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Analysis of the Automation and the Human Worker, Connection between the Levels of Automation and Different Automation Concepts

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Abstract

Manufacturing is becoming a crucial part of now-a-days fast growing economies and increase of earth's population. Recently manufacturing is changing rapidly, different manufacturing strategies are being implemented, the conceptual understanding for manufacturing is changed, and new ways of producing products are showing up. Automation has been the essential term regarding the modern manufacturing processes. The human-machine sharing is playing a major role in the production systems, and the most elegant thing is to create and design the appropriate level for interaction between them depending on the desired outcome in the production area. Technological innovation is the implementation of new more efficient production method by achieving qualitative improvements of the goods and services in a specific area in this paper's case is a production system. This paper is regarding the importance of the correct production system being chosen for an organization regarding the right level of automation (LoA) being used, which is a way of controlling the overall effectiveness of the system. Different approaches and methods are going to be used for demonstrating the choice of the exact and right level of automation and the possibility of changing it by introducing and implementing the ongoing DYNAMO research on a different conceptual solutions for a foundry application in Factory-in-a-Box. The main objective of the research is to develop a method and system for supporting sustainable flexible and reconfigurable production system providing competitive industrial characteristics in the fast developing world.

Introduction

The Factory-in-a-Box project is an ongoing project in Sweden in the production area. The industrial partners taking part in the project are ABB Robotics, Flexlink, Pharmadule Emtunga, Volvo CE, Volvo Cars, Bombardier, and the Swedish Foundry Association. There are number of demonstrator projects ,which are dealing with automation tasks and the possibility of changing the level of automation standing for the name DYNAMO ,also flexible automated assembly (FlexAA),creation of robot paths (Robust Design&Variation Simulation),and the efficient transfer of experiences from one project to the next (EXACT).

In the ongoing DYNAMO project there is a scale of automation levels being developed LoA, and also a specific method for measurement of LoA in real production system .These DYNAMO aspects, however, have to be clearly shown and developed in the Factory-in-a-Box project.

Automation is regarded as one of the most important things in the manufacturing processes regarding the modern technologies and the society; by automation it is understand that there is an achievement in high productivity and increasing the company competitiveness on the market. The basic reasons for the automation are the outer demands and changes surrounding the process, as well as inner factors concerning the organizational and human resource level. The conceptual understanding for an automated system is being changing and at the same time it differs from the basic understanding for automation.

Different reasons are being regarded and taken in mind concerning the advantages and disadvantages of an automated system, where there is a well established collaboration

between humans and machines, a system, where flexibility is well defined as well as the human participation as an utilization instrument, which is regarded as a flexible and cognitive resource. The well defined allocation between technology and an operator is a contribution alliance for a competitive manufacturing system.

The research area in this project concerns the ability and the possibility for an automated system to be treated with respect the different levels of automation it is capable of and the change of the working environment due to the automation. A foundry level company desires to change its current way of producing its goods. The factory is trying to implement new technology, which will possess abilities for changing its working status and being able to switch its automation level. The need for this automation and implementation of such system is mostly orientated in improving the worker's working conditions and increase the production capacity, which is the primary issue for the company. Still there are obstacles related to the capital investment and the uncertainty of the new technology, but the ability and opportunity of building a new factory place reinforce the application of new modernized technology.

Objective

The main objective of this research is to present the capabilities of the human participation in the production manufacturing process, regarding its role in the automation and the mutual relation in between. In present days the need for automation is highly increasing, flexible and unique automation systems possessing the ability to switch from one automation level to another are the key to successive manufacturing. The ongoing research considering the Level of Automation (LoA) and the Dynamo project are considering the possibility of dynamical level of production with high flexibility and move ability.

Human participation in manufacturing processes is contributing with its flexibility characteristics and imagination. In our research we are considering the importance of a flexible production system, which is characterized as robust and flexible, because of the sharing levels of automation between the machine and the workers, the ability for portability and the mobility of the production capacity.

The recent manufacturing environment, improving of the working conditions and the threat of outsourcing are important factors leading to the necessity of innovation in the way of producing, which improves the overall manufacturing output of a company that leads to better position on the market.

1. Automation

Description

The basic description of automation is a very complex term in the modern society, because it covers a lot of different ways of manufacturing processes differing in their conceptuality and logistics. In manufacturing there are so many definitions what automation is actually, according to Hubka and Eder (1988) automation is "the progressively transferring regulating and controlling functions from humans to technical systems". High automated product is an important means for industry to meet the competitiveness arising from the low cost countries, due to the high wages observed in the developed world. In that time of rapidly changing technologies and changing environment automation is the source for handling with competition. According to the area of the ongoing research we will define automation as a bonding sphere between mechanization and computerization together. The following figure 1 visualizes this dependence (Frohm, Linsdröm, Bellgran, 2005):

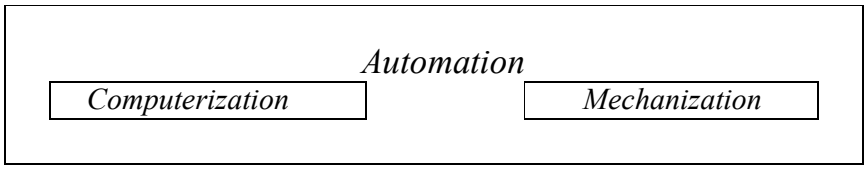


Fig.1 *Automation as a bonding sphere between mechanization and computerization (Frohm, Linsdröm, Bellgran, 2005)*

Automation has been and will continue to be in the future the most important part in the manufacturing, as the need of quick processes, achieving process targets with high quality and increased speed. However there are a lot of things that a fully automated system lacks.

As the automation progress develops rapidly the basic parameter of the manufacturing system are changing and now is spoken more about mental concern instead of physical one, regarding the developed nations. There are still some branches in the manufacturing areas where there are still some difficulties for automation and thus there is still a big concern about the human conditions with respect to both mental and physical aspect. By automating the processes the working environment is changing, the working conditions are improving and the worker's safety is changing, so even though the process is extremely difficult to be automated ,still the system can be designed in a way that machines are helping the workers and by that the overall environment would be changed.

Referring the automation it is a process, which has its routine from sensing the environment to data proceeding and decision making and going to execution of an specific action either a mechanical or information one.

Automation technology has grown so sophisticated recently, it is driven by market demands and technical and theoretical developments it is changing with a great pace. As embracing description automation is becoming major part of the engineering analysis and design in general, penetrating every traditional branch of engineering (Sheridan, 2002).

Different Automation and Production Systems

According to Miltenburg (1995) there are seven types of manufacturing systems ,which are being regarded as **Traditional Systems** ,which are job shop, batch flow, operation-placed line flow ,equipment-placed line flow ,continuous flow and **New Systems** ,which are Just-in-time(JIT),Flexible manufacturing systems (FMS).Attention will be paid on the new manufacturing systems particularly in the FMS .According to the description for a Flexible Manufacturing System (FMS) the computer system consist of computer controlled machines and automated delivery system ,everything being controlled by a supervisory computer. Everything in the system is very flexible and at the same time it has the possibility for variations in the products. The overall manufacturing output from the FMS is equally distributed among their components.

Stressing on the FMS and describing it above it is said that this paper will distinguish the difference in the conceptual understanding of flexibility. By flexible system it is understand that the system is fully automated, by means of any human presence at all, thus flexible system (FS) in this paper is a system, where the human presence is playing a key role in the manufacturing process. The (FS) is a system with high flexibility in changing the state of the automation level. Excessive level of automation may result in poor operator performance and loss of specific working skill and loss of situational awareness. Never-the-less the main evolutional path that is taken in the manufacturing systems is to replace the human worker with a machine it is still well defined and known that humans are taking a very important role in the manufacturing process and that will be described later on. Automation should be very well designed in order the process to function properly. As mentioned before the optimal output of one production system is the interaction between human and technology.

There are different reasons to be considered when it is spoken about automating one system and changing some parts of it (Groover, 2005). Automation system is one, where human presence is limited or automation is the replacement of human worker by machines. There are several reasons for one system to be automated and thus they are:

- the increase in labor productivity
- the reduce of the labor cost
- the mitigation of the effect of labor shortages
- the reduction and in some cases elimination routines of manual and clerical tasks
- the improvement of worker's safety
- the improvement of production quality
- the reduction of manufacturing lead time
- the accomplishment process that cannot be done manually
- the avoidance of high cost not to be automated

All these reasons have their explanation and at the same time they demonstrate the basic principles and information why the system is changing and how that affects the production output. Labor productivity and the increase of the production rate, the increase of the labor cost leading for automation, lack of workers, prevention of routine and boring tasks, safety conditions for the workers, precision for the work and reduce of defects, reduction of the

production time and time between order and delivery, ability to evaluate operations and tasks that are impossible for humans, increase in salaries and the product quality, all these reasonable explanations have leaded the industrial productivity to change and to develop in the field of automation. Automation is defined as a technology concerned with the application of mechanical as well as electrical and computer-based systems all working together operating and controlling the system while executing a production task.

Automation is appropriate at performing complex operations at one time and solving problems with great batch orders and quantity, that's why it is a necessity for a modern production system with all its parameters and complexities, but the case is not always to show solving and showing a technological sophistication (Wickens, 2004).

1.3 Humans in the automated systems

Humans remain the most flexible and powerful weapon for solving and accomplishing planned and unplanned problems during the production cycle. According to Groover (2005) there are several factors, which have to be considered when speaking about the advantages and disadvantages of manufacturing system and the interaction between man and machine. There are certain cases when the manual work is preferred over the automated one:

- Task is too difficult to technologically difficult to be automated. This is the case when due to technological or economical reasons the system couldn't be automate. The technological aspects for those difficulties embrace the inability to access to the work location, different adjustments, which includes the necessity of changeovers during the process and the requirement regarding adroitness and coordination.
- Task includes a production with a short life cycle, in that way there is no necessity for a complicated automation system ,because it would be economically inappropriate having in mind that the product will probably be on the market for relatively short period of time. In these cases tooling necessary for the production is easy to produce instead of an automation system.
- Task regards production of customized products; these are the cases when there is a demand for uniqueness.
- The production undergoes constant changes in the demand in cases of production output levels. These cases are not so common regarding the modern production systems, but still there are cases when the changes are too complex. On the other hand there are complex situations when the capacity of the automated system is too small for the current desired production output, in this case human labor is being added to the production system.
- The case of introducing a brand new product, the case when the market is uncertain and there is no clearness about how successful would it be. It depends on the life of the product as well; some of them are made to be for a short time. In this case the manual work prevents the loss of company's investments.

