Fachhochschule Hannover
University of Applied Sciences and Arts
Mechanical engineering

Final thesis

Antti Kortelainen

Development of user training of flexible manufacturing systems

Supervisors	Prof. Dr.-Ing. Henning Ahlers Prof. Dr.-Ing. Bernd Hager
Commissioner	Fastems GmbH

10th June, 2008
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ABSTRACT

The user training of a flexible manufacturing system is a service product delivered by Fastems Industrial services business unit. Typically it is a part of years lasting implementation project of a new system. The training affects several interest groups such as the customer, project management, and sales and marketing. Training has as well big influence on the know-how of the operating personnel and thereby on the productivity of a new system. This thesis work is done after a request of Fastems GmbH, and it intends to develop a training program based on a literary research of training and education. The development work had the phases of analysing the starting situation, setting the objectives, describing the contents of the training and training methods, and describing the required arrangements, resources and preparations. The result of development work is a FMS Start up Training program which is focused for customers buying a new manufacturing system. A parallel development method was productization. Aim of productization is to develop a service product valuable to the customer and cost effective to the producer. Within productization the sales and delivery process was analyzed, and suggestions to simplify these processes were made. This phase included as well an analyze of after sales possibilities.

FOREWORD

This final thesis is completing my studies for Finnish-German double degree: bachelor of engineering / Diplom-Ingenieur. My training programmes were machine automation in Tampere Polytechnic – University of applied sciences and manufacturing engineering in Fachhochschule Hannover – University of applied sciences and arts. The cooperation between these universities offered me a great change to learn German language and prepared me to work abroad.

I found interesting and challenging to write my thesis about a topic where I could apply my knowledge about automation technology to humanistic and also to economical sciences – fields which were fairly new to me. This will surely motivate me to learn new during my working life in the future.

I would like to say thanks to my colleagues at Fastems for supporting my work by sharing their ideas and knowledge, to Prof. Dr.-Ing. Bernd Hager for excellent mentoring during my semester in Hannover, and the professors in FH Hannover and lecturers in TAMK for their cooperation for the double degree. I'm thankful to my family for their support during my study times.

Hannover, 10th June

Antti Kortelainen

CONTENTS

LIST OF ABBREVIATIONS

CIT	Critical incident technique
CTS	Central Tool Storage
DNC	Direct numerical control or distributed numerical control
FM	Flexible manufacturing
FMS	Flexible manufacturing system
FPC	Flexible Palette Container
FPM	Flexible Palette Magazine
IT	Information technology
MLS	Multi-Level System
MMS	Manufacturing Management System
NC	Numerical control
OEM	Original equipment manufacturer
PC	Personal computer
PLC	Programmable logic controller
PPS	Production planning and scheduling
RPC	Robotized Production Cell

1 INTRODUCTION

Fastems is a rapidly growing international factory automation supplier. During the last ten years, Middle Europe has become one of its most important market areas, FMS being its most important product in this area. The mission of Fastems is to make it possible for the customer to get the most out of the 8760 available yearly production hours. To fulfil this target on the field of FMS, Fastems has to make sure that the customer can use the system effectively and that any operation downtime is minimized. Therefore Fastems is putting special effort in developing its Industrial Services business line. As a result of this development, services has become one of the core businesses.

FMS operator training is one of the service products offered by Industrial Services. The aim of this final thesis is to create a customer orientated training concept by planning a training program, evaluating the needs and possibilities for company internal trainers' training, and describing the concept to ensure properly focused sales and marketing. The training program is planned for operator training of Fastems MLS with MMS4 control software, and is easily applicable for other flexible manufacturing solutions with the same software (FPC). The flexible manufacturing solutions and MMS4 are introduced in the chapter 2.

The planning of the training program is based on a literary research of training and education. The purpose of the study is to find out teaching methods which are suitable to achieve the aims of FMS operator training. These methods are applied within the planning. The training program is planned on a module basis to make it applicable to different customers investing in different kinds of FM systems.

The evaluations about trainers' training are made to find out ways to ensure that the trainers have sufficient training skills and technical know-how to give customer oriented operator training of high quality. One mission of sales and marketing is to find out and offer the most suitable solution for individual needs of each customer. Therefore it is necessary for these departments to have proper information about the available training programs, and what they are planned for. Some targets of development regarding the sales, marketing and delivery processes were found out during the project. These are introduced as well in the sales and marketing chapter.

2 APPROACH

2.1 History of Fastems

The history of Fastems has two branches: Helvar Merca Group and Valmet Factory Automation. They were merged in 1995 as the factory automation business was bought off from Valmet by Mercantile. In 1999 Fastems was incorporated from Helvar Merca Group, and named as Fastems Oy Ab.

Mercantile was founded in 1901, and its Machinery Division began importing machine tools in 1920. Helvar was based in 1921 as an import and export company, and it became an affiliate of Mercantile in 1948. The company expanded to a group over the years, and it was renamed as Helvar Merca Group in 1996.

The Finnish machine technology enterprise Valmet originates to state weapon factories. They were reformed to state metal works (Valtion Metallitehtaat) in 1946 to work for war indemnities to Soviet Union. The factories were incorporated and renamed as Valmet Oy in 1951. Some products made by Valmet over the years are e.g. tractors and forestry machines, locomotives, train and underground carriages, trams, passenger cars, aeroplanes, military and hunting weapons, paper machines, lifts, sauna stoves, and thermometers. The first Valmet machine tool was manufactured in 1958, and the first FMS was delivered in 1982.

The factory automation business started its rapid international growth in 1991 as the first foreign sales office was opened in Göppingen in Germany by Valmet Factory Automation. Nowadays the Fastems sales and service networks cover North, West, Middle and South Europe, Lithuania, and USA. During the last ten years the number of FMS installations has grown from 120 to over 400, the number of personnel from less than 200 to 340, and the invoice from about 40 M€ to 91 M€. /4; 20; 21/

2.2 Today's organization, core businesses and industrial services

Fastems Group consists of the parent company and its seven local affiliates in Europe and in the USA as illustrated in the figure 1.

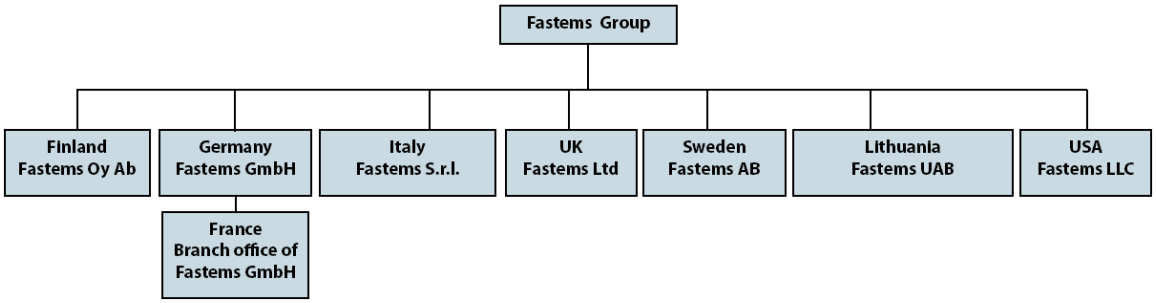

Figure 1: Fastems Group organization /24/.

