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## Teaching Manufacturing Operations and Strategies in Higher Education

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## TEACHING MANUFACTURING OPERATIONS AND STRATEGIES IN HIGHER EDUCATION

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### ABSTRACT

Students at higher technical educations e.g., bachelors and masters, are traditionally taught in software programming and factory automation. Students at higher economical and management schools are exposed to different strategies and their economical impacts. However, in many education programs, the larger perspective, of how to combine the technical and the economical aspects is not highlighted.

Technology Management is a unique program at Lund University Sweden, where a selected number of students from the school of economics and management and from the engineering faculty are taught together during their last year of study. Their views on problems and challenges in today's industry often complement each other. The course "Technology, Strategies and Structures" includes e.g. projects done in collaboration with industries.

This paper includes a discussion about how knowledge about Manufacturing Operations and Strategies, can be incorporated in higher technical and economical studies, and it describes some industry projects done by students.

**Keywords:** Manufacturing operations, manufacturing strategies, higher education

### INTRODUCTION

The ultimate goals for Lund University in Sweden, as of most universities in Sweden and around the world, are to perform research, to assure education and to interact with the society outside university [1]. Lund University was founded in 1666. Today it consists of 9 faculties with a total of approximately 39 000 students. The Institute of Technology (LTH) and the School of Economics and Management (EC) are two of its largest faculties with about 5000 students each [2]. The education at these faculties, as within the rest of the university, should be of best quality and prepare the students for their careers after graduation so that they will be able to work in high responsibility jobs in society, both nationally and internationally. After graduation, approximately 5% of the students chose to stay at the university performing research whereas the remaining part of the students looks for an employer elsewhere. In

many cases this implies finding a job in industry, this is especially true for the students with a diploma from the Institute of Technology but also many of the students with a diploma from the School of Economics and Management ends up with a job in industry. One important educational goal is therefore to provide the students with useful knowledge and material that they can apply in industry.

Manufacturing companies of today often compete on a tough market. Strategies such as Just-in-Time, Available-to-promise and Custom-made-products have become important in order to be successful on the market and to attract and win customers. The importance of software systems for manufacturing companies has also drastically increased over the past decades. Closest to management, strategic decisions should be taken and various Business Systems are available, closest to the manufacturing plant there are various process control systems in place helping with operative decisions in real time, see figure 1.

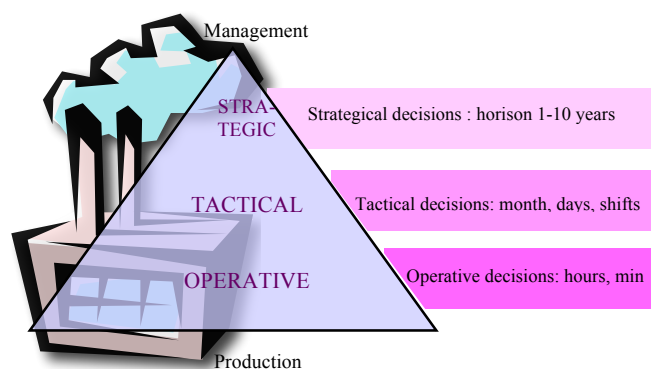


Figure 1: Various decisions within an enterprise and their time horizons.

In the middle layer, manufacturing operation systems are at hand. The aim of the middle layer is to assure that the strategic level and the operative level are connected, i.e., that strategic decisions can be communicated to the plant floor and that real time data from production can be collected, aggregated, evaluated and communicated to the management.

Students at higher technical educations e.g., bachelors and masters, often have a good understanding of process control systems as they are traditionally taught in software programming and factory automation. Students at higher economical and management schools are exposed to different manufacturing strategies and their economical impacts, but they seldom have deep knowledge about software systems. However, in many education programs, the larger perspective, of how to combine the technical and the economical aspects is not highlighted. Without a clear structure of how to tackle the puzzle of combining different software systems, the risk of getting a complex and fragmented structure is high. This can have a negative impact on both production strategies and production operations.

Technology Management is a unique program at Lund University, where a selected number of students from the School of Economics and Management and from the Institute of Technology are taught together during their last year of study. Their views on problems and challenges in today's industry often complement each other. The course "Technology, Strategies and Structures" includes, among other things, projects done in collaboration with industries.

