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MANUFACTURING COMPETITION THROUGH THE FACTORY IN A BOX CONCEPT

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Abstract

Today's business environment is dominated by change and global competition is diminishing defined markets. Manufacturing success and survival are becoming more difficult to sustain and it is recognized that low cost and high quality alone are not enough to sustain firm's competitive position in market place. Market uncertainty and frequent introductions of new products has created a growing need for responsive manufacturing systems. Thus, there is a growing demand for well-formulated manufacturing strategies which provide necessary support for developing and sustaining relevant order-winners and qualifiers, which enable rapid product realization as well as flexibility and reconfigurability within operations. The objective of this paper is to analyze and investigate flexible and reconfigurable production systems from a manufacturing strategy point of view. An ongoing research project in Sweden called Factory-in-a-Box will be presented which is one initiative in this area.

Keywords: Manufacturing strategy, Competitive priorities, Responsive manufacturing systems, Flexibility and reconfigurability

1. Introduction

Today's business environment is dominated by change and uncertainty. Globalization makes competition within manufacturing more difficult to sustain, and it is recognized that low cost and high quality alone are not enough to sustain firm's competitive position in market place. Meeting customer demands requires a high degree of flexibility, low-cost/low-volume manufacturing skills, and short delivery times. In today's highly competitive environment companies are forced to identify and develop unique manufacturing capabilities as well as to be innovative in producing and delivering products.

The national Swedish ambition to increase the number and sizes of Swedish manufacturing industry is counteracted by lack of production capacity available on demand and at any location. Also companies, without in-house production capacity, have few options if they need resources for pilot production. Instead, manufacturing orders are often placed in low-wage countries, e.g. China or Eastern Europe. The uncertainty in markets and rapid introduction of new products has created a growing need for flexible, reconfigurable, and responsive manufacturing systems. Meeting customer demands requires a high degree of flexibility, as well as ability to reconfigure operations to suit new demands (Jackson, 2000).

To develop next generation of products and services, there is a need to find and implement new innovative methods and concepts that will support industry in generating new ideas and quickly realize these into successful products and competitive production concepts. Thus, there is a need for a well-formulated manufacturing strategy, which provides necessary support for developing and sustaining relevant order-winners and qualifiers enabling quick product realization as well as flexibility and reconfigurability within operations.

The objective of this paper is to analyze and investigate flexible and reconfigurable production system from a manufacturing strategy point of view. An ongoing research project in Sweden called Factory-in-a-Box will be presented. The purpose of the Factory-in-a-Box concept is to develop solutions for mobile production capacity on demand and the key features are mobility, flexibility, and speed. Five fully operative demonstrators are currently being developed and implemented in close cooperation between different academic and industrial partners in Sweden. These demonstrators are realized and tested in real operative settings where its industrial benefits will be evaluated.

In this article, we aim at bridging the gap in traditional manufacturing strategy theory and highlight the strategic decisions covering the key features of Factory-in-a-Box concept: mobility, flexibility, and speed. This paper will first discuss some current manufacturing challenges and trends as well as relate these to flexibility and reconfigurability. The five different demonstrators that are being developed in the Factory-in-a-Box will be then presented.

Method

Research presented in this paper is carried out as one part of two ongoing Swedish research projects[1], DYNAMO - Dynamic Levels of Automation and Factory-in-a-Box. DYNAMO is a three year project, ending in 2006 and the aim is to provide industry with design, measurement, visualisation, and management tools for dynamic levels of automation in manufacturing. The aim of the concept and project Factory-in-a-box is, as mentioned earlier, to provide solutions for the availability and mobility of flexible production capacity. The key features of the concept are mobility, flexibility, and speed.

This paper is based on a literature review, a series of interviews, as well as case studies that have been used to collect data from the development of the demonstrators in the Factory-in-a-Box project. In general, case study method is the preferred strategy 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 (Yin, 1997), which is relevant for this work. Case studies are often criticized for lack of statistical reliability and validity. Furthermore, it is argued that it is not possible to test hypotheses. To overcome this dilemma, it is increasingly important to select a representative case and to validate the result continuously, and not simply at the end of the study. It is also important to describe the actual case carefully and only to draw conclusions that are valid exclusively for similar systems.