1.4 Humans in the automated systems, never everlasting contribution

When speaking about automation it is understand the changeover of humans in the production system with machines, never-the-less there should be considered factors, which are playing an important role in the production systems not only from dynamical and flexible point of view, but the strength of human labor comparing it with the machines. The following table 1 represents the strengths of the humans vs. machines (Groover, 2005).

Relative Strengths of Humans	*Relative Strength of Machines*
Sense unexpected stimuli	Perform repetitive tasks consistently
Develop new solutions to problems	Store large amount of data
Cope with abstract problems	Retrieve data from memory reliability
Adapt to change	Perform multiple tasks at the same time
Generalize from observation	Apply high forces and power
Learn from experience	Perform simple computation quickly
Make difficult decisions based on incomplete data	Make routine decisions quickly

Table 1. *Represents the strengths of the humans vs. machines (Groover, 2005)*

There are several factors that should be considered when we are speaking about automating one process and considering the advantages of it and at the same time the lack of the human presence in the production system, because there are areas in the production system, which will always be regarded and considered as a human's zone. Groover (2005) considered them to be as follows:

- Maintenance of the equipment, where skilled workers are required to maintain and use the equipment, never-the-less it is fully automated or not.
- Operations, which are connected with programming and computer literacy, as well as the overall development of the system regarding software upgrade despite the fact that it is expected in the future artificial intelligence will be more presented.
- Development of projects, upgrade of equipment and creation of new tooling.
- Planning the factory layout and the running the factory, which means that there should be sufficient staff possessing the necessary knowledge for running the plant. It is considered by means of manager technical skill.

2. Human Factor

Since human element is one of the most important parts in the production system with its flexibility, innovation, quickness and imagination. Human part in the production system is

still considered to be the incomplete part in the full automation system, because it lowers the level of automation, but at the same time it contributes a precious flexibility and cognition, and at the same time maintaining the robustness of the system. The human consciousness that originates in the brain and is manifested especially in thought, perception, emotion, will, memory, and imagination, this is the thing that the mechanized system with so high level of automation could lack.

Cognitive ergonomics refers to the modern understanding about the human presence in the automation. With the changes happening in the industrialized world it is seen that humans are doing less physical work than before, but still it in some branches it is very common to have such. Recently it is spoken about mental fatigue in the automation regarding attending, remembering and basically thinking.

People mostly don't understand the automation as a whole, as it is growing more sophisticated with time. Automation in its behaving is silent and impervious, so people cannot reveal and predict the current behavior at this moment and the next step. Consequently when automation fail it is very difficult for the operator to determine the origin of the problem and the correct action that has to be taken. In the well developed automation branches most of the systems are so automated that the system is overtaken the process and the workers over trust the system and are not acting independently any more, this restrains the human part to take action in the process .Human factor designers in the production system usually use two bases regarding the process design, originating from the engineering point of view and experimental in the field of psychology and other human sciences. There is understands the use of statistics in the process originating from observations and as well as the implementation of mathematical models where appropriate.

When designing a system usually it is considered a real environment, where all the tests are made for the appropriate functionality as well as the usage of a simulation. It is essential in the design process to consider the human factor early, because later on after the design has been done there is little opportunity for correction of any imperfections (Sheridan, 2002).

2.1 Main Goals in Human-Machine Design

When making a human-machine system design process the most used process is called a test analysis, this is the analysis when a breakdown of overall tasks is made into their elements and the specification of the different elements, which are related to each other in space, time, and the functionality between them .The task is a complex term, which relates to a lot fields of research, from the design of a given thing to monitoring the process and at the same time the term can regard to a subelement in the system.

At the same time when an existing automation system is being improved the essential thing is to reconsider the whole task analysis, which is due to the fact that automation is changing due to the change in the demands and responsibilities, which is sometimes unexpected and unplanned (Sheridan & Wickens2000).

When analyzing an existing process the visual representation of the process is of a great importance as well as clearness of the variables, which are dependant and which are not. Regardless of the complexities you have in visualizing the weaknesses of one system there are usually used techniques related to mathematical analysis, block diagram representation, arrow influence, flow charts, statistical analysis, timelines and so.

When analyzing one system it is very useful to synthesize the information required, the decisions that are being made and have to be made, and the control of the plant processes, the

work done so far. After the entire analytical step very important is the decision making process, the feedback of the work done so far. The analysis should be separated from the existing real condition so far or to be distinguished in order to have more good visualization. Since many accepted techniques exist for investigating task analysis of a system there is no accepted way of making these allocations. The first reason for that is basically connected to the fact that even if you break the tasks into pieces, these parts are rarely independent and the interaction between components is different. The interaction between the human and computer differs in different options to choose from. The various human-machine relations are difficult to be quantified and are implicit. Basically there is no universal way of locating and describing the task allocations.

2.2 A Human-Machine Interaction

Engineering one system is usually regarded to allocating the elements within it, in particular the relations and tasks between humans and technology, considering on the fields, which should be automated with respect to appropriateness for humans in the future. One of the first concepts considering the function allocations in the system is MABA-MABA list, which was developed and presented by Fitts(1952).In present days this list has a different usage than the time it was made. It is used usually for determining the differences in the tasks and in particular, which task should be automated and, which shouldn't.

Jordnan (1963) was the person who described the model as a list of tasks, which purpose was to connect humans and machines in particular and then to consider, which is best for each task. In that case it can be seen that by knowing humans as a machine leads to knowing how to replace humans with machines. The most important aspect of this study is to try not to compare humans with machines, but to distinguish the differences between machines and humans with respect to what they do best. People and machines are complementary. Even though there have been other interpretations of Fitt's model it stays irreplaceable in its simplicity and understandability. The following table 2 represents the MABA-MABA list:

Men Are Better At	Machine Are Better At
Detecting small amounts of visual ,auditory, or chemistry energy	Responding quickly to control signals
Perceiving patterns of light and sound	Applying great force smoothly and precisely
Improvising and using flexible procedures	Storing information briefly, erasing it completely
Storing information for long periods of time and recalling appropriate parts	Reasoning deductively
Reasoning inductively	
Exercising judgment	

Table 2. *Fitt's model MABA-MABA*

2.3 Relation between Human and Automation

The improving of performance and reduction of cost are the primary issues that automation justifies. The implementation of automation is usually connected with reduction of the human cost, basically expressing the human involvement in the process. The process of automation is expressed in some different cases as the necessity, which will increase the human safety in the production process. Humans play major role in the design process, development, maintenance, installation and the whole management process.

When evaluating the manufacturing system it is important to consider that the technical implementation of the system is insufficient when evaluating a performance of a system. Most of the elements that are performed by humans can't be expressed in technical term.

By human performance it is important to be understood that it is not the superior participation in the system the primary goal, but the collaboration within the system elements. Since the human response is limited in time, the system should be divided into subtasks in the overall downstream, explained in the differences in tasks. There is a difference between human participation in the process and different levels of interaction with the system elements, which are expressed within the different levels of automation LoA.

Within the manufacturing systems there are limits, which have to be taken into account when designing and evaluating one system, in most of the cases these are surrounding disturbances, which influence negatively on the worker's performance. The task itself influence the worker's performance, in case the task is an easy one, with less complexity ,the working process speeds up and the opposite, when it is more complex it slows down.
When the task is cognitive the training is of a great importance for the worker, because otherwise the effect of information overloading takes place and from this the mental stress occurs, which leads to human errors and fatigue.

Different reasons are always standing as the basic issues why to automate, in both of the cases, when we are changing existing system or when we are building new facility and applying modern technological automation. Reasons "Why to automate?" were explained in details, but two general reasons would be taken as the primary reason, these are the improvement of the working environment and the financial benefit coming from the automated system. These benefits are closely related to reduction of labor cost and saving in production time as well as the production output capacity. Automation in most of the cases is motivated by the desire to reduce the workload, which can be manual labor and cognitive work.

Mental workload is expressed in stress and fatigue. The results associated with these human conditions are related to bad working performance and at the same time human illnesses.
Fatigue leads to loss of sleep, heart problems, and muscular tiredness. Usually stress and fatigue are not clearly defined.

There are areas in the manufacturing now-a-days, where the working conditions and working environment exceeding the accepted levels of human safety and acceptable standards. The main reason for this is the fact that the existing system is rather difficult to be changed and partly automated, which will eliminate the hazardous work and difficult tasks thus that will improve the working conditions and the overall environment. This is rather complex since, there is a need for different levels of automation and mutual sharing between the machine system and the human, as it will be seen in the LoA model.

2.3.1 Human Errors and the Automation System

Human error is defined difficulty with regard to the origin and the definition based on this. Error is termed as the act or assertion that is unintentionally made and deviates from what is correct, right and true. When speaking about correct behavior we are regarding that something belongs to conventional principles and standard and incorrect behavior is the one differing from that norm. Faults and errors in human action are basically seen where there is a heavy cognitive load and outer disturbances. Human error is defined as this action that fails to meet some explicit or explicit standard, regardless of the performer or of different one. The defined standard is the principle characterization to which we regard the error; modification of the standard changes the categorization. Commonly it is the way that continuous variables are treated as errors if they exceed the fixed values.

Regardless of the human knowledge about the field and the actions they are taking, yet having the training to do it, humans shouldn't be treated as error-free. In the case when automation exists the best principle to be implemented is to inform permanently the operator about the behavior of the automation system and, which steps follows one after another (Sheridan, 2002).When error occurs in automated system the connection between the operator and the system is the source for that failure, the reason for this failure can be either from the operator or from the system itself.

Automation is the primary issue for an error-free environment. That happens in the cases when the automation doesn't fail and is robust and flexible, capable of handling different tasks. The design of the automation is made in a way that human participation interacts within it so that predispose for a human error within the system. In the automated system human error is not so well recognized, because the system accepts that error and commits the programmed task. The operator is unable to track the system unless there is a presence of constant manual inspection.

The design of automated systems should be done in such a way that it is transparent for the operator. The ability to see how the system is performing and how the automation process works, and be known what is happening step-by-step, without any unexpected occurrences. Sometimes the system itself is badly designed in a way that the operator is making an error, because of that.

The failure is different for humans and machines. Humans are unpredictable and behave sometimes in unexpected way, and the consciousness makes them able to cope with unexpected situations. Machines are reliable in a way that they perform tasks, which are only related to their capability, and machines can lack in their design a system, which can prevent a propagation of a small error.

Statistics cannot be typically used when trying to expose the processes of one system, which has to be changed or improved, especially when the processes are related to organizational behavior and management. The construction of a safety system is a primary task for a company, although that safety itself is considered differently in every different culture, which is considered as unacceptable from safe point of view (Maurino, 2000). Decision makers and designers of the system should focus mainly in implementation of a system mainly focused in categorizing and evaluating the hazards and controlling risks and preventing their existence, and at the same time to be opened for changes and improvements from lower levels.