## **TECHNOLOGY MANAGEMENT**

Academia traditionally offers, on the one hand, people with a deep knowledge of management and economics but lacking an understanding of the underlying technologies and, on the other hand, engineers with a thorough understanding of technology but with only little knowledge about business. A new academic Master's program – Technology Management – was initiated at Lund University in 1997 and involves 40 students each year. This program integrates Technology and Management in three dimensions; program curricula, students and teachers. The program has been developed in cooperation between The School of Economics and Management (EC) and Lund Institute of Technology (LTH), both part of Lund University. The aim is to provide the business students with an understanding of engineering and the engineer's way of thinking, and the engineering students with an understanding of management and economics [3].

The program can be divided in three phases:

- Phase I covers the first 2.5 years of the engineering students' program, or the first 2 years of the business administration students' program.
- Phase II prepares the engineering students with rudimentary knowledge of business administration, management and economics, and the business administration students with a basic knowledge of technology and engineering. This is done by letting the business students attend a selected number of courses in technology, and engineering students in courses in management and economics. The duration of Phase II is one year.
- Phase III is the fully integrated conclusion of the program with one year of courses plus a 6 month master's dissertation. During Phase III, the students are working side by side engineering students and business students, giving ample room for understanding each other's way of thinking and working. The students find means of utilizing each other's differences in skills and interests and turn them into advantages instead of being obstacles for co-operation. The courses in Phase III are designed to include both engineering and management aspects. For example, the course Market Driven Innovation and Product Development is studied from a technical as well as a management and economical point of view. The participating teachers in a course come from different faculties, and cooperate in the joint teaching of the course. The master's dissertation is performed during a 6 month period by a group of two to four students with at least one student from each faculty. After concluding the program, the students are awarded a Master's degree in Engineering or Business Administration depending on their academic point of origin.

## **TECHNOLOGY, STRATEGIES AND STRUCTURES**

The course "Technology, Strategies and Structures" is one of the courses the students take during Phase III. The course starts with a set of lectures on manufacturing strategy and manufacturing control. These topics are complemented with theories on general strategic management and information about the economic historical industrial development, this in order to put the manufacturing strategy and control in a holistic context. An important part of the course is the projects that are carried out in close collaboration with industries. A parallel course prepares the students with project management skills to be used in their interaction with industry.

### ***Manufacturing Strategies***

To compete in the marketplace there are several criteria that a company needs to fulfill to be considered a candidate by the customer. These criteria can be further divided into qualifiers and order-winners. [4]. A qualifying criterion is the basic performance you need to be considered by the customer at all. The order-winner is what finally will outperform the competition. There are numerous manufacturing related criteria affecting the strategic role of manufacturing. One way of clustering these criteria are time, cost, quality, and flexibility, [4,5]. These four criteria all influence the company's competitive advantage in the market place.

Time comes in several flavors with regards to winning or qualifying in the market place. For instance delivery speed, which demands a manufacturing process that can respond quickly to customer needs. Another time related issue is a company's ability to quickly respond to increases in demand. Delivery reliability is a third example. Delivery reliability is about supplying the products on the agreed due date, not before and certainly not after. In many businesses this criterion today constitutes a definitive qualifier.

Quality, an illusive, but important competitive factor is commonly defined in the eyes of the beholder. Quality comes in two distinct representations; Quality built in to the production system, thus render it possible to produce and deliver products with little or no variation between different products. The other interpretation of Quality, which is the everyday interpretation, is about the intrinsic characteristics of the product; How "good" the product is.

Flexibility is possibly even more elusive than quality. Several typologies have been developed in order to define flexibility e.g., [6]. A general finding when it comes to the perception of flexibility is individual and managers are more comfortable in relating flexibility to the resource level than to the system level [7]. Flexibility is often a means to other ends [5]. In essence flexible manufacturing can be used to compete via shorter delivery times, more cost-efficient batch production or higher perceived quality of the product.

### ***Manufacturing Operations***

The increasing level of automation in manufacturing has created a demand for better integration between the various software systems within a company. In the beginning of the 21<sup>st</sup> century a standard, known as ISA 95, was developed and published, focusing on Enterprise-Control System Integration and on Manufacturing Operations [8]. It defines terminology and concepts that make design and operation of manufacturing plants easier and facilitates enterprise-control systems integration. The standard is also known under the name IEC 62264.

In this course, the standard is discussed, analyzed and used in the projects. Further on, the strategic criteria time, cost, flexibility, and quality, are discussed in greater detail and examples on various production-related key performance indicators (KPI) are presented.