[1] The projects are financially supported by The Swedish Foundation for Strategic Research through its research program ProViking. A number of manufacturing companies also support the research by actively taking part and giving access to their knowledge and premises.

Theories on manufacturing strategy

Manufacturing strategy theory was to a great extent developed by Wickham Skinner, starting with his seminal article in 1969 (Skinner, 1969). Today, most people accept that manufacturing is an important part of company activities, which should support overall company objectives and strategies. Several authors (e.g. Roth and Miller, 1992; Hayes and Clark, 1995) emphasise the fact that manufacturing can be a strong competitive weapon if it is run properly. According to Hill (2000), the task can be accomplished with support from a well-formulated and implemented manufacturing strategy that comprises a series of decisions, which, over time, provide necessary support for the relevant order-winners and qualifiers of the different market segments of a company.

A strategy consists of the plan and type of action needed to achieve defined objectives. Manufacturing strategy is here defined as a pattern of time-specific and market-specific decisions in structural and infrastructural areas supporting competitive priorities for a company. Manufacturing strategy is not only about making the correct decisions that support competitive priorities. It is more general than that and it creates and selects operating capabilities for the future in a company (Hayes and Pisano, 1994). A manufacturing strategy is however long term and it should have a time perspective of two to five years.

A manufacturing strategy is a functional strategy, together with for example marketing, R&D, and accounting strategies. Together, all functional strategies should support the business strategy of a company (Hayes and Wheelwright, 1984). It is also relevant to make a distinction between manufacturing strategy content and process (Swink and Way, 1995).

Manufacturing strategy content

The content of a manufacturing strategy deals with aspects such as manufacturing capabilities and strategic choices (Dangayach and Deshmukh, 2001). The competitive priorities, often categorized as cost, quality, delivery aspects, and flexibility (e.g. Wheelwright and Hayes, 1985; Ward et al., 1996; Hill, 2000). They are achieved through a set of proper decisions within different decision areas, i.e. strategic choices.

Decision areas concern strategic choices related to performing the manufacturing task. Production technology, capacity, facility, vertical integration, quality, production planning and control, workforce, and organization are the most common decision areas in literature. Table 2 shows which decision areas a number of researchers have considered (Winroth *et al*, 2006).

Decision area	Skinner (1978)	Wheelwright and Hayes (1985)	Ward et al. (1996)	Hill (1995)	Swink and Way (1995)
Production process	X	X	X	X	X
Capacity	X	X	X	X	X
Facility	X	X	X		X
Vertical integration	X	X	X	X	
Human resources		X			X
Quality assurance and control	X	X	X	X	X
Production planning and control	X	X	X	X	X
Workforce	X		X	X	X
Organization	X	X	X	X	X
Management	X				
New products, product design and engineering	X	X			
Clerical procedures				X	
Function support				X	

Table 2. Decision areas described in literature (Winroth et al, 2006).

Table 3 shows the decision areas of the manufacturing strategy as described by Hayes and Wheelwright (1984) and Miltenburg (1995).

Decision area	Characteristics
Process technology	flexibility, type of equipment, technology level, layout
Facilities	location, size, focus
Capacity	amount, acquisition time, type
Vertical integration	amount, degree, relations
Quality management	definition, responsibility, reporting
Human resources	skill level, wage, training and promotion policies, employment security
Organisation structure and control	relationship between groups, decision
Production planning and control	responsibility, rules and systems

Table 3. Manufacturing strategy decision areas (Hayes and Wheelwright, 1984; Miltenburg, 1995)

These decision areas can be divided into two groups: structural and infrastructural decisions. The structural decision areas are characterized by their long-term impact; they are difficult to reverse or undo and they often require a substantial capital investment (Hayes and Wheelwright, 1984; Wheelwright, 1984).

