a technology development project either, but focused on how to realize a mobile assembly facility using already available technologies. The purpose of the ambulatory assembly facilities originated in the need for being able to offer local production when selling large built-to-order products to other countries. The demonstrator was realized as a prototype at a production plant in Sweden and is now part of the industrial partners offering to its customers.
Conclusions
The overall conclusion of the Factory-in-a-Box project was the need for new innovative solutions where the industry can utilize new concepts, such as mobile, flexible, and reconfigurable manufacturing systems. Five different demonstrators were developed that highlighted different needs within the manufacturing industry.

Since the project ended in the turn of the year 2007, the concept has continually been developed towards new applications; one is the focus on sustainable manufacturing systems where the Factory-in-a-Box concept can be an enabler [13]. Another approach has been the focus on how to enable more SMEs to use industrial robots in their production; this paper presents a new demonstrator developed for this purpose.

2.3 Product-Service Systems

Motivation
To successfully develop and implement the next generation of products and services, industry must be successful in generating new product ideas as well as having the ability to quickly realize these into successful products and competitive production systems [13]. This in the same time as the pressure to reduce the environmental impacts of a production system is increasing [14]. There is a need for a new strategy in order to stimulate a change in current production and consumption patterns [15]. One possible way to do that is with the concept of Product-Service System (PSS).

The idea behind the PSS is the assumption that customers need the product’s function, not products per se, and thus a function provider may generate profit not from selling as many material products as possible, but from providing a function of the product [16].

A PSS can be defined as [15 p. 239]: ‘a system of products, services, supporting networks and infrastructure that is designed to: competitive, satisfy customer needs and have a lower environmental impact than traditional business models’.

Sustainable PSSs are designed and marketed to provide customers with a particular result or function, without them necessarily having to own or buy physical products [14]. Through PSS the more traditional and material intensive ways of product utilization are being replaced by more dematerialized services, which are also often associated with changes in the ownership structure [15]. Within the PSS concept, customers pay as long as they have a need for the function [16].

Types of PSSs
Roy defines four main types of PSS that contribute to sustainability [14]:

Result services - (sometimes called demand services or service products) aim to reduce the material intensity of existing systems by selling a ‘result’ instead of a product, for example selling a ‘clean clothes’ service rather than a washing machine. The service provider typically takes responsibility for supplying, maintaining, taking back and recycling all physical aspects of the system. Designing result services is not necessarily just an organizational matter and introducing them often requires redesigning the products involved.

Shared utilization services - (sometimes called product use services or community products) aim to increase utilization of the material parts of a system by sharing the products required.

Product-life extension services - (sometimes called duration products) aim to substantially increase the useful life of products or materials through maintenance, repair, reuse and recycling, thus reducing the amount of energy and resources required to provide a given function.

Demand side management - (sometimes called least-cost planning or integrated resource management) refers to the principle of reducing demand rather than increasing supply, or supplying at least financial and environmental cost. The concept aims at considering the end-use service that the buyers want, and working out the least-cost method of supplying it. Least-cost could take into account environmental and other social costs, or merely reflect the financial cost to the end-user. Demand side management projects are often similar to the first category of result services.

Implications for the business
For consumers, PSSs mean a shift from buying products to buying services and system solutions that have a potential to minimize the environmental impacts. This however requires a higher level of customer involvement and education by producers. For producers and service providers, PSSs mean a higher degree of responsibility for the product’s full life cycle and the early involvement of consumers in the design of the PSS [15].

For companies, understanding PSSs is an excellent means to enhance competitiveness and to foster sustainability simultaneously [17]. PSS is a business strategy, which could be adopted in several industry sectors and has the potential to improve companies’ competitiveness and provide new business opportunities [16].

The goal of the PSS concept is to provide a system of products and services that would be able to fulfill customer needs as efficiently as possible from both an economic and environmental point of view [16].

3 METHOD
This paper is mainly based on a project conducted in close collaboration with a small Swedish company (henceforth the case company).

3.1 Phases of the case study
The project consisted of three phases: a two step feasibility study, a project of development phase and an implementation phase.

The first step of the feasibility study aimed at investigating how a future expansion could be achieved at the case company in reaction to increased production volumes. The main recommendation from this study consisted of implementing automation to ensure the company’s ability to meet future customer demands. The second step of the feasibility study therefore started in order to examine how parts of the production process at the company, in a short period of time, could be automated. The case company’s needs were thoroughly analyzed together with an investigation of possible automation solutions to come up with the best suited solution for the company.