Time could be measured by e.g., total-cycle-time or overall-equipment-efficiency. Cost is often measured in terms of material-used-per-product, energy-consumption or operator-time. Flexibility is sometimes hard to measure but examples of related KPIs are tool-change-over-time or product-change-over time. KPIs related to Quality could be scrap or products-out-of-spec.

### THREE CASE STUDIES

This section describes three case studies done by three different groups of students within the course “Technology, Strategy, and Structure”. Each case study is performed during a period of four weeks and in close collaboration with a company selected by the group.

#### “Facing the future wave at Alfa Laval”

“Facing the future wave at Alfa Laval” is a project carried out by five students at Alfa Laval in Lund, Sweden [9]. Alfa-Laval is a global provider of products and engineered solutions in almost a hundred countries worldwide. The company is a global market leader within its three key technologies – centrifugal separation, heat transfer and fluid handling.

Alfa Laval makes a good case for studying how a global company’s software systems have developed in different directions. It also provides an example of how information exchange is being handled within a global manufacturing company. Today Alfa Laval has several different software providers, not only for the execution of different tasks but also different software performing the same task but in different facilities. The information exchange between the ERP system and the manufacturing system, is another interesting aspect of Alfa Laval’s information handling. All of this has led to a complex network of information exchange, which is now being dealt with by management at Alfa Laval.

One big obstacle was the order handling system. The orders, approximately 3000 per week, were generated by the sales companies, sent to a production center and further to a distribution center. Due to historical reasons, each sales company had their own administration and their own routines, and thereby also their own way of managing and structuring the orders. Since the orders could be very different, the production centers and distribution centers had to manage each order in close contact with the Sales Companies in order to avoid misunderstandings.

In year 2000, a new business process for order handling was therefore implemented, with the aim of using the same routines independently of which sales company the order comes from. The company’s opinion is that the implementation led to extensive time savings through out the whole business process.

A question then arises: *Is there still unused potential to gain from the implementation, and could ISA 95 enhance the potential?*

Let’s have a look at how an order is realized. When a sales company receives an order of a product from a customer, the order is entered in the system. The order has a unique structure and can directly be processed by Alfa Laval’s ERP system (Movex). The ERP system performs a check to see if the item is available in stock or if it needs to be produced.

- If it is available in stock, the order is sent directly to the corresponding distribution center and from there, shipped to the customer.
- If it is available in stock, but the customer prefers a longer time of delivery together with a reduction in price, the order is sent to a production center. The PC produces the order and sends it directly to the customer.
- If it is not available in stock, the order is sent to a production center. The PC produces the order and sends it directly to the customer.

At the production center, two software systems are used to manage the MES activities. When an order reaches the production center it is received by System-A (Jeeves). System-A defines the products in terms of what has to be done in each cell, how the cells should be coordinated, and what equipment to

be utilized. System-A suggests a weekly schedule, based on the information received from the ERP-system.

System-B is linked to the PLC system in the cell, and it contains the detailed information of how to produce the products. However there is no direct linkage between System-A and System-B, this information exchange is based on manual inputs. This means that individual changes to a product have to be entered manually by the operator. After completion, the operator also has to enter production-time and status etc into System-A, so that the system can track the order and coordinate with other activities. The conclusions the students could draw were:

- With the new business process for order handling in place, greater customer satisfaction is achieved as the customer can choose between immediate delivery, or wait for the item to be produced at a lower price for the customer, due to less overhead and no inventory cost. This new way of offering customer differentiated prices enables Alfa Laval to shift the criterion flexibility from a qualifier to an order winner.
- The new business process has also enabled quicker response times in the system. The shift from a one-day to a five minutes response time must be considered as an increase in order reliability and hence a new order winning criterion.
- Every order that reaches the Production Center now contains standardized information leading to fewer misunderstandings and faster handling times. The student's estimated that the time savings could be as much as 160 000 labor hours, or equivalent to 86 full time employees.

Although the business process is almost fully automated there is still one stage that is executed manually, the link between System A and System-B. Eliminating this manual step could reduce the production time, generating yet another order winner. The students therefore found substantial advantages of the use of ISA 95 part 4, in which integration between MES activities will be discussed.

### **“Cleaning Blood with Lean Production – World Class Manufacturing at Gambro”**

“Cleaning Blood with Lean Production- World Class Manufacturing at Gambro” is a project carried out by five students at Gambro in Lund, Sweden, [10].