When analyzing the current system and the subsystems inside it we can visualize the imperfections and weak places. Worker's motivation and other facts contributing to non-working system are underestimated, and in most of the cases the human factor is not highly considered.

2.4 Controlling the Automated System, Human Interaction

By speaking about controlling of an automated system it is not considered the whole process of controlling with respect to system control and computerization, but the supervisory control over the system. Supervising operator in an automated production system is a person, who is observing controlling and maintaining the process, particularly the human operator executes and collaborates with the computer program, the instructions ,which are used for executing a task, objective trade-offs, models and statements. The human operator runs the program and the system executes the commands independently of the operator, but using the sensing system, which depends on the different levels of automation.

Humans remain the supervisors of the system during the process, but at the same time may change the status of the system into direct manual control, depending on the task, which has to be performed and the difference from the usual model description in the stored memory, this process is described as a "trading control". And at the same time when the human and the system are working together in cases, when some of the parameters are manually controlled and others are controlled by the computer system, in this case it is spoken about "shared control".

According to Sheridan (2002) in the process of automation there are steps, which should be considered, when automating one system. At first the plan is needed for the whole process, then considering the need for instructions and model, which will be entered in the system as the information flow for the product, this includes commands and programs, for performing the tasks. When designing the automation system, the role of observing how actually the system works is the process of eliminating problems and failures. The next step is to find out whether it is needed to adjust any parts in the system as well as to change certain things. Finalizing and evaluating the whole system and its performance is the step where all the feedback is observed and the ability to learn from it. The ability of changing the levels of automation in the system provides the overall system with better performance and flexibility, the possibility for reconfiguring the processes and variability in design and structure; this differs from the existing linearity in production design and planning.

2.5 Automation Limits

The different tasks that have to be done either by a computer or by a programmed machine differ in their complexity and uniqueness. Sometimes it is more easy and fast to perform an easy task manually instead of programming a computer to do it. That saves a lot of time and money in programming and execution of the tasks, but at the same time tasks considered to be repetitive, similar and easy. This can be considered as the faster and more productive control of the tasks in the process, because it saves time, money and boring repetitiveness if the task has to be done manually, that is useful in the cases only when the task complexity is executed faster by a computer than the planning time and teaching.

There are cases when the tasks are so unique and difficult that it is almost impossible and useless to program a robot for executing them, it is really very hard to figure out a way for doing it. The programming is not the most useful and most economical way for doing it. Depending on the task and the environment, but it is really quicker to do easy tasks manually instead of programming a robot to do them. There are tasks even in everyday life when the implementation of a robot to do them is useless, human planning can not foreseen moments

in, which human creativity and flexibility of the mind overcome the speed and the robustness of the automation.

As mentioned earlier when the task has to be repeated many times once it is programmed and there are no points of the process when the conditions are changing and unexpected differences occur, the planning and the teaching time can be absorbed over the repetition. Usually when having large batch operations automation is economical, but for small sized batches or unique tasks it is not and it is done manually.

2.6 Evaluating the Tasks

There is a difference in tasks that are evaluated by the designer or by the operator of the system. There should be evaluation of the tasks and objectives regarding the conditions. There is no free will in design and the operation execution, because most of the tasks that have to be done have specific standard that they belong to, management policies dictate the processes, as well as the importance of safety operations, which relates to the design of the system and the working environment. When designing the system it is important to evaluate the objective function for automation, as well as the evaluation of the training objectives that are related to the need of a trained staff for execution of the tasks. The operator has the role for an evaluator of the mission objectives. The need for a function allocation between the humans and machines plays the essentiality for the properly working system.

The system designers are evaluating the system and design at what extend the human operator will be capable of handling with the desired system parameters. The human operator presumably meets the designer criteria as taking part in the system and does constant evaluation of the ongoing process. This covers the evaluation of plans, how the automation actually performs, managing with problems occurring during the process.

The whole process needs a skillful operator who will be responsible for the whole process and the need for a specific training is necessary. This needs specific training objectives to be taken into account when making the plan and design of the system.

2.6.1 Evaluating Techniques

Delphi method is a technique used for estimating, where the judgments are made based on numerical and rank evaluations, the statement of reasons why the need of some action is necessary, the results are usually not obvious and stay anonymous, because they are shared within the group. The method is based on a structured process for gathering and receiving knowledge from a group of experts by means of a series of questionnaires followed by controlled opinion feedback (Adler and Ziglio, 1996). Delphi research is usually used as a communicational powerful device as distributing the necessary information between experts, and thus the formation of a group judgment appears. The method is used for forecasting and is usually successive in making the decisions between experts possible without permitting a social reciprocal action usually happening on regular group meetings where the difficulty of forming an opinion occurs. According to Fowles (1978) anonymity, controlled feedback, and statistical response characterize Delphi. The group interaction in Delphi is anonymous, regarding that comments, forecasts, and the like are not identified as to the creator but are presented to the group in such a way as to keep down any recognition. The need for questions

has to be asked before making the decision of selecting the Delphi technique (Adler and Ziglio, 1996):

- What kind of group communication operation is desirable in order to explore the problem?
- Who are the people with sufficient knowledge and skills regarding the problem and where is their field of studies located?
- What are the different techniques available and what results can sensibly be expected from their application?

When to the above questions is given an answer it can be clearly be made a decision whether the Delphi method is appropriate to the field in which it is going to be applied.

In general, the Delphi technique is appropriate in answering one, specific, single-dimension question regarding the field that is being investigated. There is less support for its use to determine complex forecasts concerning multiple factors. Just in the case when we are using it to answer the question whether it is appropriate to automate the system or not, and what will be the consequences from that.

Multidimensional scaling method is a quantitative method. It is mostly oriented in not giving an overall quality scores and choice, but it is rather oriented in differences between the pairs and alternatives, which can be seen between the different options. Usually it is used with the help of scales and plots. The results are usually analyzed and with the help of the graphical representation the conclusion is being made for the factors, which affect the system the most.

2.6.2 Value Stream Mapping Method

Value Stream Mapping (VSM) is a powerful tool that dives you the opportunity to identify the waste in your company and production system and to modernize the processes for getting rid of waste and improving the working system. The method is very useful in giving an overall look of the ongoing processes and identifying the places in you line, which has to be improved or changed.

The method is very productive in identifying the company's parameters such as:

- Reduction of the lead time
- Improvement of the product quality and the company utilization
- Reduce the scrap and inventory level
- Reduction of the cost of the labor

Value Stream Mapping helps to identify the current flow of material and information in processes for the products, evidently showing the opportunities for improvement that will

most significantly impact the entire production system. Implementing the method during the process gives an opportunity for correcting some parts of the production system; VSM has shown the ability to increase the chance for success.

The application of and adoption of production technique and the necessary equipment for reducing the waste and improving the overall quality of the system itself and the products is very important for companies recently (Sullivan, 2002).

The tool is important for visualizing the operations in the process and improvement technique for the production. It seems that the impact of the technique on the processes is relatively low when the complexity of the product is high, due to the complexities of the value added activities.

2.7 Decision Making in Automation

Workers at the factories and other places where automation is being implemented and takes place usually look suspiciously the automation process. People trust more human than a machine regardless whether the automation is reliable or not. Humans are making mistakes as well as the machines do failures and mistakes. Regardless of the mistake is done humans and machines are having a lot in common, as well as they differ enormously in a lot of things.

Humans are variable in their decision and despite the fact that they should do something precise they express creativity every time they do something. Unpromising in the detailed work they are doing, but humans are very adaptable and stable in their whole behavior, because they are very perceive and correct their mistakes.

Describing the worker at his work place we have to regard him as a human being not only a part of the automated system. That affects many of their decisions in the working process, prefer benefit to themselves, the salaries, the working conditions, the one they loved, social class and other factors, which shouldn't be underestimated. This is what everybody should expect, because it is not related to social status or morality or religion, humans are taking decisions sometimes affected by their emotions. It is the lack of overall clear definition of the probability and utility that people are lacking (Sheridan, 2002).

2.8 Automation Affecting the Personal Behavior

Automated systems are designed in such a way that usually humans are removed from the process even temporally. This includes their functional and cognitive contribution in the process, which is ongoing. That is basically, because of the difference between the human and the automation process, which is expressed in different timing, different logic in what the automation does actually and what it "thinks".

Automation is breaking the monotony related to repetitive work and boring operations, which characterize it. This is not always true for the better mental condition of the workers, because workers will not be as satisfied from their new role as supervisors and monitoring the process. People should be more involved in the process to extend where it is possible and receive satisfaction from what they are doing should be a primary objective for companies' strategy.

2.9 Automation Extends

People who haven't deeply been involved in the automation processes and have no sufficient experience with automation regarding the technological aspect of it are treating automation as the system controlled either manually or automatically, with no connection in between. As the robots are becoming a major part of the automation systems recently, no serious attention is being focused on the design, installation, maintenance and other functions mainly done by the humans. There are extensive discussions regarding the human and automatic machine saying that they are and will be always closely connected and collaborating together.

Considering the state and the progress to which the automation is extending it is clearly seen that there are different and unexpected situations, in which automation is incapable of handling them. Different states of the automation level and degrees of automation are characterizing the flexibility of the system.

Regardless of the automation degrees that are developed and extend to which the automation is developed there is no answer about the limits of automation and its boundaries. The way to full automation with no human involvement depends on so many criteria and at the same time it depends on the situation in which the automation is being made. As the automation level is getting higher and the human participation is limiting in the process there is a tendency that the systems are safer and cheaper, but at the same time they exclude the human level participation at greater extend and the control is decreasing. For some tasks designers of automated systems accept that the tasks that can be automated should be, and the others not, depending on the manufacturing output, but keeping the human participation in them, because the system is safer in this way. People are trusted more than machines, because machines are unable to be predicted what they will do, despite the fact that the machines are programmed and known what they will do. Humans are more capable in handling with the unexpected situations, which depends basically on their literacy. The task is to define the capability to range from the different states of automation level from fully automated to fully manual.

Human centered design of an automation system is the case when automation isn't the only thing which is considered in the design process, but the human participation in it as well. In the design process of an automated system, the allocation of the different tasks is the way, in which the system will work, allocating the tasks suitable for the man and allocating the tasks suitable for the automation. Achieving the most suitable combination of human and automation control is the most desirable output for one automation design.

The human factor is playing a major role in the automation system since it contributes with the properties of creativity and free will. Desirably human operators keep these characteristics and apply them to the workplace with wisdom and flexibility in the thinking and that makes them different from the monotony in the robot's behavior with its plainness and inflexibility.