The core businesses of Fastems Group are projects, products, and services. The business unit in charge of services is called Industrial Services. Industrial Services is further divided in six departments. The figure 2 illustrates this division.

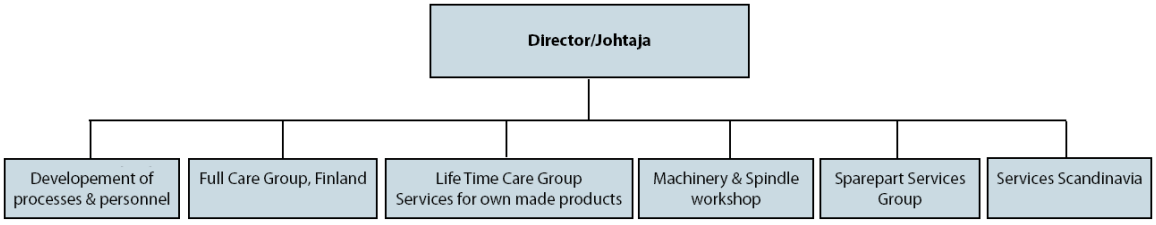

Figure 2: Organization of Industrial Services business unit /24/.

The two main departments are Full Care Group and Life Time Care Group. The Full Care concept is intended for Finnish market area. Its idea is to provide service not only for the products made by Fastems, but also e.g. for the machine tools imported and represented by Fastems. The Life Time Care Group operates mainly in European markets providing services only for Fastems made products. The service supply at Scandinavian market area

differs from the two main concepts, and is therefore further differentiated as its own department. Development of processes and personnel, Machinery and Spindle workshop, and Sparepart Services Group are supporting departments.

The service palette offered by Full Care Group and Lifetime Care Group includes

- contract services
    - spare parts
    - preventive maintenance
- on call services
    - machine repair
    - fault service
- engineering services
    - control retrofits
    - spindle repair
    - mechanical retrofits
- expert services
    - Teleservice
    - training
    - installation services
- start-up services.

FMS operator training is a service product offered by Lifetime Care Group. The figure 3 shows the responsibility areas and management of the Lifetime Care Group. /25; 26/

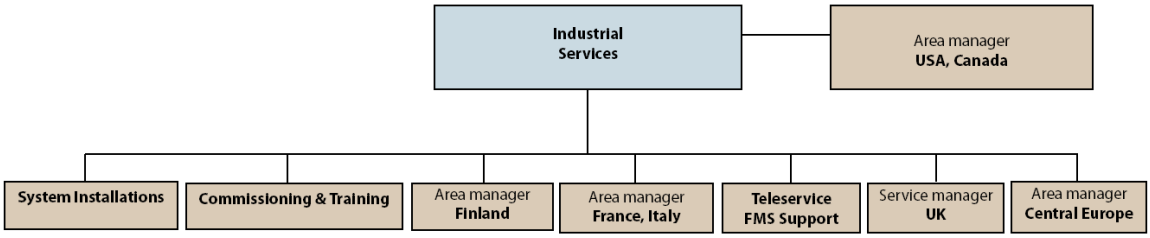

Figure 3: Lifetime Care Group /24/.

2.3 Product groups and market fields

The product groups represented by Fastems are factory automation, plastic industry products, robotics, and machine tools and auxiliary devices. Machine tools and auxiliary devices business is operated only at the Finnish market. /26/

2.4 Factory automation

The application fields of Fastems factory automation are automotive industry; vehicle, construction machine and machine building industries; aerospace industry; and subcontractors and product factories. Fastems offers various solutions for flexible manufacturing from robot automated loading to full size FMS. The next introduced systems MLS, FPM, and FPC are based on FMS having a stacker crane automated warehouse for machine and material pallets. The use and control of these systems are done by a master PC with soft PLC and Windows based software. However, they may not fill all the FMS requirements; they may, for example have only one machine tool installed /2/.

MLS – Multi Level System

The oldest concept, project delivered Fastems flexible manufacturing system is called Multi Level System. A MLS is highly customizable, and consists at least of one or more loading stations and one or more machine

tools. Other devices or options attached to a MLS can be material stations, robotic applications like material handling or deburring, hydraulic clamping, washing stations and tool presetting.

FPM – Flexible Pallet Magazine

FPM is a standard solution for flexible manufacturing. The main difference from MLS is that FPM has fewer options available. The benefits compared to a MLS are quick installation and start up, and cost effectiveness via product manufacture and delivery. A FPM has 1-4 loading stations, and 1-10 machine tools.

FPC – Flexible Pallet Container

FPC is a small sized solution for flexible manufacturing, and is pre-installed in a container. It is sold via partners as an OEM product. The main idea of FPC is to offer an easily transportable and quickly erectable product as an alternative to pallet pools. A FPC system consists of one or two containers. The system has one or two loading stations, and one or two machine tools.

Robot applications

The smallest solution for automated material loading is Robotized Production Cell, RPC. A RPC can serve one machine tool, and does the loading from a material trolley by a robot instead of a pallet warehouse and a stacker crane. Apart from a single machine tool, a RPC can serve a FMS as well. With this solution, the machine pallets are loaded by a robot.

Other robot applications are robotized deburring, Central Tool Storage - CTS, and customized cells. A CTS is a solution, which exchanges cutting tools between tool magazines of machine tools and a tool storage

automatically using a robot. This is suitable for FMS with short cutting tool life times, typical for example within aerospace industry. /26/

2.5 MMS – Manufacturing Management System

The control software of MLS and FPC is called MMS. Its actual version is MMS4. At the same time, development of new control software called Manta is going on. This will be introduced at the launch of a new FPM. MMS handles and supervises the system status and functions. The interfaces between MMS and the system are soft PLC for various sensors, switches, buttons, lights and some machine tool control functions, and Ethernet connection for NC program and tool data transfer. MMS also uses databases to save information such as pallet locations and article data.

The users can operate the system components via MMS either manually or automatically. Also all the data that is needed for automated manufacturing is entered on MMS. This information consists of

- NC programs
- item information for manufactures items, manufacturing phases and raw material
- item information for items in the storage
- manufacturing routes of machine palettes
- fixture information
- material handling information
- production orders.

The full automated using mode of the system is called Autopilot. The Autopilot can be activated for each loading station and it handles production orders automatically based on priority calculation. When a loading station is operated by Autopilot, the task of the operator is to clamp, re-clamp or unclamp the work pieces on the machine pallets. The Autopilot will decide which work pieces are clamped based on the information given by the operators or other users. As soon as the work pieces are clamped to a pallet,

the pallet can be sent to the manufacturing route. The manufacturing route defines the manufacturing operations of each machine palette. Based on the item information, the Autopilot or the operator will decide which manufacturing operations have to be activated to manufacture the items that are ordered.