In today's competitive global market, for the survival of any industry, manufacturing companies need to be flexible, adaptive, responsive to changes, proactive and able to produce a variety of products in a short time at a lower cost. Companies that previously prospered due to their superior technology are now forced to reduce their costs as the competition increases. In renal products, e.g., kidney dialysis, quality has always been the number one priority and cannot be compromised; quality must be the dominant part in the manufacturing strategy. Gambro is the global leader in renal products and blood component technology because of its superior knowledge and quality. Over the last ten years Gambro has been faced with a tougher market and diminishing profits. It was obvious that something needed to change in order to sustain its competitive advantage.

*A question then arises: How can a company manage to reduce cost and at the same time deliver equal or even better quality? How should the manufacturing strategy be changed and how is this supported by the manufacturing and control systems?*

Gambro had identified production as a field where they could further increase the effectiveness and thereby lower the costs. Gambro therefore decided to implement a program called World Class Manufacturing (WCM) aimed at both lowering the costs and enhancing the quality of production.

WCM is based on Lean Manufacturing thinking and Just in Time Production. This implies minimizing the waste in production and generating “only the necessary products, at the necessary time, at the necessary quantity”, the workers in the plant should also have an extended responsibility and involvement.

To see the effects of the WCM program Gambro uses a model called the Savings Book. The model is used for estimating the efficiency of changes and translating them into financial terms. A number of Operation Performance Indicators (OPI) and Key Performance Indicators (KPI) generate the foundation of the Savings Book. An OPI is assigned to an activity and is used to evaluate whether the specific activity is on track or not. These figures are only used at the plant level and not reported upwards. The purpose of the KPI is to break down an overall objective into measurable variables. The KPIs, such as productivity, cost of non-quality, and number of complaints is however used to track the overall performance of the plant, but these measure only the general input and output of the production. Some of these measures are included in the company’s Balanced Score Cards, which is only available at the top management at Gambro (excluding staff, plant- and production managers).

The conclusions the students could draw were:

- As an effect of the WCM strategy; Gambro had changed their module-based production to a line-production. Line-production creates a pull-oriented system in which the waste of overproduction is better controlled. As the pull strategy becomes faster in responding to changes in both order volume and failure of production, waste can be minimized.
- Gambro’s team-based production offers a possibility to spread knowledge and reduce the dependency of specialized employees. This flexibility is further improved by the rotation of teams to different working stations, developing their knowledge in several areas. Gambro is aware of the fact that specialized labor at every working station may produce more units at a faster rate. But in the long run, and that is what Lean is all about, Gambro will benefit from their flexible structure.
- Although MES systems are usually understood as computerized infrastructure systems, they do not have to be computerized. The case study shows that the division managers and controllers act like a people-managed MES system, summarizing facts like resource availability, production scheduling, and production performance. Gambro deliberately chooses to make the information flow manual, thereby forcing the employees to process the data on their own. Gambro believes that a computerized system would tend to aggregate the information and thereby not gain workers understanding or involvement. However, the case study suggests that a computerized MES system would save the controller or local manager the time –consuming work to get the information from the handwritten papers to a spreadsheet. Furthermore, information about the production would be accessible in real-time. A well-developed MES enables a new level of production mapping, where managers are able to pin-point critical information about every activity in real-time, and the possibility to develop the production line is increased.
- The case study shows that the initial stages of WCM have been successful but further improvements in infrastructure are still needed. By implementing a MES system, Gambro can analyze information otherwise lost due to human interpretation. A Balanced Scorecard can further support the manufacturing strategy of the WCM program. Quality will be assured by measuring Key Performance Indicators in the learning and growth perspective. Combining the MES and the Balanced Scorecard generates an accurate system for motivation and



compensation for employees. This provides a streamlined strategy which, in the long run, leads to a competitive advantage through cost, quality and flexibility.

**“Exploring the Milky Way – can increased traceability improve the delivery reliability at Skånemejerier?”**

“Exploring the Milky Way – can increased traceability improve the delivery reliability at Skånemejerier” is a project carried out by five students at Skånemejerier in Malmö, Sweden, [11]. Regulations and laws that emphasize a higher traceability in the supply chain have lately affected the food and beverage industry, not least the dairy industry. The Swedish dairy market and Swedish dairy farmers are becoming actors in a global dairy market. In recent years new competitors have entered the market and affected the trade of dairy products. As the competition in the dairy market increases the customers are being flooded with new dairy products, packages and flavors. To be competitive in the market Skånemejerier, a Swedish dairy producer, would like to increase their delivery reliability and customer satisfaction.