3. Flexibility as a Company Strategy and Innovation

A strategy is an important part of the company strategy; it is related to a lot of objectives and business strategies, which are based on planned actions for the competitiveness of the company. There are several aspects that are related to system's flexibility, and all of them are related to the overall output of the production system. In this research the competitiveness is expressed more towards the productivity methods regarding the flexibility of the system despite the product variability.

An increasing concern for the many manufacturing companies is the ability to compete with low cost countries, and so one of the answers regarding this is the implementation of automation in their productivity.

Flexibility in manufacturing has been a great concern, because it is a great competitive factor now-a-days. In the fast developing industries flexibility is becoming necessity. When speaking about flexibility the concept have different meaning every time it has been used. Slack (1990) defines flexibility as a different level hierarchy, starting from resources, system flexibility, production performance and overall competitiveness of the company. This paper deals with the importance of having a system flexibility in the way of producing goods, which leads to overall competitiveness of the company in the same area of production. Another classification of flexibility is the ability to adapt to the changing circumstances (Linder, 1990).

Machine flexibility will be the classification that is most closely related to area of this research, which is a premise for successive process and product flexibility with a lot of abilities, mirroring in the overall system.

Flexibility is a multidimensional concept that couldn't be measured as well as be clearly defined. From technological point of view flexibility characterizes processes as easier, faster and with capability of changing the level of performance and automation levels, reflecting on the manufacturing output. Flexible way of producing goods depending on the capacity and batch size, uniqueness of products and transportable way of manufacturing, one competitive weapon in the manufacturing production systems. Flexibility can be characterized as the ability to respond effectively to changing circumstances. Flexibility itself is the characterization of one manufacturing system to change and be sensitive to outer or inner changes and circumstances (Chryssolouris, 1996).

The flexibility is dependent on various resources during the production process. Labor and machines are being classified as the important resources for a flexible system (Gerwin, 1987). Most of the authors considering what a flexible automation system is, are oriented in the resource coming from the availability in the machine equipment capacity (Chambers, 1990).

There is a difference in the understanding for a flexible system from the two different sides. From one side manufacturing managers are considering flexibility as a solution in production processes and contribution to the entire productivity. Most of the analysis considering the resources of a system and its capacity are focused in one specific problem, which is insufficient for the entire analysis, which is made on the system. The change in one specific area in the system reflects mostly on other parts of the system. Flexibility contributes to more deep and overall collaboration between the systems parameters, thus the most important is the aspect in the mutual connection between the machine equipment and the workers.

The treat of outsourcing the productivity to low cost countries is part of a money saving strategy. At the same time possessing the necessary equipment that will let flexible production and portable abilities, which will provide the same manufacturing output is an important concern as a strategy for competitiveness. Keeping the production in the country of origin is a goal for successful manufacturing, there will not be a lost of control over the process as well as the production will contribute to workplaces in the same area of production.

Another definition of flexibility characterizes the system objectives and the flexibility implementations as the obvious and the appropriate response to the external uncertainties. It is defined as the "ability of the manufacturing system to adapt successfully to the changing environment and the conditions and the process requirements" (Swamidass, 1988).

3.1 Objectives

The present world is changing, the change is reflected in every field, but mostly we are interested in the manufacturing processes. The result is that the performance of the way we produce products in the production systems is a key for a strategic weapon withstanding the arising competition. The ability of one system to be flexible and be able to reconfigure according to the demands and circumstances is the primary objective for successive system.

Adaptation in early stages of the changing environment is important in taking part of the change instead of just observing the consequences. Certain organizational solutions are leading to better development in flexibility and reconfiguration. There are a lot of methods regarding reconfiguration of a system, but we are considering that the system is reconfiguring according to a demand in the work process. Globalization visualizes the processes ongoing in the world and the comparison in global perspective is more obvious. The different technologies and manufacturing strategies are pushing and speeding up the changes in the manufacturing processes. The uniqueness in design and competitive production system are important solutions for the growth in the globalization. Competing in the changing environment is a necessity that is related to acquiring and implementing new technologies and innovations in production systems.

Global competition and outsourcing creates a delicate and specific environment that place the surviving in the manufacturing harder and uncertain. That also provides opportunities for innovations and creation of new technologies, contributing to sustaining in the market.

The environmental changes are influencing the production systems and it is spoken more for whether trying to keep the production inhouse or to be outsourced to other countries and companies. This leads to questions of how to change and improve the existing manufacturing systems.

Competitive advantages are differentiation and lower cost (Potter, 1990), which are premises for flexible successive system.

3.2 Robustness and Strategic Orientations

Implementing a change in the production system is usually connected with a plan, which was developed in advanced and which leads to some desired results and outputs. That is connected with budget for implementing these changes. The robustness and the flexibility of that change reflecting in the production systems will characterize the desired achievement. Robustness determines how well the change applies to the new environment. From strategic perspective it is important for one system to be able of producing different activities and it is even more important for that system to be able to produce similar activities in different way, characterizing the system with competitiveness among others. Leading operational effectiveness for successive productivity is placing advanced technology, working environment, eliminating waste, motivation of the employers as an important characteristics

for the overall good manufacturing output. The operational efficiency is important for the constantly improving the goals of the company and the overall output. Flexibility is a successive way of reacting in now-a-days' business environment. The strategic goal is the necessity of strategic flexibility (Hayes, 1994).

3.3 Changing Abilities

Ability to adopt the production system to the response of changing needs and demands is the reconfigurability of the system, which is the system ability to adopt, be changed and customized. This paper is dealing with the possibilities and advantages of one system to be able of being flexible, movable and reconfigurable. Flexibility characterizes the system with the ability of being able to handle with the changes in the existing production system. Flexibility is a successive weapon for dealing with unexpected system changes; the main advantage is that the system doesn't need change of its current status. The main advantage of such systems is that they are designed in a way that they are capable of handling with changes in the existing production system without changing it, just using another state of the system.

Mobility of the system is something that characterizes one system as a competitive one; it contributes to the system with the ability to be portable and changeable, which is due to its design and abilities to be reconstructed and deconstructed. The flexibility is expressed in a way that the production system isn't build with restricted parametrical abilities in its variety and production capabilities.

3.4 Flexibility related to Production System Changes

As mentioned earlier the fast changing environment in the productivity recently raises the demand for different design and uniqueness in the production systems. The system development and system design to handle changes is the primary task for handling with the overall changes in the competitive manufacturing.

Flexibility and changeability reflect in the capacity demands and robustness of the system. The reduction of the cost, flexibility abilities, quality, reduction of waste, achieving better working conditions, reduction of the lead time are important parameters by which the overall manufacturing outputs improve. These important parameters can be designed into the system with the ability of reconfiguring of the operations and the usage of different automation levels, which will characterize the flexibility possibilities.

The recent outsourcing strategies and developments of new market relations lead to a need for reconfiguring capabilities of its production operations and system behavior, which is achievable and express the enormous need for a flexible system development.

Customization is a term characterizing the product's uniqueness and its difficulties in producing. This difficulty can be expressed as well as in the uniqueness of the product design and the difficulty for its treatment. In order to handle with these obstacles, the system requires capabilities in handling with these complex operations and difficulties during the process, these demands are achievable with the help of flexible machine system able to reconfigure, perform difficult tasks and interact better with the workers and the changing environment.

By achieving the desired flexibility of the production system the product variety extends as well as the production size.

Complex operations are usually associated with large number of workers handling with them, and these tasks can be associated with inappropriate working condition and environment, which lower the manufacturing output parameters and overall competitiveness on the market. Designing the system in a way that these obstacles can be overcome and the system improved by applying capability in changeability of the production system and effective adjustments during the production, that is becoming a necessity. This will lead to better competitiveness on the market, and improvement of overall manufacturing outputs.

3.5 Evaluation of the Flexibility

Evaluation in the strategic directions means in most of the cases the ability of evaluating the production system design. The evaluation process can be achieved and represented in several steps according to Bennet (1993):

- Evaluating the presence of shortcomings in the performance of the system, the starting point of investigation is finding out the needs and areas, where a change is necessary to be made, then the installation and implementation of new machines and technology. This eliminates the performance gap in the operations.
- Evaluation of the system performance by evaluation and measuring of the company's targets related to productivity, quality, cost, human resource, manufacturing output.
- Evaluation of the operational overall performance of the system, this is related to considering the important elements of the system with respect to physical system design, control and integration, and work design, these designs are important for the system performance, and they are evaluated one after another, the physical system is a predecessor for a specific work design and organizational behavior.

Other evaluations won't be considered, because they are not relatively close to the overall goal of the project issues.

As a conclusion the presence of suitable and appropriate environment for developing new systems based on technological and organizational changes is a premise for successive and overall manufacturing output. The evaluation stages are related to analysis and investigation of the company's current condition. These evaluations are related to the impact of the business environment over the company, the performance measurement related to that, the competitive advantages and competitive dimensions (Jakson, 2000).

Whenever there is a problem in one production system the need for finding out this problem and isolating it is essential in making the correct and appropriate changes related to the current production status. In order to find out what the problems and reasons are and where the system is having gaps there are several fields, which should be considered when analyzing the system. The analysis is related to:

- Internal manufacturing or the way of outsourcing;
- Efficiency and effectiveness of the current and the desired system;
- The value system analysis;
- Effect of flexible capabilities of the system.

Analyzing and identifying the problems and errors of the existing systems, identifying the need for improvement and the targets for development has been specified then the next step is the development stage to be started, which is related to acting over the system. During the implementation process different alternatives will be proposed and changes will be seen, as well as constant evaluation of the decisions taken and being implemented. Generally considering the system design (technologically and functionally), and improving the change capabilities. The most important aspect is to change the system design which will lead to overall change in improving capabilities. The need for a specific plan and project management is necessary for the implementations of all the decisions and actions being taken, this area is quite important for the impact of actions being taken and applied over the system.

The conclusion based about the flexibility of one manufacturing system can be made as based on a buildup of the process and its characteristic, the design of the facility and its capabilities, and the infrastructure of the plant. As it is represented on the following figure the more is the presence of process, design and infrastructure the more flexible the system is.