A manufacturing strategy describes the competitive leverage required of – and made possible by – the production function. It analyzes the entire manufacturing function relative to its ability to provide such leverage, on which task it then focuses each element of manufacturing structure. It also allows the structure to be managed, not just the short-term, operational details of cost, quality, and delivery. And it spells out an internally consistent set of structural decisions designed to forge manufacturing into a strategic weapon. These structural decisions include:

- What to make and what to buy
- The capacity levels to be provided

- The number and sizes of plants
- The location of plants
- Choices of equipment and process technology
- The production and inventory control systems
- The quality control system
- The cost and other information systems
- Work force management policies
- Organizational structure

The infrastructural decision areas include more tactical decisions. They generally do not require large capital investments and the decisions are more short term dealing with day-to-day questions. It can, however, be quite costly to perform changes also among the infrastructural decisions, which should by no means be neglected. The crucial issue is however to make the right combination of infrastructural and structural decisions that support each other. The infrastructural issues need to support the structural changes and technology development in order to make investments profitable.

A focused strategic objective or ’manufacturing task’ is based on one or two of the seven objectives and is derived from the firm’s competitive strategy, economics, and technological opportunities. These performance objectives need to be supported by decisions on a number of categories concerning manufacturing. One problem encountered is that the decision categories described in the literature sometimes have different denominations for similar areas. The content of the decision categories in various literature is interpreted which leaves a possibility for other groupings than the following.

For example the decision area, or equally decision category, Plant and equipment (Skinner, 1969) is also called Production process (Olhager, 2000), and Equipment and process technologies (Wheelwright and Hayes, 1985). Furthermore, different groupings than those provided originally by the decisions categories are used where it has been motivated to separate the content in smaller parts, e.g. Plant and equipment contains structural decisions concerning both the production process and the facility (Skinner, 1969), which means that both Production process and Facility get a mark in the overview provided.

Manufacturing strategy and competitive priorities

Although competitive priorities are acknowledged as a valid mean to study and analyze a manufacturing strategy, still debate continues over the relationship between competitive priorities. There are two main models around which most conceptual, as well as applied, research is done.

- Trade-off Model

  Trade-off model was first proposed by Skinner (1969). He proposed that companies must make selection of those competitive priorities which are most important and thus demand more investment of resources. A company is not expected to perform well on multiple manufacturing targets simultaneously. Instead some features must be traded off. This notion is termed as a “trade-off” model. Companies need to trade-off the competitive priorities on the basis of their relative significance. According to this model, a company should focus on one priority at a time because e.g. cost, flexibility, quality, and delivery require quite different operational infrastructure.

After this initiation of the “trade-off” issue by Skinner, various researchers have strengthened this concept. It is often claimed that manufacturing plants must make choice between attaining low cost and high flexibility (Hayes and Wheelwright, 1984; Hill, 2000; Ferdows and de Meyer, 1990).

- Cumulative Model

The cumulative model states that manufacturing should follow a stepwise progression through the capabilities in order to maintain a “unity of purpose”. Researches supporting the cumulative model claim that trade-offs are neither desirable nor necessary because of two reasons. Firstly, today’s highly competitive scenario has intensified pressure on plants to bring improvement along all dimensions. The plants which ensure high quality products at acceptable cost and ensure on time delivery as per customers immediate response, are market leaders. Manufacturing operations compete on the basis of quality, delivery, cost, and flexibility, all at the same time (Collins and Schmenner, 1993; Roth and Miller, 1992). Secondly, it is claimed that advance manufacturing technologies enables plants to develop multiple capabilities simultaneously (Corbett and Wassenhove, 1993; Noble, 1995; DeMeyer et al., 1989).

The “Sand cone model” is one example of a cumulative model developed by Nakane (1986). This model was proposed to describe practices of Japanese manufacturers. Nakane proposed that manufacturing plants follow a pre-specified path for development of manufacturing capabilities. Plants build capabilities subsequently and improvements of preceding capabilities support

> improvements of succeeding capabilities. First high quality is achieved, then delivery dependability, followed by low cost, and finally flexibility. Noble (1995) statistically tested the cumulative model and presented a “pyramid” of competitive capabilities. Sequence of these capabilities to develop a cumulative pyramid is first quality, then dependability followed by delivery, cost efficiency, flexibility, and finally innovation. He proved that best performing firms generally compete on the basis of multiple capabilities.