The MMS software can be delivered with two different kernel software modules: MMS Express or MMS Enterprise. MMS Enterprise can be equipped with more optional packages such as automatic storage for material palettes, capacity simulation, PPS interface, machine data logging, washing machines, and various robotic applications. MMS Express, by contrast is designed to need minimal amount of data input and supervisory operation for systems with less optional functions and simple material handling structure. Both of the kernel packages can be delivered with or without NC Program library and tool checking. This option is a DNC interface which enables saving NC programs on the master PC, and thereby makes it possible to use a lot bigger number of NC programs compared to a solution whereby the programs are saved to a limited memory of a machine tool. The available MMS options are

- MMS2000 Automatic Storage
- MMS3100 Capacity Simulation
- MMS4100 NC Program Library and Tool Checking
- MMS4200 Tool Data Management
- MMS5000 Machine Data Logging
- MMS5100 Remote Alarm. /28/

3 DEVELOPMENT METHODS

3.1 Productization

Productization of a specialist service can be defined as processing the know-how to a saleable, marketable and deliverable service product. As a result of productization the service providing specialists should have clear guide lines of what they are doing, as well as the sales personnel should have clear definitions of what they are selling. This is not possible if the service will be fully tailored each time for each customer. Therefore the first and the most important task when planning a service product, is to define who the customers are, and what they need. If performing this task is failed, or any other objective is seen as more important, there is a risk to provide a useless service. /1/

3.1.1 Objectives

The objectives of a productization process are to increase the profit of the provider and to improve the quality of the service. Reducing the production costs and improving quality is possible by following a planned programme. Having a ready made programme and clear instructions for each part producer saves time compared to a service which has to be planned and described every time individually. As each one of the part producers have their role and tasks clarified, they will be able to aim their expertise to their specified task which is put to achieve the original objective: fulfil the customer's need. As well as clarifying the role of the producer, productization aims at bringing benefits to the customer. Some of these benefits are description of the meaning of the service, clarifying the contents of the delivery, and a quicker response to an invitation to submit tenders or a published price list. /1/

3.1.2 Principles

Defining the customer group

Defining the customer group is an action to prevent the situation where the service should have to suit all, and would therefore be too general to be specified clearly enough. Of course, before defining the customer group the business idea already exists. It is not important to define the customer group before defining what kind of needs the service should satisfy. Even the solution might exist before the problem is clearly defined. If the action to define the customer group is done at a later phase of the productization process, it should be re-checked to make sure that the chosen customers really need the service which is being developed. A solution can not be offered without knowing what is needed. /1/

Finding out the needs

This phase should produce an answer to the question: what is the customers' problem? Concrete products at private market are often bought because of irrational reasons; meanwhile with business to business services the buying motives are very rational. Services are bought for example because the customer doesn't have the knowledge or time to perform the task or a specialized provider is able to perform the task more cost effectively. By finding out what the customer needs, it is possible to develop a service which is valuable to the customer. /1/

Setting the objectives

This phase will set and prioritize the conditions for the service to be developed. As the customers' needs are once defined, the next phase is to decide which needs have to be satisfied. Strict limitation will probably dramatically narrow down the amount of possible customers. However, this

is often gainful if it makes it possible to create a product which has fewer competitors or no competitors at all. Specializing in certain objectives helps to fulfil the chosen objectives better than developing a service which should somehow suit everyone. This phase will assure that the result of the development process will respond to customers' needs. The wideness and the costs of the development process, as well as the characteristics of the final product should be appreciable after setting the objectives. As well as setting the objectives, it should be estimated that they are realistic; if there is a conflict between the objectives, the only possibility might be to give up on the one which has the lower priority. /1/

Creating the concept

In this case concept means the actions which should be taken to reach the objectives. In addition to defining the actions to be taken, it has to be defined who does what and at which time. This phase is not disconnected from setting the objectives. It has to be re-checked that the concept really fulfils the objectives, and if it does not, either the concept or the objectives have to be changed. It will typically take several rounds of re-checking and re-adjusting to find out a reasonable concept. /1/

Dividing into modules

A fully tailored service would be a project instead of being a product. Very often different customers have different kinds of needs. Modulating is a solution for customized serial production. This method is already for years well-known for example from car industry: typically thousands of variations of one car model can be built by choosing different kinds of engine and accessory combinations. A service product can as well be produced this way to achieve cost effective customizing. /1/

Sharing out the knowledge

As the concept is finally prepared, checked and accepted, it has to be documented. This means writing clear guidelines to the personnel, so that each one knows his role and tasks. This is done to save the time of the specialists by preventing them from doing various and in the worst case overlapping additional tasks. Therefore the personnel will be able to concentrate on their core know-how better. Some tools for sharing out the knowledge are for example manuals, work instructions, check lists, document templates, diagrams, process descriptions, and training occasions. One example of concept regulation is a franchising manual: a whole business concept can be defined and shared out via one. /1/

Internal marketing

As rapid changes are more and more common in modern business, the organizations have to be capable of changing quickly as well. This requirement has brought the new term of internal marketing into the field of business communication. It means a strategic way of communication that helps the members of the organization to accept their new tasks and to motivate them in reaching the goals defined in the business strategy. Internal marketing should support external marketing so that each one of the employees has sufficient knowledge about their roles. Further internal marketing should increase the market orientation of the whole work community. /22/

3.2 Training

Training or teaching can be seen as a tool to satisfy a certain need of learning. Often the need of learning appears as a consequence of a change. This basis should not be forgotten, because the training itself should not be seen more important as learning. Planning reasonable training occasions is

necessary in supporting the learning of the trainees. However, there is no theory saying what kind of training method is actually the best one; after all each training method and each training occasion is an application of theories, experiences and believes. /7; 8; 12/

3.2.1 Terms and topics regarding training and education

Education

The science education has many definitions. The earlier definitions are saying that education examines educating and teaching, while the latest ones are giving more importance to the question how human learns. The modern definitions are more objective. /6; 10/

Pedagogy

The term pedagogy refers to the principles and methods of instruction, the profession of a teacher, or the activities of educating, instructing or teaching. The words teaching method, teaching, instruction, education and educational activity can be seen as synonyms of pedagogy /37/. Some researchers are having the opinion that the word pedagogy refers too much to teaching only children. This is because of the Greek origin word *paidagogos*, which literally means “to lead to the child”. /6; 13/

Andragogy, adult education

Andragogy concerns learning and teaching of adults, accentuating the special characteristics of the learning process of adults in comparison to the learning process of children. These kind of special characteristics are self-concept and motivation to learn, experience, readiness to learn, and orientation to learning. The learning process of adults has its characteristical limitations, such as deep-seated conceptions as well. /6; 14/

Didactics

Didactics is a field of education researching learning and teaching, and educational psychology. Didactics can also be seen as a practical application of the theory of learning and teaching. Didactics can be divided in descriptive and normative didactics. Descriptive didactics aims at describing reality as it is, while normative didactics aims at committing the applicability of teaching methods. The normative didactics aims also at taking the whole learning process into account in planning of teaching. /6; 15/

Teaching

Teaching is a method of education, which aims at learning. Learning can however happen or not happen with or without teaching. Therefore teaching can be described as guiding of learning. Successful teaching requires good knowledge of the topic to be taught as well as knowledge of meaningful teaching methods considering the target group /6/. The words training and tutoring can be seen as synonyms of teaching /23/.