Based on the results from the feasibility study the project’s development phase started in order to plan the construction and implementation of the demonstrator. The goal of the development phase was to develop a physical demonstrator which was feasible and simple and on which the Factory-in-a-Box concept was applied i.e. a solution that was flexible enough to handle all of the company’s products, and portable so that it could be installed at the workshop quickly.

The implementation phase consisted of developing the actual Factory-in-a-Box demonstrator based on the result from the development phase.
The objective of the overall project (defined in phase 2) was to:

- Show the potential of industrial robotics, mainly to SMEs and lines of business traditionally not subject to automation.
- Inspire and demonstrate an unconventional automation solution for SMEs that for example can be used in order to in a short time meet increasing customer demands.

### 3.2 Scientific approach

There are four fundamental research goals [18]: exploration, description, explanation and evaluation. The research goal that has formed the basis for the study this paper is based on is exploration. Exploratory research is used when better knowledge in a certain field wants to be achieved and is most often used with the aim to find something out or increase the understanding for a new or little explored field or phenomena [18]. Therefore the explorative research is in line with this study’s objective which was to further investigate the possibility for SMEs to use the Factory-in-a-Box concept in order to stay competitive.

Explorative researchers tend to use proportionately small selections of research objects that allow them to get a close-up picture and first hand information [18]. Therefore the main method used in this project was the case study which allows the investigator to obtain a good insight in a company’s operations and points of view.

In general, the case study is the preferred method when ‘how’ or ‘why’ questions are being posed, when the investigator has little control over events or when, the focus is on a contemporary phenomenon within some real-life context [19], which is relevant in this study.

Common criticism concerning case studies as a research strategy is the potential lack of statistical reliability and validity. Furthermore, it is argued whether it is possible to test hypotheses or not. To evade these situations it is of high importance to validate the result continuously throughout the study and to select a representative case. The validation was done by performing complementing studies of other similar cases and literature on the topic.

### 4 CASE DESCRIPTION

#### 4.1 Company description

The case company is situated in the town of Eskilstuna, Sweden. They produce quality products, mainly different types of marmalade. The company was launched 2006 and currently have a production of about 50,000 jars of marmalade per year. Their resellers are carefully selected shops with premium products of high quality.

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The company has two full-time employees, but during production peaks, for example before Christmas, the workforce is reinforced with at least one more employee.

One year ago, in 2007, the company was contacted by a new, major customer. Due to lack of production capacity, the company had to reject the large order. Their current production method and system could not handle the large increase in production volume (four times the current volume) the orders would result in.

This episode became the starting point for an investigation of finding solutions for how to increase the productivity of the production process. An important aspect was that the craftsmanship must be preserved, while at the same time more efficient production methods, probably by adoption of new production technologies into the production system.

#### 4.2 Current process description

A thorough analysis of the current production was conducted during the feasibility study in order to attain a good overview of the process and discover potential problem areas or bottlenecks.

The schematics in Figure 1 show the activities in the current process together with respective activity time for one batch (30 jars).

![Figure 1: Schematics of the process of making marmalade.](image)

**Marinating, cooking and sterilizing**

The marinating of the berries takes place during the night and the sterilizing of the jars and lids is performed while the marmalade is cooked.

**Filling**

From large pots the hot marmalade are poured over into the jars, with a pitcher.

**Sealing**

The marmalade jars must be sealed at once, while they are still hot. The task is highly repetitive and includes movements that are straining for the wrists. Since the jars are hot the task also must be performed with protective gloves not fully adjusted for this activity, thus the activity time increases.

**Cooling**

Because the jars are handled by hand, they must cool down before they can be labeled which causes unnecessary waiting (between two and four hours).

**Labeling**

The jars are hexagonal and have two labels placed on the opposite side off each other. The two labels are identical in size. The front label shows which marmalade it is and the company logotype and the back label contains the declaration of content etc. Due to narrow
margins in fit, it takes time to place the labels on the jars by hand. This activity appeared to be the most significant bottleneck besides the cooling.

4.3 Development of a solution
The feasibility study showed that all steps in the process needed to be automated to achieve maximum profitability with the potential future production volumes. However, it was highly unlikely that such type of automation could be accommodated in the existing premises. It was also very important that the solution maintained the craftsmanship to ensure the high quality of the product and maintain the brand of the marmalade.

To solve the case company’s initial problems and allow them to in the future accept and meet large orders within a short period of time, an industrial robot automation solution was developed to perform selected steps in the production process.

Because the robot would be used in a non-traditional environment, one objective of the development of the solution was to provide a simple and standardized robotic solution. It should also be portable, making it possible for the case company to lease the solution if a suitable provider was identified.