Traditional competitive priorities, such as cost, quality, delivery reliability, and flexibility, are not enough to compete. Companies in search of greater customer value must find additional factors to compete with. Progression of priorities from cost, quality, delivery reliability, and flexibility to additional new innovative factors would suggest that scope still exists for new competitive factors. In this paper responsive (flexible and reconfigurable) manufacturing systems is proposed as an innovative mean to exploit new competitive priorities. To further analyze and investigate responsive (flexible and reconfigurable) manufacturing systems from a manufacturing strategy point of view, an ongoing research project in Sweden called Factory-in-a-Box will be presented.

The Research Project: Factory-In-A-Box

The visionary definition of Factory-in-a-Box concept is “mobile production capacity on demand”. The aim of the concept and Factory-in-a-Box project is to provide solutions for availability and mobility of flexible production capacity for Swedish industry. This is one example of an initiative towards exploring and realizing responsive manufacturing.

Companies that succeed in transforming their product delivery process to a more flexible, mobile and rapid process will create a major competitive advantage compared to its competitors. One way of doing such a transformation is to implement the Factory-in-a-Box concept for one or more functions in their product delivery process, i.e. a flexible unit that is mobile and can be moved around the factory, construction site etc.

The key features to realize such a responsive manufacturing system are flexibility, mobility, and speed. The concept consists of standardized modules that can be installed in containers and easily transported by e.g. trucks, rail vehicles, boats etc. The modules shall be easily combined into complete production systems and reconfigured for new products and/or scaled to handle new volumes. The goal of this project is to build five fully operative demonstrators – Factory-in-a-Box production cells– that are developed in close cooperation between different academia's and industrial partners. The goal with the demonstrators is to exemplify and realize the Factory-in-a-Box concept, they will be practical examples of the usability of the concept in industry. All demonstrators are practical solution for a particular function(s) and provide a real business case for the concept. The five different demonstrators are described in the paper.

Factory-in-a-Box 1 – Automatic assembly with focus on flexibility

A first example of a Factory-in-a-Box module has been developed and demonstrated within ABB Robotics production system – an automatic production module to assemble robot components. The overall goal of this pilot demonstrator was to develop an automatic production module, which assembles robot controller cabinets, meeting the overall Factory-in-a-Box requirements of flexibility, speed, and mobility. The demonstrator has been developed in parallel with an ongoing product development project of a new robot controller at ABB Robotics: “IRC5”.

- Factory-in-a-Box requirements – flexibility: In order to assemble different variants of cabinets with short set-up time, it is necessary to have flexible equipment and fixtures. There will be a need for reconfiguring the module and its components while still having a robust and efficient manufacturing.
- Factory-in-a-Box requirements – speed: Short set-up time is vital for the success of this module. The Factory-in-a-Box module will enable a structured production requirement process and a support for design of future cabinet variants. A “standard” Factory-in-a-Box module will also enable virtual system configuration and module modelling and simulation.
- Factory-in-a-Box requirements – mobility: The Factory-in-a-Box module will have to be designed as a “Mobile Platform” to be moved anywhere within ABB Robotics production system. Possibly also moved to a supplier or another production site in Bryne, Norway.

The vision of this demonstrator has been a production system that can be assembled and configured according to your needs and that can be delivered to any location. Factory-in-a-Box module #1 has explored this vision and tried to make this a reality. The focus of this demonstrator has been to investigate the following requirements that were specified in the original project plan;

- Modules that are easy to transport to the production site as well as to move them at the site, e.g. external and internal mobility. In order to attain internal mobility i.e. air cushions can be used for fast and smooth transports of modules or for the entire Factory-in-a-Box.
- Reconfigurability in order to meet changing demands and automatic/semi-automatic configuration of modules and system are prerequisites for scalability for changing production volumes and for fast ramp up of production.
- Reusability of system components and modules together with simple and fast simulation and programming makes conditions for faster and cheaper system solutions and system robustness towards disturbances, especially during ramp-up of production. The reusability also makes it possible to achieve a profitable reduction of production capacity. This is as important as the ability to increase the capacity. The reusability makes it possible to reuse the equipment in other applications in the same or in other companies. Many companies hesitate to invest in new production capacity/equipment because of the financial risk involved in the case of future declining production volumes.
- Standardized hard- and software interfaces and integrated highly flexible production equipment, integrated metrology, and sensor-based calibration, combined with sensor-integrated robot/equipment control are prerequisites for flexibility/agility.