Learning

The traditional assumptions of learning are accentuating receiving and remembering information, or repeating tasks correctly, while the modern assumptions are bringing out understanding, change of attitude and behaviour, and development of personality. Learning involves all the behaviour except operations based on reflexes or instincts. /3; 6/

3.2.2 Applicable theories and methods of learning and teaching

Behaviorism

Behaviorism was the dominative learning theory from the 1920's to the 1960's. According to behaviorism, desirable behaviour can be contributed by rewarding, and undesirable behaviour can be prevented by punishing. Behaviorism concerns only the noticeable change of behaviour – it ignores understanding, and development of values and attitudes. /7/

Cognitivism

The cognitive learning theory started gaining ground in the 1960's. Cognitivism is more a way of thinking than a single theory. However, cognitivists are focusing on information processing in human thinking and remembering. As a result of cognitivism, pedagogic started to focus more on learning instead of teaching. The modern learning theories (e.g. constructivism) and instruction methods (e.g. tutoring and mentoring) are based on cognitivism.

According to cognitivism, schemata are controlling the information receiving processes. The received information will be meaningful or meaningless, depending on how it is attached on the existing information after the schemata. In other words, the personal schemata define what kind of information is useful and thereby interesting to an individual. Schema could be described as sort of a preconception which gets adapted all the time by new perceptions and experiences.

Another concept related to cognitivism is orientation basis. The learner illustrates the topic and its inner relations by means of orientation basis. For example, orientation basis could be a table of contents, introduction, an example given by the teacher, or a mind map.

The concept of learning process was introduced as well as a result of cognitive thinking. Learning process means that learning is not only remembering, but happens through various steps which are fulfilling each others. Most often, learning is seen as a cyclic process, whereby the steps are being repeated over and over again completing the learner's knowledge and understanding. The concepts schema and learning process are overlapping. /7; 16/

Constructivism

Constructivism points out learning as adapting, fulfilling and rebuilding of the learner's earlier information, understanding, experiences, problem-solving methods and schemata. Further, according to constructivism it is important that the learner himself tests and evaluates the re-built constructions.

The constructive way of thinking is based on the argument, that people cannot just transfer information, but it has to be discussed. If the learner understands (as a result of adapting new and earlier information and self-evaluating) why certain topic is important to be learned and remembered the learning will be more effective. In the end the real activities will bring out the result of learning.

The role of a teacher in constructivism is guiding; the teacher should place the learning objectives and lead the learners to place reasonable questions for self-evaluation. /3; 7/

Experiential education

The term is often mistakenly used interchangeably with experiential learning. It is noticeable, that the German and Finnish equivalents of

experiential education (Erfahrungsbasiertes Lernen, Kokemuksellinen oppiminen) would literally mean experiential learning.

The idea of experiential education is that the learner gets towards theoretical understanding and better operations models by reflecting his experiences and activities. A big difference with traditional cognitivism is pointing out the importance of practical applying. According to some criticisms, only doing and practical applying is not enough to evoke learning. Therefore the philosophy of experiential education is named even “naive constructivism”.

Reflection is an important concept related to experiential education. Reflection means rational and affective activity, whereby the learner goes over one’s knowledge and experiences to attain better understanding. One way to do reflection is interaction; the learner’s thinking processes and believes will be known via interaction, and can thereby be evaluated and questioned. Reflection can be done for example by self-evaluating, group discussion or feedback. /7; 17/

Cooperative learning

Cooperative learning is a teaching method based on team work. Within it, the group is divided to small teams which can be very heterogenic. The teams are given learning tasks to be solved with various learning methods, and the whole team is responsible of individual learning of each team member. The team division can be temporarily re-built to form expert teams to solve single learning tasks. The cooperative learning aims at

- collective discussion and self-evaluating in teams
- taking advantage of dissimilarity and interdependency of the group members
- development of interaction and group work skills
- emphasizing individual responsibility. /7; 18/

Critical incident technique, CIT

The CIT can mainly be used as a method of collecting research material and as a learning method. The present form of CIT was presented by John C. Flanagan as part of the US Air Force Aviation Psychology Program during the World War II. Flanagan's studies aimed at differentiating effective and ineffective work behaviours. Later on Flanagan used the method for researching typical aspects of activities in various profession fields, in industry among others.

The critical incidents are experiences and situations which are noticeable from the learner's point of view. Analyzing these experiences is essential to turn them to useful learning experiences. This analysis is called reflection as well as within experiential education.

CIT aims at recognizing the assumptions on which the learner's way of thinking is based, and thereby developing the way of thinking towards critical reflection. Critical reflection consists of

- recognizing the assumptions
- collating the relation of the assumptions and real experiences
- reforming the assumptions to make them extensive and solid. /7; 19/

4 FASTEMS FMS OPERATOR TRAINING

4.1 Background and development of Fastems FMS operator training

The development of existing operator training started in 1998 as the first version of MMS control software was introduced. Some of the changes MMS brought were the use soft PLC which is integrated in a PC, instead of using a separate hardware PLC, and new programming tools. Since almost all the operation functions of Fastems FMS are done using the MMS, the training is focused on it as well. Until the year 2004 the tasks of the programmer have included programming, acquisition and commissioning of the master PC, commissioning of the FM system, and operator training at the customer site. The latest version of the MMS is MMS4. Because it is a standard software package without any customer specific programming, the programmer is not needed at the customer site. Since 2005 the commissioning team has been separated from the software team, and the commissioning and training at the customer site by local commissioning engineers has been possible. /27; 28/

4.2 Present conditions and resources

4.2.1 Available training variations

Fastems offers FMS operator training within the start up at the end customer's site, and advance training in FMS Training Center in Finland. The training at the end customer's site is done right after the commissioning. The training in Training Center is advance training before the commissioning to speed up the start up process. It is noticeable that most of the customers rule out the option to advance training. One more

available variation is on-site support. On-site support is held after the actual training session, and it provides assistance during the system start-up and support in special situations. Fastems is offering the customers three variations to choose from, but the majority of the customers find only the on-site training at start up useful. /26; 27; 29/

The training is done as a part of the delivery project, and each project has a project manager. Some tasks of the project manager are to agree about the timing of the project with the customer, and to defray the project costs. Therefore the project manager is also the contact person regarding the training. As the timing of the training is agreed with the customer, the project manager should still agree with the team leader of training and commissioning team about booking of the trainer.