To preserve the craftsmanship, the study suggested that the actual making of the marmalade should be kept manual. The three steps that were identified as having most potential for automation was: sealing, cooling and labeling. With automation, the long cooling time could be eliminated as well as the high precision and time-consuming manual labeling. Further, and maybe most important for the employees, the ergonomically unsound activity of sealing the jars could be removed.

After the problem areas were identified, the development of the robot cell began. The main function of the cell was identified as: Sealing and labeling filled jars. In order to structure the further development the function of the cell was divided into seven steps which had to be solved. These steps were: (1) jars entering the cell, (2) fixturing, (3) robot gripper, (4) lid input, (5) sealing, (6) labeling, and (7) jars leaving the cell.

4.4 Automated process description
In this section the function of the developed solution (robot cell) is described based on the seven steps mentioned above.

Jars entering the cell
A standard conveyor (with a plastic belt) carries the jars to the robot. The conveyor has adjustable racks that can be adapted to different jar sizes. The length of the conveyor can also be altered depending on the end-users needs.

Fixturing of jars
Sensors indicate when a jar enters the cell so that one jar at the time is transported into a custom-made fixture. A piston makes sure the jar is held in position.

Robot gripper
The robot uses a single standard vacuum gripper during the whole process. It simplifies maintenance and lowers the costs.

Lid input
A lid magazine was developed that automatically supplies the robot with lids. The lids are stacked manually in interchangeable modules placed outside the cell for easy access. The magazine is driven by compressed air and one by one pushes the lids into a picking position in the cell.

Sealing
The robot collects a lid from the magazines picking position, puts the lid on the jar and fastens it. Using the same gripper, the jar is moved to the labeling system. During the whole process the robot uses the same grip, lifting the jar from above, which enables all following steps to be performed without putting the jar down or changing the grip.

Labeling
The cell contains a standard labeling system. Both labels are printed at the same time and kept in place by vacuum with the glue side out. The robot lifts the jar and labels one side by pressing the jar against the label, then rotates the jar 180° and labels the opposite side.

The jars leave the cell
The jars are placed in a tray in the cell. The robot stops when the tray is full and the operator may enter the cell and retrieve the tray. One could if appropriate use a conveyor system instead or, if suitable, let the robot pack the jars directly into boxes.

4.5 The results
A flow which eliminated the need for several grippers or a re-gripping station for the robot was created by first picking up a lid and then keeping the same grip during all the steps of, fastening the lid, labeling the jar and stacking. This maintains the simplicity of the cell and also keeps the cost down.

The equipment used in the cell is mostly standardized equipment and can therefore be reused for other purposes. The use of an industrial robot keeps the cell flexible since its range of possible applications is vast and new tasks easily can be added.

The user interface, on a PC-screen, was made as simple as possible to enable easy handling of the cell even for persons not familiar with industrial robot systems. For example, a touch screen was used to manage start/stop and the choice of labels.

The use of parameterized programming makes it easy to change the programming and the cell behavior, for example, to change the type of jar or the batch size.

The cell has been made as portable as possible. The robot is placed on a platform that due to its weight does not need to be secured to the floor. The small size of the cell (2774×1868×2000 mm) also enables it to fit in many environments which were a requirement if the cell were to be leased to different customers.

The length of the conveyor inbound can also be adjusted to the customer’s needs and requirements.

Wireless sensors were used to provide as few cables as possible and to allow an easy installation and reconfiguration of the cell.

The resulting solution was demonstrated in a lab at the university with real marmalade being produced during demonstration. Figure 2 shows a 3D overview of the final robot cell.
5 DISCUSSION

The case study set out to investigate whether automation in combination with the Factory-in-a-Box concept could be a suitable solution for how to increase the production volume of marmalade for the case company. During the initial phases of the project, following a process mapping, different conceptual solutions were compared in order to identify which type of automation that could be used. The conclusions of the feasibility study was that a fixed automation solution where appropriate, if the production volumes where to rise to very high. The difficulty is that the making of the product is a craftsmanship, and part of the trademark of the marmalade is that it should be manually produced. This means that the marinating and actual cooking of the marmalade should be done manual, which in turn means that production volumes cannot rise above a level where this part of the production can still be performed manually. This made an investment in fixed process automation for the rest of the production process hard to motivate.

Further, as the company was run by two persons who were really good at the process of making marmalade but had no knowledge at all in production engineering or automation technologies, it would be difficult for them to take on too advanced manufacturing technologies. Due to this, one of the main objectives when developing the robot cell was to focus on simplicity and usability, to in the next step be able to guarantee smooth and fast installation of the solution at the end user.