The Factory-in-a-Box module at ABB Robotics consists of two robots, a gluing station, a folding station, and robot handled tools. Material and components, supplied to the module from stock, are oriented and automatically assembled by flexible automatic equipment. The cell is designed for mobility using mobile base plates that either are heavy enough to be placed directly on the floor or, as in the case of the robot, a base plate which can be secured to the floor by vacuum or air cushions for fast and smooth transports. The cell is flexible, using flexible equipment, and designed for reconfigurability. Four different types of controllers are today assembled in the cell. Through technical solutions, supporting mobility and flexibility, the requirements of speed are achieved by e.g. quickly reconfiguring the cell at another location and /or introducing a new product.

Factory-in-a-Box module at ABB Robotics has been commercially developed and put into operation in December of 2006.

Factory-in-a-Box 2 – Welding with focus on mobility

Factory-in-a-box 2 is developed in collaboration with Pharmadule Emtunga. Pharmadule Emtunga (PHEM) is a supplier of modular facilities to the off-shore, telecom, and pharmaceutical industries. At present the company is striving to implement the same concept in their manufacturing system as they have in their products, i.e. modularization.

Factory-in-a-box 2 is a semi-automated manufacturing cell, which is used for cutting, beveling, and welding of carbon steel pipes. All machinery will be fitted into a standard container, which also will contain, fume hood exhaust, lighting, computer terminal etc.

Factory-in-a-Box 2 has approached the key concepts flexibility, mobility, and speed as follows:

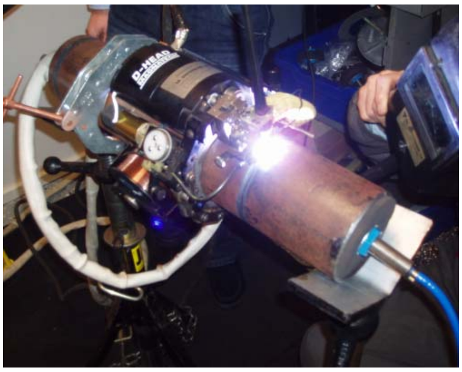
- *Flexibility* - In order to weld different variants of pipes as well as conducting different joint preparations with short set-up time, it is necessary to have flexible equipment and fixtures. There will be a need for reconfiguring the module and resources, e.g. configuring the robot online still having a robust and efficient manufacturing. The optimal level of automation will be investigated in the project. Different machining operations in the module are drilling, joint preparation, and cutting. Pipes will have different dimensions in terms of diameter and thickness.
- *Mobility* - The Factory-in-a-Box module will have to be designed on a “Mobile Platform” to be moved anywhere within the production system, to a supplier, or to site. The equipment should easily be mounted and reconfigured on standardized rigid base plates with flexible fixation points. The Factory-in-a-Box module should be moveable by a truck – specifying the need for a standardized container.
- *Speed* - There is a need to quickly reconfigure the module without long set-up time. Operations should be started as soon as possible after movement within the manufacturing system or transport to site. The Factory-in-a-Box module will reduce the welding time compared with today’s manual process. With

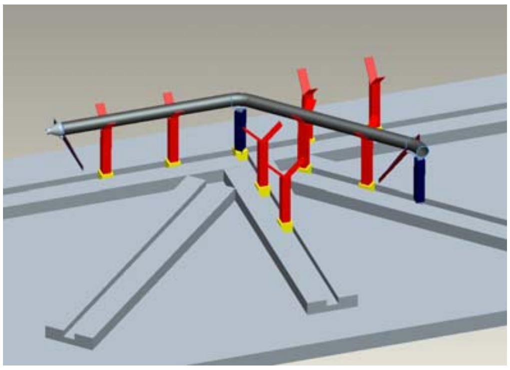
increased automation, quality will be improved and the disturbance time will decrease.

Factory-in-a-Box 2 can perform the following operations;

- Cutting and seam preparation of pipes
- Manual welding when fitting the pipes together
- Orbital welding
- The Factory-in-a-Box 2 will also contain suction of the welding fumes, shelves for storage and a small office space

The greatest news value of Factory-in-a-Box 2 is the usage of known technologies in all new applications and context. Orbital welding of carbon steel pipes with straight-angle chamfers has never been done before within the company.