4.2.2 Available human resources

Life time care group has a commissioning and training team whose operation area covers the biggest market areas in Europe. The team has seven employees in Finland and three in Germany and it is prepared to give training in Finnish, German and English. The countries where the commissioning and training team is available for training in local language are Finland, Germany, Austria and Switzerland (German speaking area). Other countries, where the team is available to give training in English or German are Belgium, the Netherlands and countries where no active sales business is done. In these countries there are 338 out of total 709 FMS installations. After existent FMS installations the commissioning and training team is capable of giving training in 48% of the market area. The commissioning and training in North America, Italy, France, in the UK, and in Scandinavian countries excluding Finland are done by local service team members that are taking care of other service tasks like maintenance and repair as well. /24; 30; 31/

4.3 Conclusions about present conditions

The operator training has been seen essential, as it has been given as long as FMS have been produced. Earlier the size of the company has been dramatically smaller, and it has been possible that the programmer of the control has done the training. The MMS program is the interface between the system and the operator, and therefore understanding the functional philosophy of the program has been seen as an important result of the training.

As the company started the rapid grow phase, specializing into tasks has become possible by dint of more personnel. At the same time the sales and service operations have been internationalized. Having local employees has many advantages such as language skills and understanding cultural factors. Decentralized service operations of course bring challenges such as distributing knowledge inside the company, and unequal resources and various ways of action at various market areas. This is substantially making it more difficult to standardize the operator training.

Currently the number of training personnel is relatively small, but more trainers are needed increasingly. Many of the current trainers have years of experience, and they have developed their personal training methods. The training is done more as case-specific consultation as by following a program. The content of the training has been easy to decide according to characteristics of the delivered system. However, setting aims for each project has not been done, and the responsibility of deciding the duration of the training has been left to the customers. At least those customers, who do not have earlier experience of FMS, can not know which level of knowledge should be reached to meet their demands and how much training is actually needed.

The process to agree about the practical arrangements regarding the training is complicated. There are two steps between the customer and the trainer: the project manager and the team leader of the commissioning and training team. Both, the project manager and team leader operate from Finland as the trainer usually operates from a local affiliate near by the customer. This means that the information from trainer to the customer and vice versa might be translated various times as it could be given directly. If the contact would be direct, it would be possible to change a lot more information with minimal amount of work. On the other hand this would mean that Industrial Services would defray the training costs instead of the project manager.

5 RATIONALIZING

5.1 Customer orientation

To attain its mission, Fastems has to be able to help the customer to get the most out of the available yearly spindle hours. One important factor is to supply a proper system for automated manufacturing. However, the possibilities to support the customer in addition to system delivery are a lot wider. Veli Matti Kuisma introduces in his recent published doctoral thesis an approach, whereby FMS is described as a socio-technical system. According to socio-technical way of thinking there is an interaction between the technical system and a social system: the investments in technology have their influence on the organisation, optimizing technology and optimizing organization can not be separated from each other, and the changes in operational environment require self-direction of the organization. According to Kuisma /2/, it can be seen that a FMS is comprised of a technical system consisting of material, information and tool handling. The role of a user thereby is to maintain, to control and to develop the function of the system.

The social organization related to using of a FMS is formed by the operators and other personnel who influence the use of the FMS indirectly. This group normally consists of various employees of the customer, and is in its entirety responsible for the use the FMS. /2/

A FMS is a system where not only the operators are influencing the result, but also e.g. work planning and NC program structure have remarkable roles in the process. To achieve the wanted result, the people in charge of these planning tasks have to be conscious of how their work will affect the function of the system. In the end using the system and such things as work planning are at customers' responsibility. However, as a designer,

manufacturer and supplier, Fastems has the best knowledge about the effective use of its systems. To support the customers in the best possible way, Fastems should be capable of distributing this information in each individual project. At the same time, Fastems needs information about the customer's production process to provide relevant information about the system functions. This information can be provided at the training, but as preparation Fastems should let the customer know what will be needed when the training begins.

5.2 Developing the training

5.2.1 FMS start up training

Starting situation

The training concept FMS start up training is best applicable to situations when a customer has a new FMS with personnel who have never used FMS before. In that case the training will be a part of a start-up, whereupon all the data required by automatic usage will be entered in the system. The training concept is well applicable to situations in which the customer has an existing FMS with new operators. In that case it has to be checked if training of other user groups is reasonable. Different parts of the training concept can as such be applied to other situations, e.g. the situations where a customer has an extension to an existing FMS. In this case it has to be separately agreed what is included in training.

Training contract

In the most of the cases, the training is a part of the FMS delivery, and training contract is included in the sales contract. In other cases, a separate training contract has to be signed. Only the duration of the training is

mentioned in the sales contract. Therefore the use of customer's resources has to be separately agreed. The customer should as well be informed, to which employees the training is related.

Trainees

The training is mainly focused on training the FMS operators, who are often machinists with years of experience. In addition to that a FMS system affects the work of various employees in a machine works company because it handles NC programs and material information. FMS includes at least one PC as well, and it is a part of the data network of the customer.

The trainees are divided into four user groups which are

- FMS operators: the people whose main task is to operate the system FMS operators are mostly machinists
- Production planners: the people who are in charge of material flow and item information regarding to FMS
- NC programmers: the people who write NC programs which are used in FMS
- IT personnel: the people who are in charge of the data network, holding the installation media, computer user accounts, and the people who have computer administration rights.

One of the operators will be named as main user by the customer. The main user will participate in the whole training. The role of the main user is to plan how the system will be operated, and to be the contact person between the different user groups.

The largest recommended group size is four FMS operators and in addition the other personnel. Who takes part of the training is, however, to be decided by the customer.

Facilities

A serviceable FMS is needed to realize the training. In addition to customer's works there is a system available in the FMS Training Center located in Tampere, Finland. However, usually the customers require that the training will be given with their system as part of the start up. The training at the customer's works has the advantages that the customer's employees do not need to travel, and the training will be given with the actual production resources. Many of the customers have a conference room available. If a conference room is used, the availability has to be checked in advance.

Duration

Duration at the training will be agreed with the customer and confirmed by the training contract (or sales contract). The training will be completed during one week if possible. Because the normal working time of a trainer in one week is five times eight hours, and travelling time has to be counted in, the time to be used for training is usually limited to four days. Continuing the training with one or two days in the next week should be avoided, because then the trainer is not available elsewhere during the same week. The duration of the training has to be taken into account at planning the training objectives and contents.

Setting the objectives

The main objectives of the training are that after the training

- the personnel of the customer is able to use the system safely
- each employer who deals with the FMS has sufficient information about his or her tasks regarding to FMS to set up the operation with the system and to use the system under typical operation conditions.

The task-specific learning objectives for each user group are presented in the appendix 1.