Finally, the seasonal demand and mainly the uncertainty in the future demand of the product, made it difficult for the small company to decide on investing in capital equipment. Since the suggested solution follows the Factory-in-a-Box concept the idea is that the case company can lease the robot cell when needed. With the Factory-in-a-Box solution the case company will temporarily benefit from the desired extra production capacity during the peaks in production volume without the extensive cost of a fixed automation solution or investing in an own industrial robot. Using the Factory-in-a-Box solution also enables the company to fast ramp up production and therefore be able to accept and meet big, unexpected customer orders that they with their current capacity cannot manage. The focus on simplicity in the suggested solution also enables fast ramp up of production volumes when new orders are being placed which was one of the case company’s main requests.

5.1 The solution’s effect in the case company

The solution that was investigated trough a feasibility study, and later developed and demonstrated in a lab, consisted of an industrial robot that sealed the jar and applied two labels. The reason for choosing those two tasks was that they had the greatest impact on cycle time (because of the elimination of the cooling period) and the elimination of two ergonomically unsound activities. For the case company the suggested solution is both economically and socially viable since it would allow them to concentrate on their core competence (making marmalade), shorten their lead time, increase the production capacity, and at the same time improve the work environment for the employees.

The flexibility of an industrial robot also increases the flexibility of the production system since more operations, for example packaging of the jars, easily can be added to the cell.

5.2 Factory-in-a-Box’s potential for SMEs

This paper set out to discuss the possibilities for SME to use automation and the Factory-in-a-Box concept to stay competitive.

We propose that the Factory-in-a-Box concept, with the possibility for the customer to lease a cell when needed, enables SMEs to use automation to increase productivity and to handle production volumes that otherwise might not be possible. If a small company themselves where to develop a solution similar to the one demonstrated in this project there could be several difficulties and obstacles. As pointed out in section 2.1, SMEs often have inferior conditions compared to larger companies when it comes to financial situations and knowledge and experience in advanced automation technologies. For example, a smaller company often does not possess enough knowledge to themselves evaluate and/or decide upon a suitable automation solution. Therefore they must solely rely on a third party to develop a solution suitable for their needs and economy. Hiring an integrator could be expensive since they often charge by the hour and if the company have difficulties creating a well formulated requirements specification, much time can be needed for the development of a solution. There is also a risk for unnecessarily complex and expensive solutions. Often is a ‘good enough’ solution more than enough for the company’s needs. Consulting a third party for developing and implementing an automated solution is also a very time consuming process that could take up to a year and that is very valuable time that many SMEs does not have when, for example in the case company’s situation, a new customer appears with large potential orders.

The Factory-in-a-Box concept is beneficial, especially for SMEs, since leasing of a cell is both faster and less costly (in the short run) than the alternative solutions. A Factory-in-a-Box strives for simplicity and flexibility in order to enable easy installation and use for the customer and fast ramp-up.

The idea of the concept is also not only to supply the box itself but also to perform support activities as implementation and maintenance of the cell. This is also of assistances for SMEs that often, due to the size of the workforce, lack the necessary competences and/or suitably skilled workers.

5.3 Factory-in-a-Box as a PSS

One of the objectives of this paper was to discuss the possibility of realizing a Product-Service System (PSS) using the results from the Factory-in-a-Box concept.
The technical solution developed in the case showed promising results and the test runs in the lab were successful. However, to turn this into a generic solution that may fit other similar companies, a business model should be applied to the technical solution. This business model should be designed so that the company in need of production capacity can get that capacity when needed, but not pay for more than actually required.

The initial idea of the Factory-in-a-Box project was to supply production capacity on demand, meaning exactly that. Looking at the area of PSS, the same core values apply in those systems. This Factory-in-a-Box provides a service (increased production capacity) instead of a product (industrial robot), which is one of the main characteristics of a PSS.

We argue that the Factory-in-a-Box concept has the potential of realizing at least three of the four previous mentioned types of PSSs. These three are: result services, shared utilization services and product-life extension services. These PSSs concepts have previously been explored in the Factory-in-a-Box research project. The project have explored and analyzed underlying reasons similar to those for developing a PSS and also through the demonstrators developed solutions helping to realize a PSS concept.

As mentioned before, the Factory-in-a-Box developed during this case provides a service instead of a product which is the idea of the result services PSS. This idea was previously also explored in demonstrator 4. From a SME point of view this types of PSS are very useful since small company’s often lack capital and knowledge to invest in equipment themselves.