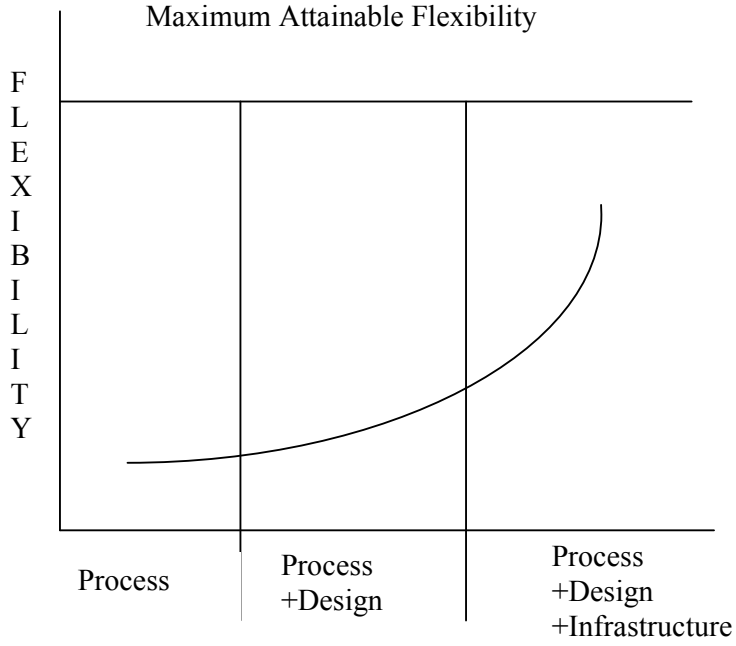


Fig. 2 *The importance of process, process and design and the additional presence of infrastructure (Swamidas, 2000).*

3.6 Balanced Automation System

The role of the human operator has been changing with years and the tasks that have been executed changed with time. The reason for this is the evolution from simple tasks like loading and unloading to more advanced operations such as operating the automation processes. The change affecting the process was expressed from the modernization of the machines and processes, thus the role of operator has become more important and appreciated. The knowledge that is necessary and the experience is of a skilled operator manipulating the processes is quite difficult and expensive to be achieved into the system. The reason for the automation implementation is being discussed and the reasons and factors affecting this decision are the primary reason. Humans are becoming an increased cost of the process. But at the same time the cost for modern equipment and intelligent machines has been decreasing comparing with the cost for a human operator. The ideal condition is the balance between appropriate necessary skilled operators and the presence of such equipment.

A well balanced automation system is defined as such a system that combines the automated and manual activities and the machines. The effect of the changing environment reflects in the cost of the product, because the cost is connected with the price of the equipment and the machinery.

One's operation list describes the steps that have to be taken in the production process on a specific facility. The mapping is one of the main activities that have to be obtained by the supervisor (Fabian, 1995).

The achievement in making the study of the system and identification of the conditions under which it is appropriate to rely upon either on an operator or an automatic system is the necessary output. The adjustment made are done by considering various relations and aspects such as time for productivity, money regarded to savings, safety considering the humans, flexibility in production and quantity.

3.7 Automation Concepts

The satiation in which the exact amount of automation is necessary to be implemented is governed by certain number of concepts, which are time, safety, flexibility and quality. The concepts and how they affect the system are considered below:

- Time

  This concept is typically associated with the level of automation and how this level affects the productivity. The higher the automation the faster the production is and thus it saves time, this is not always the case when speaking about high automation. Another aspect of this is that it is difficult to optimize the production, and that leads to longer overall production time.

- Money

  This concept considers the relation between the identification between the degree of automation and the costs and savings. The basic concept is associated with the relation in which the normal operator is replaced by an automatic system, which is reduction in the

cost, because the human worker is considered to be the most expensive part of the system, but as well in this case this is not always true, because the operator can be as well cheap and sometimes the production system demands such one, because otherwise the process is unachievable. There are cases in which it is more appropriate to use humans instead of unmanned automated machines.

- Safety

This concept is oriented mostly in automation, because the automation is limiting the human participation in hazardous and dangerous processes. This leads to reduction of injuries during the process. Despite this when it is considered the services it is usually safer for one operator to work manually in an operation system.

- Flexibility

This concept is concerning the advantages of the human operator over the automation system, because when speaking about flexibility man is the unbeatable. When there is a need for flexible operations man is preferable than a robot.

- Quality

The quality concept is regarding the automation as the source of improving the product quality. The introduction of computers, robots and intelligent machines into the productivity quality is improved.

Taking into consideration the safety and quality it is recommended that the balanced manufacturing system should consider the automatic material transportation, automatically operated machines, automatic synchronous material transportation as factors reflecting in the balanced automation system. These factors are affecting the balanced manufacturing processes' cost.

Number of automation levels of automatic control and production has been presented in order to identify the activities and the appropriate level of automation, with respect to allocation of tasks between the manual worker and the automatic system, this is necessary in achieving balanced automation system with respect to cost, flexibility, safety, quality. Certain parts of the automation system can be abandoned in order to reduce the cost and at the same time keeping the production quality. The cost of having reasonable equipment combining computers and powered together with machine capabilities is reasonable and affordable. The most necessary thing is that in order to be able to produce good quality products it is required to have the appropriate equipment.

3.8 Characterization of the Manufacturing Outputs

The manufacturing process is a complex mixture of different areas and branches that are working together for achieving an overall output of the company, which is important for the competitiveness of the company on the market and the reflection of the whole production on the customers and the entire internal and external parameters. According to Miltenburg (1995) for a company in order to succeed on the world market there are six criteria that are important for that. The table 3 characterizes the Manufacturing outputs.

Cost	The cost of the material, labor, overhead, and other resources used to produce a product.
Quality	The extent to which the materials and the operations are in accordance with the specifications and the expectations, and how difficult is it.
Performance	The product's features and how the design and the features permit the product to be different and unique among the others.
Delivery time and delivery time reliability	The time between the order and delivery time.
Flexibility	It is about the volume of the products, the increase, decrease, the speed with which it is responded, the way the products are produced.
Innovativeness	The ability to quickly introduce new different products and the ability to make adjustments of the existing ones.

Table 3. *Manufacturing Outputs and the Reflection on the Customers (Miltenburg, 1995)*

3.9 Productivity

The competition depends on the comparative productivity; with the increased competition recently mainly will the low cost countries the need for a manufacturing strategy becomes very important. Although there is no a precise measurement for the comparison of ones productivity there is an opportunity for individual production systems to be compared and ranked according to the overall manufacturing output.

One of the keys for achievement in the manufacturing is the integration of function perspectives into a strategic orientation, and it is important to explain the difference between the conventional approach for analyzing and different approaches.

Providing the manufacturing processes with certain advantage that distinct the company from the others on the market is a competitive issue. Manufacturing provides the market with uniqueness in new technological approaches in the processes and in the operations that are incapable to be done from the competitors. Providing the necessary support in essential way that will help the company to be strong on only on the production level, but as well on the overall market where the competitors are. The design and the processes are important part of the competitiveness of the company on the market, because that predominates the ability to win orders and reflects in the ability to change existing product lines with the demand of new needs with respect to quality, volume and quantity.

The achievements in the entire competitiveness of the production companies on the market is the necessity of involvement of company's strategy, which will be accepted in accordance with the marketing needs, company orientation and business demands. That is important for the long term decision process. The necessity of the company to be able to respond to the changing environment creates the need for system flexibility, adaptively positive capacity for demands (Hill, 1995). When the production system plan isn't successfully managed and the system strategy doesn't meet the necessary company's objectives, the company lacks the ability of making decisions and has difficulties in long term processes with system capability.

The necessity of clear defined company's objectives can protect the company from the inability to react over the changing environment, as well as the impossibility for the company to take clear and objective decisions and can be locked in undesirable routine.

Paying attention to the managerial decisions regarding the manufacturing inputs and that it is working properly in accordance with the company's main complex issues and objectives.

4. Sharing Levels in Automation

Machines are penetrating the human lives in the expanding and developing world. The automation is becoming a competitive weapon in the manufacturing. Despite the fact that the machines are sophisticated, efficient and with outstanding performance they are still machines (Jordan, 1963). Evolution in capability of the equipment is not seen only in replacement of heavy and dirty operations performed by human workers, or only do repetitive operations.

Various types of operations exist and are concerned with human sharing. As being mentioned earlier automation won't be considered as the total replacement of workforce, but the appropriate sharing levels existing in the production process. Automation is partitioned by tasks and by behavior. The tasks are physical and cognitive, and the overall behavior of the system is a mixture of all the tasks.

4.1 Task Partitions

Automation can be divided into tree types. They are control automation, information automation, management information (Satchel, 1998).

- Control automation assists the human in the guiding process of executing the task, and the machine movement through the dangerous tasks. The control automation is playing a role of an observer of the whole sub-systems.
- Information automation is this type of the system, which is changing very rapidly and it provides the system with information about the progress and the execution of certain tasks.
- Management automation allows to the humans to exercise not only demands oriented to technological actions and activities, but a strategic point of the automation process.

4.2 Technology-centered and human-centered Automation

Technology-centered automation is machine oriented automation, which achieve the goals with the help of machines, which is the leading factor with great importance. Technology-centered automation regards the ability of the manufacturing plant to automate and its capacity, not the decision which is based on the reason to automate (Sarter and Woods, 1995).

This kind of automation is very capable of increasing the flexibility of the human-machine sharing. The system is capable of adapting to variable environment, process operations and human participation.

Final users and the owners of the companies dealing with automation are looking for designing a flexible and dependable system, possessing the capabilities of desired relations in the human-machine interaction, which is capable of delivering flexibility, predictability, variety in product, dependability and adaptively capabilities.

4.3 Human-Centered Automation

Human-centered automation is based of the alternative way of productivity comparing with technology-oriented automation. In the beginning stages when the design of the system is started the major role in it is the human, possessing its capabilities and differences with the machine and its advantages and disadvantages in the execution of the tasks. The design of the system characterizes the successful output and the interaction between human and machine.

As the process of production takes place the sharing between the humans and machines in achieving the desired outcomes can be in two different aspects. The first one considers the outcome as the most important issue, the second one is the process of achieving this issues. Many specific techniques are available and used in testing the collaboration between the units in the system. They are used to probe subjective and objective satisfaction with in the interface.

Special cases when the control of the automation machines is overcome by the human, never-the-less there are trainings to accept the machine predominance and authority. Humans as explained earlier are seeking to control the process and to exert dominance. Deviation form the procedures doesn't mean incapability of handling with the procedures. Training, standardization, motivation these are all characteristics that lead to individualism, frustration and this human desire to show variety and innovation in the work and the procedures. The technology-centered automation with its flexibility and dependability can dominate the autonomy and the authority of the machine set, and that will lead to undesirable consequences, which is not the usual case (Degani and Wiener, 1994). This is the case when the authority exerts control over the machines, by inspecting and operating their behavior.

4.4 Sharing with Machines

The sharing is common for the species and it is a way of communicating, exchanging information, achieving specific goals. The sharing is a complex process of exchanging ideas and thoughts, thus the mutual relationship between different species is different. The relation between a human and machine is very straight forward. There have been a lot of theories and researches about the sharing and despite the conclusions and investigations there is a vulnerability and artificiality and that makes the sharing difficult at work places and among the humans and machines.