Content

The training content is made up of eight modules. Each module has its learning objectives and topics, and is directed to those user groups that have learning objectives regarding to it. The training contents are described in the appendices 2 and 3. There are 2 versions of the training program: a 3 days version for systems without MMS options, and a 4 days version for systems with one or more of following MMS options: 2000, 3100, 4100, 5000 or 5100.

Arrangements and resources

The training will be done by one trainer. Training of a larger group at the same time with more trainers is not usually possible because of only one available FMS. The resources to be used within the training are a FMS and the resources that are needed to use it, user manual of the FMS, final test for the operators, the trainer's laptop with MMS Demo software, and a conference room with a data projector if such an arrangement is agreed with the customer.

The resources which are needed to use the system are to be provided by the customer. These resources are

- machine tool
- palettes
- fixtures
- raw material
- NC programs
- cutting tools
- item information.

According to concrete experience, missing resources is the most common cause of delays, and in the worst cases the availability of the system is so badly decreased that the training cannot be held at the appointed time. Often the customers who do not arrange the production resources to the training occasion are putting the system slowly into operation. Therefore special effort should be put to inform the customer about the importance of these resources. Fastems should as well clarify the responsibilities in case of missing resources.

Training methods

The primary training method for operator training is demonstration and practising with a FMS. Everything that is taught will be exercised instantly. Additionally, the training program includes repetition and practical exercises. The knowledge of the operators will be tested by a final test. The final test is presented in the appendix 5.

The other user groups will be informed how the FMS affects their work. The trainers will also give advice how to use the system in an effective way.

Preparations

The preparative tasks are to agree with the customer upon the time when the training will be given, which employees are going to participate, who is the main user, and that the needed resources are available. A contact person is needed to carry out the preparations. Possible contact persons could be project manager, commissioning and training team leader, local area manager or the trainer.

5.2.2 Trainers' training

Requirements of the FMS operator training

As described in the chapter 3.2, the topic training touches various fields of science. The modern learning theories are pointing out the importance of understanding, as the traditional assumptions are concentrated on remembering and repeating tasks. According to Kuisma /2/ most of the FMS users find their job challenging and offering opportunities to learn new things. The productivity of a FMS depends very much on work planning – many production phases, such as re-clamping or unmanned work shift can be organized in various ways, each having their advantages and disadvantages. FMS is an effective system with high degree of automation, but requires a high level of knowledge as well. Most of the FMS delivery projects of Fastems are realized with new customers without earlier FMS experience. Therefore the expectations of becoming FMS operators can be anything – as well enthusiasm as fear.

The Start up Training aims at advising the customer how to put the system into operation, and how to operate it. The most important topic of the training is putting data into the system. It will be advised at the training which data the system needs and how it handles the given data. The responsibility of settings goals for productivity and planning the production in an effective way is finally the task of the customer. One important aim of the training is therefore to motivate the customer to find a suitable production model. Optimizing production however requires years of experience of FMS: the productivity of a FMS reaches its top in average about ten years after the start up /2/. Start up training is often the first experience of FMS for the becoming team, and the possibilities of the user team to develop the production during the next years depend on the training.

The trainer should be capable of finding out training methods that are encouraging the customer's team not only to perform the required actions to use the system, but to find out ways to develop the productivity, and to optimize the use of the system. Organizing a training occasion whereby an ongoing learning and development process will be started is an important skill of a FMS operator trainer.

Possibilities to train the trainers

The manufacturing systems delivered by Fastems are as well designed and manufactured by Fastems. The functionality of the MMS control system is designed by the software team. Use of the functions is explained in user manuals, but the range of possible applications is very wide, and not documented. Therefore the trainers have to have a very good knowledge of the system functions and understanding to apply the functions in an optimal way for various production models.

At the moment Fastems does not have any training program to train the trainers, and the knowledge of the trainers is not tested either. The local affiliates have only few trainers, and the only Fastems FMS for training purposes is the FMS Training Center in Tampere in Finland. The big advantage with the FMS Training Center is its location in the same facilities where the product design teams work, and where the technical knowledge is at easiest available. A training program to develop the technical knowledge of the trainers is possible to organize with these facilities. However, at first it should be defined what level of knowledge is actually required from the trainers.

Even though Fastems has good resources to develop the technical expertise of the trainers, the potential to upgrade the skills of teaching, motivating and planning training events are missing. To test and to evaluate the training skills of an individual trainer is also a task which does not meet the field of

know-how of a factory automation supplier company. Therefore using an outside consultant could be a worthwhile investment.

5.3 Marketing and sales

One of the important interest groups of training is the sales organization. The most of the training packages will be sold as a part of a FMS delivery. In these cases the training is included in the sales contract of the whole system, and it will be realized as a part of the delivery project.

After the training is once sold, it shall be delivered by Industrial services organization. The most important factors in the sales situation are the price and the costs of the training. The costs are depending on the duration of the training and other actions needed to organize the training. To determine the costs and the price, the sales organization should be capable to know at least the duration of the training. The task of the sales organization is to calculate the price through costs, but the organization responsible of the costs is finally Factory (project management). The role of Industrial services is to deliver the training as it is sold, and as it is agreed by project management. Figure 5.1 illustrates the role differentiation of present delivery model.

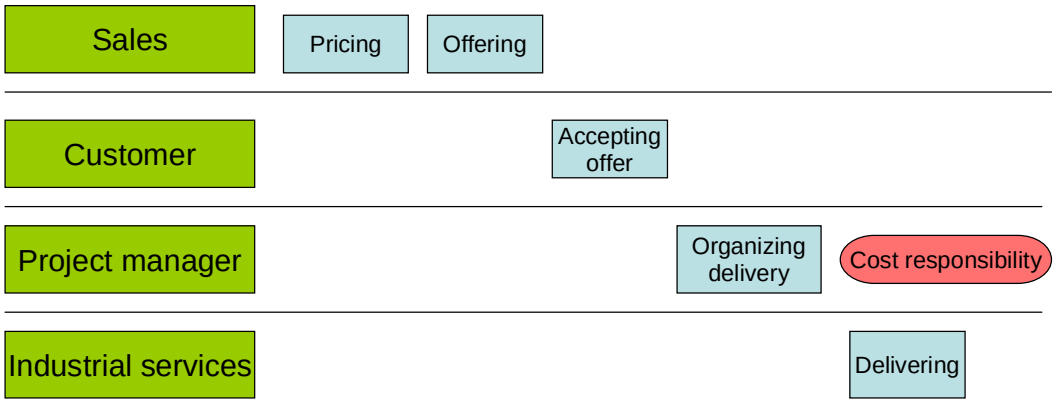

Figure 5.1: Present role differentiation of the training delivery process.

As an alternative to the preceding role differentiation could be a constant internal pricing. The internal price would depend only on the amount of given training days. The sales organization would offer a training packet based on the sold FMS modules, and the duration of the training would depend on the training packet modules which are sold. After the sales operation Industrial services would take the responsibilities of costs and the delivery of the training. Within this operations model the agreement about arrangements regarding to the training would be done directly between the customer and Industrial services without project management in between. Figure 5.2 illustrates the delivery model of constant pricing.