A question then arises: *Is it possible to increase the delivery reliability to the customer at Skånemejerier by using increased traceability in the warehouse?*

The dairy warehouse of Skånemejerier in Malmö receives products from three providers. The main input channel is the in-house production, the second input is goods received from another production site of Skånemejerier, and the third input channel is goods received from external producers. The product is stored in the warehouse.

Typical customers of Skånemejerier in Malmö are grocery stores in the region. They order large quantities of dairy products. To simplify the managing of the products in the warehouse, the goods are loaded in different types of secondary packages. These packages are trays (contains 16 cartons) and steel carrier (contains 10 trays).

The incoming orders to the Malmö site are registered in the ERP system. The ERP system checks the status and the balance of the ordered goods in the warehouse. If available, it generates a manual and an automatic picking list. The automatic picking list is sent to a production system and the manual pick list is sent directly to the warehouse staff. When loaded on a truck, the products are shipped to the customers.

Approximately every 5<sup>th</sup> worker at Skånemejerier is an inspector, controlling that the amount loaded on the trucks corresponds to the ordered amount. Skånemejerier regards the issue of loading steel carriers on wrong trucks as a major problem.

There are currently a number of issues that affects the delivery reliability:

- If the balance of the good is incorrect, it is up to the driver of the truck to decide which customer will get a reduced amount of goods. The driver has to manually report back to the ERP system which customer got a faulty delivery.
- Another issue with the system at present is that the outgoing deliveries are not registered to the specific steel carriers. Nor are the loaded steel carriers associated with the specific customer. This reduces the ability to automatically check at the customer's site that the delivery is correct,

i.e. a reduction in delivery reliability. There is also a risk of losing the steel carriers since they are not associated with a specific customer.

Automatic Identification and Data Capture (AIDC) is the term used to describe data collection by means other than manual notation or keyboard input. It currently involves 18 different technologies such as EAN, bar code data capture, RFID and voice recognition. Information technology plays an important role in many producing companies. The demand for increased control, overview and planning of products makes it necessary for companies to use AIDC. To be able to track and trace goods it is necessary to mark packages and carriers.

The conclusions the students could draw were:

- By tracking every single carton in the warehouse it would be possible to increase delivery reliability to the customer. However, the same delivery reliability could be achieved by tracking only the types of products.
- A comparison of three different Automatic Identification and Data Capture (AIDC) systems were done. The EAN and RFID are principally implemented in the warehouse in similar manner, both solutions would increase the delivery reliability and possibly also reduce the time required to control steel carriers when loading the trucks, hence reduce the costs associated to staff. Further the solution would reduce costs of steel carrier losses to customers. The RFID technique would not increase the delivery reliability to the same extent as the EAN and Voice picking techniques, however these techniques would probably reduce the time for loading the trucks.
- The implementation of a registration system can be seen as part of a process to fully integrate and automate the distribution chain in order to reduce the human factor and deliver more efficiently. When this system is increased with supplementary measures, like individual product identification and sophisticated follow-up systems, the full potential can be used. The outcome will be better information.

## CONCLUSIONS

The importance of software systems for the planning and execution of production has drastically increased over the past decades. This has led to a growth in number of software systems used within sites. The companies' problem today is no longer only to find relevant software systems but rather to coordinate and synchronize existing systems.

Students at higher levels of technical education e.g., bachelors and masters, are traditionally taught in software programming and factory automation. Students at higher economical and management schools are exposed to different manufacturing strategies and their economical impacts. However, in many education programs, the larger perspective, of how to combine the technical and the economical aspects is not highlighted.

A new academic Master's program – Technology Management – was initiated at Lund University in 1997 and involves 40 students each year. This program integrates Technology and Management with the aim of providing the business students with an understanding of engineering and the engineer's way of thinking, and the engineering students with an understanding of management and economics. One of the courses in this program is "Technology, Strategy and Structure" in which the students are taught about manufacturing strategies and manufacturing operations. An important part of the course is the

projects that are carried out in close collaboration with industries. In the projects the ISA 95 standard is used as a tool for structuring complex information exchange within production sites and for harmonizing the company's information flow.

Three different case studies performed by the students were presented in the paper. The students were able to reason about manufacturing strategies and their implications on the software systems used for manufacturing and vice versa.

We believe that the Technology Management program in general and the course "Technology, Strategy and Structure" in particular, provide today's industry with students highly skilled and sought after.

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