Sharing is much more complex and difficult when we are speaking about a sharing between a human and an automated system, because in this case man and machine are achieving a specific task together. As comparing the different approaches as human-centered and technology-centered, the second one is more able to produce useful sharing, even in the more

difficult collaboration of cognitive aspect rather than physical one. The contradiction occurs when as machines and humans are focused in achieving a specific goal simultaneously, this is more represented when the cognitive fight lets physical difficulties.

The sharing occurs in many forms between the machines and the humans, and this sharing can be expressed in different levels of automation in the production (Billings, 1996; Endsley and Kiris, 1995). At one of the extremes there is the machine operation, which is operating autonomously, but at the other side there is the manual control. As will be considered later on there is not really a situation in which the systems are working in these two extremes. And between these two extremes there are different levels of involvement, which are different in the sharing and human involvement in the processes. The topic considering the different levels of automation hasn't been discussed and there appears to be not a complete agreement on how these levels are defined. This paper is dealing and considering the definitions and usage of the different levels of automation, which have been considered and outlined, and the ability of switching these levels if there is such a need, which can originate from various and specific circumstances.

4.5 Sharing Output

The sharing has one specific purpose which is a satisfaction outcome of the production related to the demands and strategies of the company. Task allocation lies deeply as one necessity in the work between human and machines, since the machines are replacing human work in many directions and branches of the manufacturing. The basic idea as described earlier by Fitts (1995) is to allocate the different tasks and to solve the problem concerning the problem of distributing appropriate tasks among the machines and humans. As the tasks are allocated the next step is to define and realize the effectiveness of this allocation, with respect to overloading one of the sides (Kantowitz and Sorkin, 1987). This so called competitiveness in allocation of the different tasks has been improved by the system designers and the question has been asked about the overall control of the system and who is in charge of it.

4.6 Creativity in Technology-Centered Automation

The high level of automation is preventing the human operator to participate in the process with its creativity and flexible characteristics. This is due to the fact that the system is preventing from free actions and undesirable involvement of human participation, which can lead to system errors and failures. Such limitations in the abilities of the automation machines reflect in the so called tightness in the realization of the human potential and its contribution in the system. There are systems, which with its flexible characteristics are able to afford opportunity for such human participation even in high automated systems. They contribute with creative approaches for the performance of the system, thus this production systems are rather flexible and possess higher abilities. On the other side stand the competence and the knowledge of the operators and their abilities, because such involvements require sufficient knowledge and training.

Creativity involves an interaction with the environment, where the humans react with respect to the surroundings and the surrounding environment on the other side respond to the

human worker. This interactive relationship with the environment is a feature that contributes to the creative processes and technology is capable with its design to increase this interactivity, these possibilities are dependable on the system design.

There are conditions of the automated system, which are considered to be present in highly automated systems and are associated with unpractical behavior; there is an inappropriate conditional awareness and the satisfaction of the working system. It is important to consider as well the repetitive procedures, which lower the presence awareness and that leads to incidents and accidents, which is another reason for lowering the human creativity and participation. The dynamical levels of automation with the possibility for the human part to participate in the process at different levels characterize the system as able to handle with non-routine circumstances or emergency situations and at the same time contribute with its creativity and system awareness, that's one of the reasons for a trained staff with sufficient knowledge and capabilities.

5. Environmental Issues in the Competitive Manufacturing

The management of the companies and the production systems are trying to minimize all the negative effects of the environmental impact on the productivity. It is becoming quite important in the manufacturing processes as customers, suppliers and public demanding the minimization of these unwanted effects due to the environment on their products and operations. The management is trying to determine and isolate the negative impacts and to change the necessary branches, the change of raw materials, and waste, dangerous chemicals resources, which have negative impact on the productivity. Technology is straightened in the direction of minimizing all the negative effects of the productivity related to the environmental impact on the product and the most important on the working staff. Sustainable development is the concept is the strategic weapon for managing with these problems.

At a strategic level the product design and design of the system, with respect to process technology and managerial systems determine the overall performance of the system of the manufacturing firms and enterprises. Management of the environmental issues influencing the production and the decisions taken with respect to the necessity of new technology, tools, programs, education, and all these changes will characterize the entire competitiveness of the company on the market. Operation mangers are playing a major role in taking these decisions regarding the implementation of necessary changes, which will lead to better manufacturing outcomes.

The product design and the process technology are typical issues related to the pollutants emitted, like gases, dust, chemicals. The supply chain and the production with its transportation, logistics, customer relations, and organizational behavior play a major role in the production and the increase of the environmental risk.

Many initiatives to better manage environmental issues regarding the operations in the production are oriented to improving productivity, raising the resource efficiency, and encouragement of innovations and technological upgrade (Porter and Van der Linde, 1995).

5.1. Technology Role

Technology and the innovation in can be defined to include better design, equipment, methods or different systems that conserve resources, minimizing the environmental impact, increase the human safety and protect the natural environment.

5.1.2 Effect on Performance

The improvement in the environmental performance and the cost necessary for this can be easily overcome by the other benefits, which are related to increase of productivity, better working environment, reduction of liabilities, the ability of increase the production on new markets, better worker satisfaction, a better name on the market with increased public reputation, companies will have better competitive position.

Search in the field of finance, corporate and social performance, economics, investment and environmental management have been testing and investigating the overall company's performance in relations to the economical performance (McLaughlin, 1996).

Thus the flexible automation is a complex gathering of processes of machine systems with their dominance and presence, but still there are other forms of flexible automation. Industrial robots are a part of one flexible automation system, which can be used for more than part handling, because if the design permits and the machine is having the necessary equipment like sensing devices and monitoring set, they can perform complex operations.

6. Analytical Evaluation of Flexible Investment

The modern technology is developing so rapidly and the demand of faster product flow as well as possibility of handling of different products and unexpected circumstances. This is a competitive factor for handling with the demands of the modern market as well as with the necessity of variability. These factors as well as some other factors connected with the necessity for improvement of the existing facilities make these adjustments operating and being developed with uncertainty and unpredictability. In the manufacturing analysis managers are making the necessary evaluations for the necessity of budgeting for doing necessary changes. The production system is considered to be a powerful weapon for business development (Hill, 1989). Deep economical analysis is needed with respect to the necessity of understanding of the strengths and weaknesses of the new installation and equipment (Persson, 1990).

Investment evaluations are made based on cost-accounting analysis for the product, demand for the new technology and the forecast for the future outcome. When a new technology is being implemented for the first time in production systems the environment is even more uncertain, but the realization of the positives and negatives as well as the innovation strategic analysis is giving a better perspective of the investment.

This paper is not dealing with the strategic investment and the pay-back periods of such an investment. The history shows that the pay-back periods are considerably low and especially for rationalization investments which are considered to be robots and transportable equipments.

Analyses show that the flexibility shouldn't only be evaluated, but also has to be analyzed, because in this case the overall impact of the flexible equipment will be considered and respectful measurement can be taken for necessary improvement.

The manufacturing and the technology that is being used in it is changing rapidly, the presentation of new products, new technological demands, modern production systems, improvement of the working conditions, reduction of cost of material, reduction of waste of material, reduction of work process time, all these characteristics are considered to be a strategic goal for the companies in the turbulent manufacturing environment.

There is a lack for understanding and visualizing the effect and the quantitative measurement of manufacturing flexibility and the implementation of new technologies and equipment. Despite the uncertainty and the insecurity, the company managers recently are focusing more on the flexibility consequences and the positive effect of the changing of the environment of the production equipment, giving more opportunities for flexibility and competitiveness in the manufacturing systems.

Even though there is uncertainty in the investment in new flexible technologies there is utilization about gaining competitive advantages on an increase of the uncertain and dynamical markets.

7. Levels of Automation-Introduction

Manufacturing companies experience growing need for increase in their productivity, improvement in quality, lowering the cost, entire improvement in their manufacturing systems. High performance is achieved when the strategy and the construction of the system is related to the company's technological choice of production. The evolution of the process technology is oriented to the increase of the production capabilities in different production process stages. It is important for planning a manufacturing system and implementing new technologies and ideas to consider some important things, which are not only oriented to investment and cost, but unexpected situations, in which no predefined solution can be applied. In such cases the manufacturing strategy must be oriented towards a system, in which a well established combination between manual and automated operations is established. The term Level of Automation is described as the task division between the human and the machine (Parasuraman, 2000). It is the ability of controlling the level of automation that can eliminate the waste, and the waiting time. Thus the basic principle is of finding and implementing the right Level of Automation in a way that it can be controlled and that could a way of maintaining the effectiveness of the system (Safsten, Bellgran, Frohm, 2005).

The interpretation of improved usage and system's ability is being related to the increase of extend of levels of automation. In the studies it is regarded that excessive level of automation doesn't usually means increased benefits (Bainbridge, 1982). Automation is a very successful weapon for achieving manufacturing goals and improvement of system environment.

The idea beside the Level of automation is to determine and choose a specific level of automation for the system or to present a possibility of varying the levels of automation. These dynamical levels of automation are capable of increasing the system parameters leading to more efficient productivity.

Researchers are oriented in both advanced technical system and skilled operators with sufficient knowledge and training, this is the key for a successful manufacturing, not only in the correct choice for a manufacturing level, but as well for the ability of changing the Level of Automation for the critical operations in order to achieve the right level of automation for the production as a way of increasing the system robustness.

The authors of books connected with manufacturing are mostly oriented towards explaining and presenting the different ways of existing systems related to production methods, mostly oriented in manufacturing strategies and manufacturing systems. Thus there isn't enough research developed on the controlling the levels of automation and the reflection on other parameters.

Automated system is being characterized as hybrid one in case when there is a well established connection between humans and machines, combining manual and automated operations together. Such systems usually benefit from the flexibility of the human presence. By that mean the whole system can vary on a scale regarded to its automation level related to its physical and cognitive aspect .Implementations in the automation and the different levels regarding the process should be made in respect to the different levels.

Researches and theories are stressing mostly on whether to automate or not one production process and in this case there is a forming gap in the essentiality of the process and that doesn't represent the automation in details representing the automation level. In this case there could be unexpected problems in the production system by not knowing the correct LoA. Usually in the manufacturing by automation it is understand a system basically working either on the two poles, which are totally manual or fully automated, but that is not the case, usually with the LoA it is visually and more clearly represented the interaction between the different levels of automation in the hierarchy.