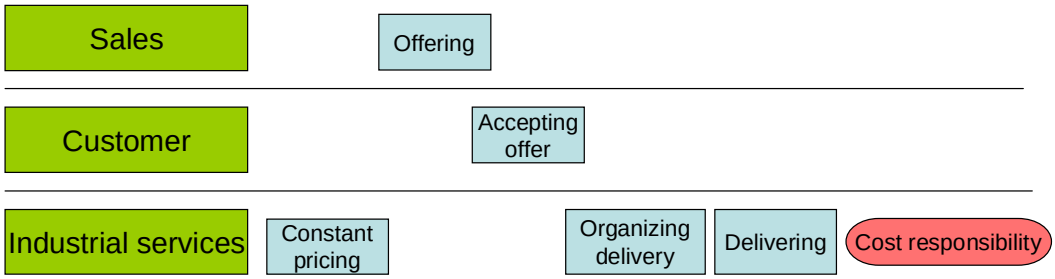

Figure 5.2: Role differentiation of training delivery process with constant internal pricing.

5.3.1 Marketing tools

A description of the Start up Training program for customers was done, and it is presented in the appendix 4. The description is made short and informative because the start up project already includes a lot of information exchange between Fastems and the customer.

5.3.2 After sales

After sales service means a service which is provided by a manufacturer after the delivery of a system. Existing after sales services provided by

Fastems are service contracts for regular maintenance, warranty maintenance, maintenance without service contract, training, and system modifications and extensions. Training after a system delivery is mostly given after a customer's request. In many cases a second training occasion after the actual start up would improve the chances to gain the productivity of a FMS. Some months after the actual start up the customers have already some knowledge and experience about using the system. As the users are already able to use the system, the training can be concentrated on speeding up the production process. A secondary training is also often a good chance to find out what kind of wishes the customer has about the system, and how the customer would speed up his production process. There is a possibility to find out if possible system extensions or modifications are needed. The after sales services are sold by local service affiliates. For active training after sales business Fastems would need to define whose task is to offer secondary training. By testing and finding out the most typical customer needs it would be possible to productize some secondary training concepts. According to Kuisma /2/ the development activities after the actual start-up phase of a system have at least as significant a role as the start-up; productivity will increase as a result of continuous improvement.

6 CONCLUSIONS

As a result of this development project the first training program for Fastems FMS was described. The program is intended for the most typical situation, where the customer has bought a new FMS and requests for training at his site. The module based program is suitable for all other MMS4 standard applications except systems with Tool data management and robotic solutions. The next phase of this project should be to plan and describe training modules for these rarely appearing applications. The training for Tool data management can be added to the FMS Start up Training program as an additional module. Robot as an application differs a lot from a manufacturing system, and the robot training should be arranged as a separate program from the FMS training.

The trainers' training program should be developed to ensure sufficient know-how of the training personnel. Fastems already has existing resources to arrange trainers' training, but the first task will be to define the level of knowledge required from the trainers.

Clarifying the roles of different interest groups regarding the sales and the delivery process should be done at Fastems. The tasks of pricing and organizing the delivery of the training could be simplified by leaving them to be done by Industrial services. Thereby the Industrial services would take the overall responsibility of the training product.

A secondary training as after sales product would be possible to realize with the same kind of concept as the Start up Training. It can be offered and delivered by local service affiliates as well as other after sales products. The first task is to find out what kind of secondary training the customers need and how it will be possible to help the customers to use their system more efficiently.

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APPENDICES

Appendix 1:	Start up Training objectives	1 page
Appendix 2:	Start up Training program 4 days	5 pages
Appendix 3:	Start up Training program 3 days	5 pages
Appendix 4:	Short description of Start up Training	1 page
Appendix 5:	Final test for operators	3 pages

Objectives - FMS start-up training

Operators	Production Planners	NC Prog-rammers	IT Personnel	
✓	✓	✓		Understand what happens during automated machining cycle
✓				Are able to use the system components (PCs, stations, operating panels, stacker crane) for automated manufacturing and manual operation
✓				Are able to put pallets in the system, take pallets out of the system, change pallet locations and work with pallet defined fixture information
✓		✓		Are able to work with the most important NC program data (If MMS4100)
✓		✓		Are able to accept new and changed NC programs from CAM and from the machine tool, and to send programs to CAM (If MMS4100)
✓		✓		Are able to make tool magazine queries, magazine planning and tool simulation (If MMS4100)
		✓		Understand how Fastems FMS uses NC program header
✓	✓			Are able to create items, items for resource materials, and manufacturing operations
✓	✓			Are able to create and edit manufacturing routes
✓	✓			Are able to create, handle and check resources for manufacturing orders
✓	✓			Understand the principle and requirements of adaptive priority calculation
✓	✓			Are able to handle defective parts
✓	✓			Know where to find web reports and how they are generated
✓				Are able to operate the stacker crane manual drive modes
✓				Are able to recover from typical error situations
✓			✓	Are able to perform controlled system shutdown and start
✓	✓	✓	✓	Understand the safety instructions regarding FMS
✓	✓	✓	✓	Know how to find manuals and other documentation
			✓	Know the liabilities regarding software installations and other configuration changes
			✓	Understand the network structure of Fastems FMS
			✓	Understand how the backup of system data is realized
			✓	Understand the configuration and the usage of the remote access system
			✓	Receive the admin rights
			✓	Receive the CDs / installation media

Program

FMS Start up Training

1st day

Morning – Introduction (Conference room)
Operators
NC programmers
Production planners
IT personnel

- Briefing
  - Checking the resources
    - Network
    - Machining pallets
    - Fixtures
    - NC-programs
    - Tools
    - Materials
    - Material pallets
    - Item information
  - Training contents and objectives, timetable and participants
- Introduction
  - FMS overview
  - FMS components
    - Hardware
    - MMS Control software
  - What happens during automatic machining cycle?
  - Documentation
- General safety issues
- NC program header (For NC programmers)

1st day

Afternoon – Introduction
Operators

- User interface
  - MMS Process and MMS Planning
  - Windows (Control Room, Loading, etc.)
  - Colors and symbols
- Pallet locations
  - Putting pallets in and taking out
  - Fixtures
  - Changing the pallet locations
- Loading stations
  - Moving, tilting, lifting
- Stacker crane
  - Automatic drive, transferring pallets
- Introduction to manufacturing routes
  - Making a simple route

2nd day

Morning – Automated manufacturing
Operators
Production planners

- Creating items
  - Resource material
  - Manufacturing operations
    - NC programs
- Material handling (If MMS2000)
  - Using material station
    - Entering new pallets and new material
      - Fixing a batch with an order
    - Taking material out
  - Material locations: outside, material cell, and storage
- Creating and editing manufacturing routes
- Production planning and scheduling
  - Creating and handling production orders
    - Importing from a file
  - Adaptive priority calculation
  - Resource checking
  - Handling defective parts
- Loading wizard and autopilot
- Web reports