PHEM has had a business concept in mind when developing the Factory-in-a-Box 2. This kind of mobile orbital welding equipment could make a great asset for a lot of different construction and installation sites where carbon steel pipes are being welded. The FinaBox can be leased out to PHEM by a supplier or be owned by PHEM themselves; the final commercial solution will be decided at a later time when the concept has been fully developed. The FinaBox 2 will be implemented within PHEM operations during 2007.

Factory-in-a-Box 3 – Foundry with focus on mobility

To ensure applicability of the FinaBox project, a third example of a FinaBox module will be demonstrated within Swedish foundry industry in cooperation with the Swedish Foundry Association. To maintain its competitiveness a foundry must meet increasing demands for efficient production and a good working environment.

Varnäsföretagen AB is a Swedish foundry that produces sand-casted aluminium goods. The company has modern and highly operational facilities for both casting and subsequent machining. However, the process step between the two, deburring and grinding has been neglected, as it is in so many other foundries. This middle step between the casting and machining is important, but often performed manually using handheld tools. This type of work has a tradition of being ergonomically not suitable and generally inefficient. This is the motivation for Varnäsföretagen to take part in the Factory-in-a-Box project. The aim of the third demonstrator is to create an automatic solution for deburring of casted products.

Factory-in-a-Box 3 has approached the key concepts flexibility, mobility, and speed as follows:

- Flexibility - In order to handle different components with short set-up time, it is necessary to have flexible equipment and fixtures. There will be a need for reconfiguring the module and resources, e.g. configuring the robot online still having a robust and efficient manufacturing.
- Mobility - The Factory-in-a-Box module will have to be designed on a “Mobile Platform” to be moved anywhere within the production system, or to another foundry company. The equipment should easily be mounted and

reconfigured on standardized rigid base plates with flexible fixation points. The Factory-in-a-Box module should be moveable by a truck.

- Speed - There is a need to quickly reconfigure the module without long set-up time. The Factory-in-a-Box module will reduce the handling and material removal time compared with today's manual process. With the right level of automation, quality will be improved and the disturbance time will decrease.

During 2006 a pre-study at the company has been performed which included a mapping of the production process at the company and a study of the products that are being produced. After that the results of the study were analyzed it was concluded that not all the operations could be performed within an automatic solution. The ideal solution would be to use several small and cheap standardized automation cells that could perform a couple of operations each. This project will focus on developing one cell that can perform a set of operations that can be used for some of the deburring work. This first cell could for example be used to saw off larger pieces from the casting followed by some milling and grinding. These operations are today a burden for the persons doing the manual work.

This project has been ongoing as pre-studies during 2006 and will enter development and implementation phases during 2007. The resulting demonstrator will be presented at the Technical fair in Stockholm in October 2007.

Factory-in-a-Box 4 – Functional sales with focus on flexibility

Factory-in-a-Box 4 has been developed in association with FlexLink Systems. FlexLink's focus is automation of production flow within the following processes:

Assembly - Filling - Machining - Packaging. FlexLink will, in this project, use their Dynamic Assembly System (DAS) concept in order to demonstrate the principles in the Factory-in-Box-project - flexibility, mobility, and speed - in a real customer case.

Factory-in-a-Box 4 has approached the key concepts flexibility, mobility, and speed as follows:

- *Flexibility* - Different variants of products with short set-up time require flexible equipment and fixtures. There will be a need for reconfiguring the module and resources online to a customer specific product while still having a robust and efficient manufacturing. The optimal level of automation will be investigated in the project.
- *Mobility* - The Factory-in-a-Box module will have to be designed as a “Mobile Platform” to be moved anywhere and reused for a new customer in a case of leasing.
- *Speed* - Short set-up time is vital for the success. The “programming” should be fast, which will demand reuse of experience.

During 2005 and 2006, a pre-study at the company has been performed which has included an investigation of “functional sales” and a mapping of interested companies for this commercial solution. A number of companies have been contacted (over 40 different companies) and possible candidates for a FlexLink and Finabox commercial application where identified.

After identifying one company that was interested, the project has participated in a quoting phase. No order has been placed so far. The demonstrator 4 project has investigated the concept of functional sales of manufacturing capacity. The project has shown that industry is very interested in this concept. No “real” example has been generated so far which was the initial objective.