The level of automation (LoA) will allow not only to compare systems with each other or to improve systems design and reconfiguration, but also to increase the robustness during start up and operation by the possibility to vary the automation level

Designing task and operational management of the system are achieved by several different ways. One of the ways is the technical part focusing mainly on the technical part of the system, where the high level of automation in the physical tasks related as mechanization, and the application as well in the cognitive information tasks related as computerization.

The concept of LoA has to be oriented in the area of manufacturing and its implementation there since the involvement of replacement of the cognitive and physical work takes place in the production system (Frohm, Lindström and Bellgran, 2005).

The importance of this representation is to present the relationship between the input parameters of the system and the output ones with respect to the level of automation of the system represented on the operational level.

High technical system as well as skilled workers is necessary for a successful manufacturing. The need for appropriate level of automation is the necessary condition for successive manufacturing. The correct level of automation is a predecessor for well functional system with high robustness and flexibility.

The Level of Automation can be classified as the relation between the human and technology in terms of task allocation and it is ranked from 1 to 9, where the first level is the total manual work and the last level is the fully automation system and they are related to the physical and cognitive tasks. The balanced relationship between human and technology is the Level of Automation.

There appear that the concentration in finding the right automation level for a working station and line is most important for the effectiveness of the system (Bellgran and Säfsten, 2005).

7.1 Content in the LoA Modeling

Frohm (2005) regards that the increase in automation doesn't necessarily result in more efficient productivity, where there is a decrease in the robustness of the manufacturing system, which depends on the flexibility to handle variations of processes. As stated earlier the definition behind automation is the allocation of tasks between the human and the technology. The combination of the information level with the technological part is very essential in increasing the effectiveness of the system.

The system designer should pay attention to the processes in case of which to be performed by the operator and which by a machine or both. There are operations, which can be hazardous or fatigue that's why they are preferably not executed by an operator, but by a machine and there could tasks that can't be automated and thus no technical solution could be appropriate. Tasks should be separated between the workers and the technical system in a way that the workers should benefit from the help of the technical system.

In order to be able to design the adequate process of manufacturing we have to recognize the most important factors that have the product. Some operations may be hazardous or fatigue, etc for being performed by an operator, and other operations may not imply a realistic technical solution due to complexity etc. The remaining tasks that both human and technology are able to handle should be design in such a way that the human can get maximum support by the technical system (Lindström *et al,* 2005).

Once a process has been automated, it is usually less capable of performing a wide range of activities. This may restrict future improvement through redesigning the process. If customer requirements change, it will be hard to modify the technology if the process is hardly automated. Although a highly automated technology might require fewer people and have greater capability, it can be less robust than a combination of basic technology and less fragile than humans (Hill, 1995). There are high and low automation and their relation and difference can be seen in the following table 3.

High Automation	Low Automation
• Low cognitively and judgment	• High cognitively and judgment
• Lower direct cost	• Higher direct cost
• Design is strenuous	• Control is strenuous
• Cost for maintenance	• Cost for creativity

Table 4.*Comparison between Low and High Automation*

The following table 4 represents the separation between the computerized cognitive tasks and the mechanized physical tasks. The separation is made into 9 levels each of, which represent the different automation level as described earlier the dependence and levels of automation. The table has been created and developed with deep research analysis and it appropriate for visualizing and considering the automation levels. It has been developed to assist the visualization and the acceptance of decisions regarding the manufacturing process and the choice of the appropriate level of automation. It is a part of Dynamo Research Project (Lindström and Frohm, 2005).

LoA	Computerized/Cognitive Tasks/ Activities	Mechanized/Physical Tasks/ Activities
1	The human produce the options, decide and execute the option without any assistance of the computer.	Total manual physical work, no physical tools are used, only human muscular strength.
2	The computer presents all suitable options; the human can choose and execute one of the options.	Manual physical need support of static hand tool.
3	The computer suggest a number of options, the human can choose and execute one of the options.	Method physical work with support of a static of a dynamic tool.
4	The computer produces a number of options and recommends one of them; the human can then choose to execute that option.	Manual physical work with support of an automated hand tool.
5	The computer suggest one option, the human can decide, and the computer execute the decision	Controlling of machine/robot on site that execute the task.
6	The computer suggest one option, decide and execute the option, the human is always informed.	Supervision of machine/robot on site that execute the task.
7	The computer suggests one option, decide and execute the option, the human is always informed if the human demands information.	Supervision and control of one or many machines/robots from a central control-room.
8	The computer suggests one option, decide and execute the option, the human is only performed if the computer demands that the human should be informed.	Automated physical work by machine/robot, the human is only involved when the machine needs assistance.
9	The computer suggests one option decide and execute the option without any assistance of the human.	Total automated physical work, the machine/robot solves the problem by itself when they emerge. The human are never involved.

Table 5. *Level of Automation - Dynamo Project*

7.2 Computerization of LoA

Computerization can be defined and expressed as the transformation between cognitive tasks distributed among the human operator and the technical system. A special connection between the different levels of acquisition of the information can be represented in the following sequential order that can be regarded as the application of the human-machine system figure 3 .

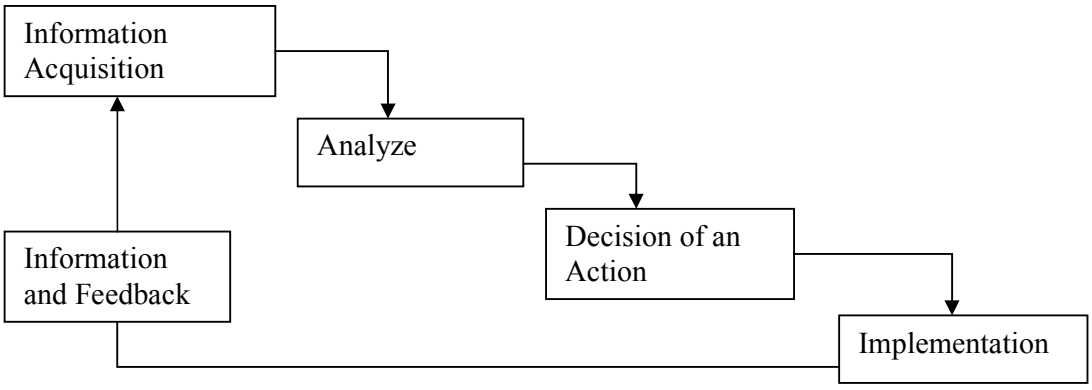


Figure 3.*Human-machine tasks*

A different and detailed implementation of the different stages in task implementation can be represented as the different level of automation, when the decisions are being taken. The different stages can be characterized as the different automation levels and their appropriate level in the production system figure 4.

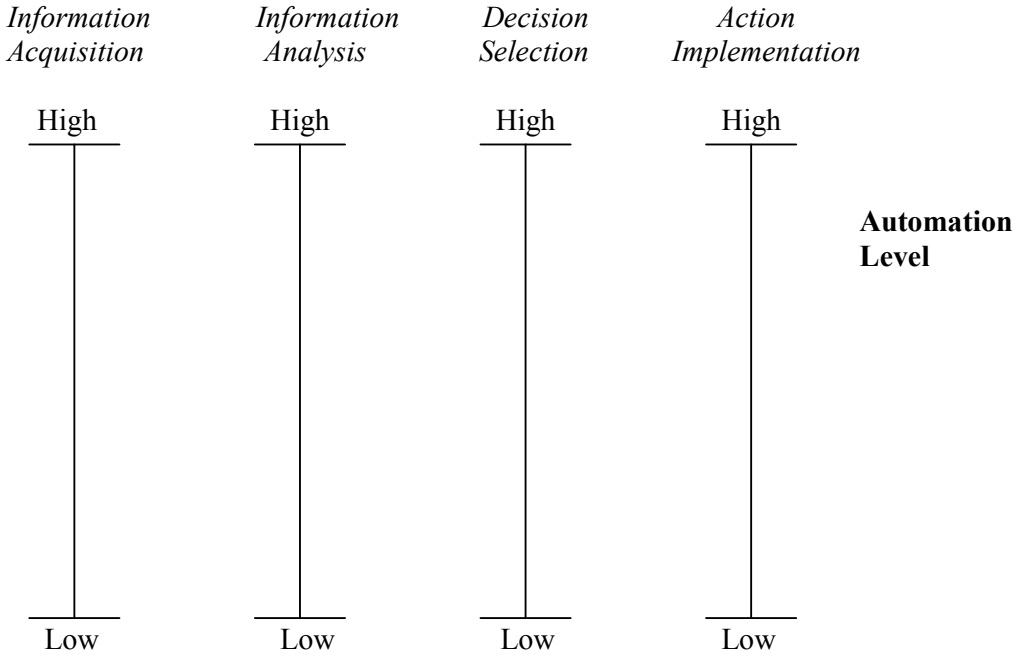


Figure 4. *Different automation levels*

There are several dimensions that have to be considered when arranging and following the human-machine interaction. Firstly we have to regard the level of specification necessary by the human for inputting the requests into the system. Secondly the level of specification that the machine possesses and how that affects the human-machine relation, the level at which the machine has the ability to take decisions and use the alternatives provided by the human.

Thirdly is the degree at which the human has the responsibility to implement an action. Fourth is the timing and the feedback that follows after this.

The most important thing according to Sheridan (2002) is to consider the dimensions and options and to decide the degree of automation at each of these stages.

7.3 Task Allocation and Measurements

The choice of the right level of automation of one system is the determination of the right level of automation which is achievable by allocating the tasks in the processes, with respect to identifying which task is appropriate to be handled by the machine and by the human. It is often regarded that the machine and the worker are two static and individual parts that have to be able to allocate the tasks between them (Sheridan, 2002; Billings 1997). That task allocation between the machinery and the workers can be criticized for creating a distance between the operator and the equipment, as a measurement of avoidance of the complex components between them.

7.3.1 Allocation of the Manufacturing Strategy and Levels of Automation

The process innovation becomes very important in comparison with the product innovation. The competitiveness arises highly by introducing the process, which is a predecessor for the product development. The process technology evolution is structured in a way of process steps that follows a specific order. The ladder of the processes is following from standardization of the equipment, rationalization of processes, mechanization, and automation (Hayes and Wheelwright, 1984). The most important need is regarded to the need for increasing the operational flexibility and the correct implementation of Levels of Automation, which is the solution of all the difficulties.

LoA models can be implemented in the early developing stage, as it can be laid over the existing equipment. At the next stage some critical tasks can be varied and at the final stage the complexity of the tasks has been solved by automation with the possibility of varying it. The information of the LoA can vary within the processes depending on the speed of the production and the computerized equipment being used. When designing the set it is important to take into consideration the time perspective, because it is important for the feedback of the design, whether it is supportive or critical, influencing the period for which the manufacturing performance is in action. The automation level is not an easy and linear description. The choice for the right level of automation can be seen on the different dimensions as in the process life cycle stage, fitting the company's manufacturing strategy, and the organizational level. The success of one's company is the close connection between the manufacturing strategy and the technological choice in the different stages, and the attitude of the managers to the decision of the automation levels. The decisions for the right automation level for one production system are quite complex and dependable on many outer factors.