2nd day

Afternoon – Safety and operation at exceptional conditions
Operators

- Manual stacker crane drive modes
  - MDI drive
  - Manual drive
  - Forced drive
- Recovering from error situations
  - Stacker crane alarms
  - Device alarms
  - Shut down controlled by UPS
  - Emergency stop
  - System status diagnostics
  - Contacting service
- Safety instructions
  - Stacker crane
  - Loading and material stations
  - Emergency stop
- System shutdown and start up
  - Autostart folder

3rd day

Morning – Exercises
Operators

- Repetition
- Practical exercises

Afternoon – Final test and IT (Conference room)
Operators
IT personnel

- Final test for operators
- Training diplomas
- System information for IT
  - Controlled system shutdown and start
  - Backup system
  - Admin rights
  - Remote system
  - CDs

Program

FMS Start up Training

1st day

Morning – Introduction (Conference room)
Operators
NC programmers
Production planners
IT personnel

- Briefing
  - Checking the resources
    - Network
    - Machining pallets
    - Fixtures
    - NC-programs
    - Tools
    - Materials
    - Material pallets
    - Item information
  - Training contents and objectives, timetable and participants
- Introduction
  - FMS overview
  - FMS components
    - Hardware
    - MMS Control software
  - What happens during automatic machining cycle?
  - Documentation
- General safety issues
- NC program header (For NC programmers)

1st day

Afternoon – Introduction
Operators

- User interface
  - MMS Process and MMS Planning
  - Windows (Control Room, Loading, etc.)
  - Colors and symbols
- Pallet locations
  - Putting pallets in and taking out
  - Fixtures
  - Changing the pallet locations
- Loading stations
  - Moving, tilting, lifting
- Stacker crane
  - Automatic drive, transferring pallets
- Introduction to manufacturing routes
  - Making a simple route

2nd day

Morning – NC library
Operators
NC programmers

- Editing program data
  - Run time calculation
  - Program type: main / sub / parameter
  - Security class: locked / automatic start disabled / free to run
  - Program class: temporary / constant / data server
- New NC programs
- Transferring NC programs
  - Accepting programs from CAM
  - Sending programs to CAM
  - Accepting changed programs from the machine tool

Afternoon – Automated manufacturing
Operators
Production planners

- Creating items
  - Resource material
  - Manufacturing operations
    - NC programs
- Material handling (If MMS2000)
  - Using material station
    - Entering new pallets and new material
      - Fixing a batch with an order
    - Taking material out
  - Material locations: outside, material cell, and storage
- Creating and editing manufacturing routes
- Production planning and scheduling
  - Creating and handling production orders
    - Importing from a file
  - Adaptive priority calculation
  - Resource checking
  - Handling defective parts
- Loading wizard and autopilot
- Web reports

3rd day

Morning – Safety and operation at exceptional conditions
Operators

- Manual stacker crane drive modes
  - MDI drive
  - Manual drive
  - Forced drive
- Recovering from error situations
  - Stacker crane alarms
  - Device alarms
  - Shut down controlled by UPS
  - Emergency stop
  - System status diagnostics
  - Contacting service
- Safety instructions
  - Stacker crane
  - Loading and material stations
  - Emergency stop
- System shutdown and start up
  - Autostart folder

Afternoon – Tool magazine and option modules
Operators
The ones concerned

- Tool magazine and tool check (If MMS4100)
  - Making magazine query
  - Magazine planning
  - Tool simulation
- Other MMS option modules
  - Capacity simulation (If MMS3100)
  - Machine data logging (If MMS5000)
  - Remote alarm (If MMS5100)

4th day

Morning – Exercises
Operators

- Repetition
- Practical exercises

Afternoon – Final test and IT (Conference room)
Operators
IT personnel

- Final test for operators
- Training diplomas
- System information for IT
  - Controlled system shutdown and start
  - Backup system
  - Admin rights
  - Remote system
  - CDs

FMS Start up Training

INFORMATION

Trainees:	System operators (max. 4 operators) Production planners NC programmers IT personnel
Place:	Customer's works
Duration:	3-4 days
Needed resources:	FMS Machine tool Palettes Fixtures Raw materials NC programs Tools Item information

DESCRIPTION

The course prepares the users to set up the operation of a FMS and to use it under typical operation conditions. Demonstrations and exercises include inputting all the data that is needed for automatic operation. The operators will practice using all the system components in manual and automatic operating modes as well as preventing faults and recovering from error situations. The course consists of following subjects:

- Operating a FMS safely
- Operating system components in automatic and manual modes
- Inputting pallet and fixture data
- Handling NC programs
- NC program header
- Creating items
- Creating and editing manufacturing routes
- Creating manufacturing orders
- Recovering from typical error situations
- Contacting service

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Operator test
FMS Start up Training

Name: _____

Company: _____

Date: _____

Choose the right answers to following questions. There might be one or more right answers.

1. Crane access to a loading station is blocked. Possible reasons are
    a) User doors are open
    b) There is no palette in a loading station
    c) Crane is already in a station
2. An operator is using the crane manually. Automatic movements are disabled because
    a) The emergency stop circuit is broken
    b) The key switch is offline
    c) Security door is open
3. A palette is loaded and sent to the route. The tool check is failed to perform. The palette will be moved to the storage and marked as
    a) yellow
    b) orange
    c) red

4. An error occurs during machining. The palette will be moved to storage and marked as
    a) yellow
    b) orange
    c) red
5. Editing the route of a palette is possible when
    a) The palette is not loaded and is in storage
    b) The palette is loaded and at the loading station
    c) The palette is not loaded and at the loading station
6. The system is equipped with a UPS. In case of a power failure
    a) A controlled system shutdown will be performed automatically
    b) The user has to perform a controlled system shutdown
    c) The system can be operated with a battery
7. The adaptive priority calculation is based on a CR value. The CR value is
    a) Ratio of available and needed production time
    b) Ratio of number of ordered and finished items
    c) Ratio of manned and unmanned production hours
8. To set the priority of a production order lower (higher CR value) the operator can
    a) Set a later due date
    b) Reduce the number of ordered items
    c) Delete other production orders

9. A NC program is edited at the machine tool

    a) The changes will be actualized automatically

    b) The user has to load the program to FMS to accept the changes

    c) The system will automatically delete the program from the machine tool memory

10. To perform a controlled system shutdown the crane has to be

    a) In automatic mode

    b) In MDI mode

    c) Stopped by emergency stop

11. The machine tools in a same NC group

    a) Can run the same NC programs

    b) Have the same cutting tools

    c) Are manufacturing the same items

12. Before resetting the emergency stop circuit the operator has to

    a) Check the pallet locations

    b) Check that no people are in the storage

    c) Contact Fastems service