Factory-in-a-Box 5 – Manual assembly with focus on mobility

This part of the project is directed at Bombardier Transportation. Many of Bombardier’s customers have strong desires about placing some part of an import order within the borders of the customer’s home country. By sending a Factory-in-a-Box, Bombardier fulfils this production relocation desire and yet they maintain control over the production. This can lead to winning orders on markets otherwise closed, which will create job opportunities not only for foreign countries, but also for Bombardier in Sweden since the main part of the order is produced here.

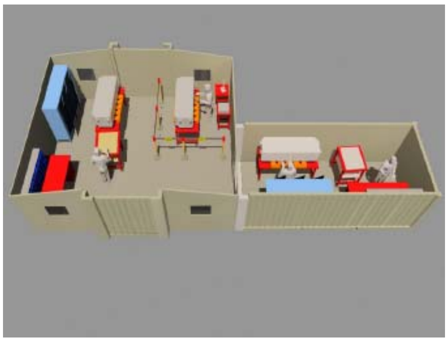
Bombardier Transportation in Västerås is facing a market where the customers are becoming more and more powerful due to the tough global competition. Many customers have strong wishes that part of the production should be carried out locally in order to create new jobs. Instead of building factories which will be abandoned as soon as the order is processed, Bombardier and the Factory-in-a-Box project aim to develop mobile production facilities which can be re-located as soon as the production of an order is finished.

Factory-in-a-Box 5 has approached the key concepts flexibility, mobility, and speed as follows:

- *Flexibility* - Different variants of products with short set-up time require flexible equipment and fixtures. There will be a need of reconfiguring the module and resources to a customer specific product while still having a robust and efficient manufacturing.

- *Mobility* - The Factory-in-a-Box module will have to be designed as a "Mobile Platform" to be moved anywhere and reused for a new customer and a new project.
- *Speed* - Short set-up time is vital for the success as well as readiness for transportation

An analysis has shown that a Factory-in-a-Box, mobile production capacity, can be used to reallocate working opportunities in a cost-effective way when the customers demand this as a part of the business deal. The concept contains four parts: a technical solution, a logistics solution, a training solution for the local labour, and a methodology for how to move, install, and put the Factory-in-a-Box into production.



A fully developed Factory-in-a-Box enables a substantial reduction of the resources needed for sharing experience and knowledge compared with a conventional outsourcing strategy. The pre-study has resulted in two technical solutions for moving and housing production capacity abroad: a special container and a modular building solution. The choice of final solution will be decided upon including a prognosis on usage frequency, production capacity needed, and the strategically value this solution gives Bombardier.

In order to exemplify a valid solution with a cost-analysis, the project has focused on a technical solution for the assembly of High-Voltage boxes demanding a capacity of 1-2 boxes a week. Even using this delimitation, the pre-study indicates that the Factory-in-a-Box easily can be modified to handle a much higher production volume. It also indicates that the same kind of solution can be useful for other Bombardier products. The pre-study has also resulted in a checklist that the person responsible for the installation of the Factory-in-a-Box can use in order to shorten the start-up time at the customer.

Besides being used as an enabler to win orders, the pre-study has shown that the Factory-in-a-Box concept provides a substantial potential for cost-cut in the ongoing production at Bombardier. Thus, the pre-study recommends that the development of a prototype should be started at the company.

Conclusion and discussion

It is concluded within manufacturing strategy literature that competing on the basis of one or two capabilities as suggested by a trade-off model is no longer acceptable. Better performing companies are competing on the basis of multiple capabilities. Progression of priorities from cost, quality, delivery reliability, and flexibility to additional new innovative factors would suggest that scope still exists for new competitive factors. In Factory-in-a-Box project we have indicated that it is possible to develop conceptual as well as operational manufacturing cells that meet the requirements mobility, flexibility, and fast set-up and ramp-up of production. Thus, in this article we have aimed at bridging the gap in traditional manufacturing strategy theory and highlight the strategic decisions covering the key features of Factory-in-a-Box concept: mobility, flexibility, and speed. Implementing responsive manufacturing systems is proposed as an innovative solution and a mean to exploit new competitive factors giving future competition within manufacturing industry.

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