Shared utilization service is the second type of PSS that could be realized with help of the Factory-in-a-Box concept. A production module that can be transported or placed at a central location in order to be utilized by several, needs to be mobile and flexible. These are two aspects that has been explored in demonstrators 2, 3, and 5.

As a third example, a product-life extension service might be realized by a mobile maintenance module. The concept of ‘Maintenance-in-a-Box’ is a visionary maintenance application that is mobile and possible to ship to any location where maintenance needs to be performed [20]. This concept match a Factory-in-a-Box module dedicated for mobile assistance of maintenance. This Factory-in-a-Box could provide solutions for mobile and flexible maintenance capacity, possibly increasing the useful life of products and/or production equipment.

As described in the quote in section 2.3, one of the implications of implementing PSS can be improving the environmental footprint of the manufacturing system. One of the ideas behind having a standardized mobile robotic working cell is to reduce the cost for the end-user, but also to create a more environmentally sustainable manufacturing system. With one company as an owner of the production equipment, leasing it to different lessees will make sure that the utilization of the equipment can be ensured, even if the end-users are SMEs with very short planning horizons.

6 CONCLUSIONS

The conclusions from this case study can be summarized in terms of industrial relevance and scientific contribution. The industrial relevance of this case study is partly in the technical solution, where the focus on making an overall simple automated solution resulted in a system that the untrained craftsman at the case company could handle. The cell also fulfills the initial requirements for the case company and provide a way to in a short time increase the production volume of marmalade. The robotic working cell was evaluated by the case company, and resulted in a ‘letter of intent’ from the company stating that they would invest, if the production volumes kept increasing and if an appropriate system builder could deliver the solution.

The scientific contribution of this case study is partly the results of the investigation of the potential for SMEs to use automation through the Factory-in-a-Box concept in order to stay competitive and partly the investigation into the Factory-in-a-Box concepts potential to realize a PSS that could help SMEs.

We argue that SMEs could strongly benefit from the use of automation mainly to increase productivity but overall to stay competitive and have the possibility to expand. But if the company themselves are to develop and implement automated solutions there are some obstacles to overcome and areas to improve in order to guarantee the most suitable solutions. For example, must the company’s knowledge and experience in automation technologies improve in order to assure the ability to correctly evaluate and/or decide upon the most suitable solution. However, with the Factory-in-a-Box concept this requirement for SMEs is no longer needed in the same extent. This since the concept is concentrated on offering complete manufacturing and automated systems including development, installation, ramp-up, maintenance, management and reuse. This way the demands on the end user decreases since the responsibility for the entire solution lies on the provider of the system. This is very beneficial for the customer and especially SMEs, therefore the Factory-in-a-Box concept can be seen as an enabler for SMEs to use automation in a greater extent. From an economical point of view the concept of leasing a production unit when needed is also a key issue for SMEs since they often does not have the economical prerequisites to themselves invest in an automated solution. One of the main economical benfifs with using a Factory-in-a-Box solution is the savings of not having to pay for overcapacity but still have the possibility to fast and during a short period benefit from increased capacity to a lower cost. Other economical benefits from the concept is the possibility to focus on activities related the business core competence when it comes to new investments and in other areas lease the equipment required only when the need occur. Using this approach investment costs, or in this case leasing cost only occur under periods with guaranteed income which increases the companies ability to take action and invest/lease.

As discussed above, the concept of Factory-in-a-Box, and the demonstrators developed, is one approach towards the concept of functional sales and product-service systems. When a system like the demonstrator described in this paper is developed together with a business case, the resulting system provides several benefits, such as the possibility to lease production capacity in the form of robot automation without having to have a deep understanding of the technological aspects of the system. However, to be able to realize those kind of systems, we need companies that can provide the business model required. Further, there are technological enablers that have to be developed in order to reduce the perceived complexity of the robotic working cells so that the end-user can feel confident in using these types of advanced manufacturing technologies.

We also believe that in order to make PSS a successful method there is a need for a change in the traditional relationship between the suppliers/producers and the consumers/customers. The suppliers/producers need to change the way they provide a product/service and the
consumers/customers demand needs to change from a product to the function of the product.

In conclusion, the concept of PSS is often credited as being economically and environmentally beneficial. We argue that the concept of PSS have great potential, especially for SMEs, since it combines the need for flexible production systems that can be used by several with the environmental and sustainable issues that needs to be in focus in the future. However, more case studies like this one are needed to identify and develop a theoretical and methodological foundation for how to realize those systems within industry.

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8 REFERENCES