Manufacturing strategy and the system itself are often oriented to both the technical part of the system and the human worker in it as the components of the whole system and the whole environment influences can be dealt by adjustments of the parts of the manufacturing system by providing the necessary desired output (Granell, Frohm and Winroth, 2005).

7.4 Level of Automation Measurement

Manufacturing systems are very effective and productive and at the same time they have obstacles when dealing with complex tasks. This situation is observed when the system tries to deal with unforeseen situation in which there is no possibility for the automated system to handle with the task. The solution is the switching of the automation level for being able to handle with the task, because there is no predefined solution. With the complexity of the product the risk of causing disturbances increases. Complex systems require a high demand for people to be active of the system, handling with disturbances and unexpected situations.

Material handling processes should be separated from the whole manufacturing process and the measurement of automation level can be used to improve the decisions taken for both the working processes and the strategic orientation of the company. The research of the LoA has given an understanding of the concept oriented in understanding and visualizing the types of operations that have different level of automation from low, medium or high. There are many elements that influence the level of automation and the understanding and the linkage between them is the important part in controlling and affecting the manufacturing output.

The manufacturing process could be separated into two classes of automation, which are mechanization and computerization. As being described the computerization is the replacement of the cognitive tasks taken by the humans and using the collection of information and its usage in order to control the whole manufacturing process. The following Figure 5 demonstrates the separation of the functions:

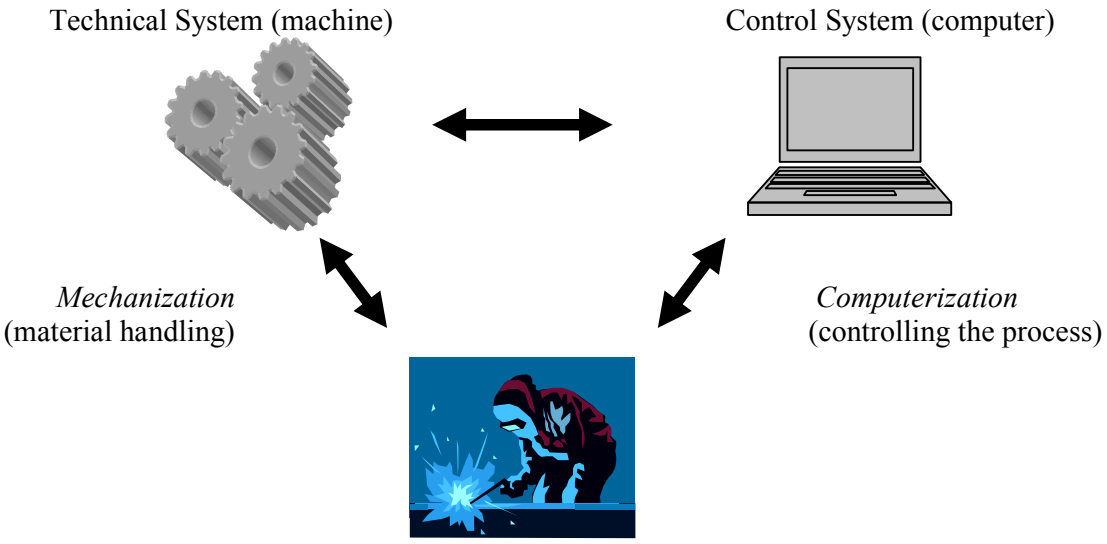
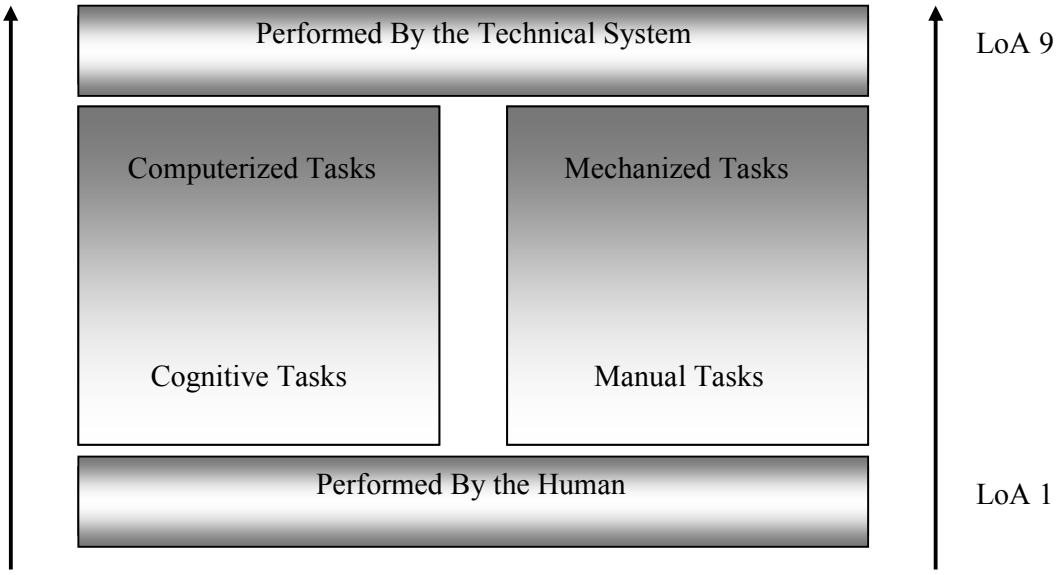


Figure 5: Separation of Functions

As was said LoA is the "relation between human and technology in terms of task and function allocation, which can be expressed as an index between 1(total manual work) and 9 (total automated) of physical and cognitive work" Frohm (2005). Knowing the description of

the level of automation it can be represented in the following way, by separating into two basic classes of activities, which are represented in Figure 6:

Figure 6. Model of allocation of tasks between human and machine Frohm (2005)



Depending on the type of production and the necessary technology used different kinds of LoA can be chosen, and the chosen one will be considered the most appropriate one. Low technology level of automation is difficult to sustain and manipulate by a variable LoA, but at the same time a higher one permits that the LoA can be varied in a certain dimensions.

As being explained in the beginning of this paper to make one manufacturing system as robust and flexible at the same time it is needed to assign the appropriate tasks and functions at the right level. It can be noted that there are tasks that are not possible to be allocated to the human or to the technical system. A more realistic characterization of figure 6 represents the capacity of the two extremes. When presenting the human extent and machine extent it is understand to be the maximum capacity capabilities. The following figure 7 illustrates the two border lines, which are called automatibility and humanizability (Frohm, Lindström and Bellgran, 2005).

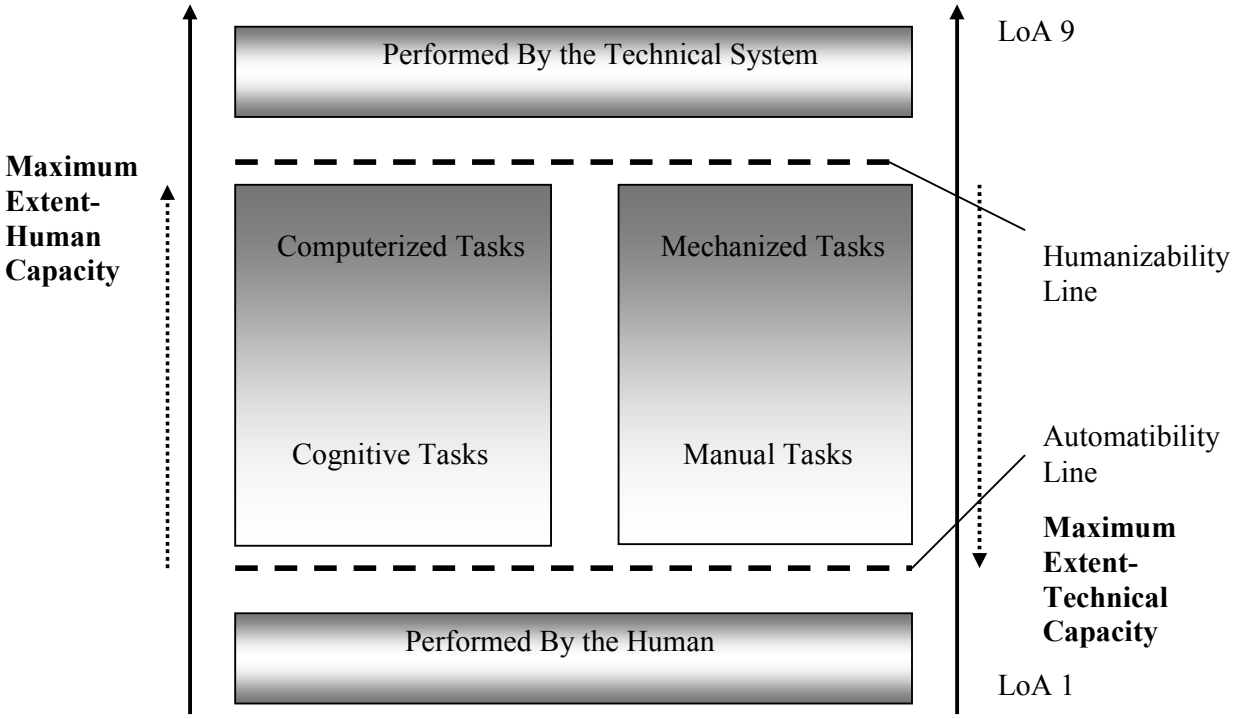


Figure 7. *Automatibility and humanizability (Frohm, Lindström and Bellgran, 2005).*

The lines that represent the maximum extents are the *automatibility line* and *humanizability line,* there is a point in the LoA ladder, where the task couldn't be evaluated and performed by either the human or the machine. At the automatibility line it can be stated that there are a lot of tasks that requires human automation. With the increase of the complexity of the tasks the human operator role increases, and its presence and role is more necessary. There is no possibility to automate all tasks in the manufacturing process, since there are some tasks that are so complex and unique that it is impossible to be automated. The other side is the human part, because there are tasks that are so difficult to be performed by the human, so it is necessary for the automation to handle them. The humanizability line is limited by the cognitive and physical abilities that the humans are capable of. Both of the lines are considered to be important and their level is not only influenced by the tasks, but as well from economical factors. The most important aspect in taking decisions about the processes is the relation between the humans and the machines in such an orientation that the technology should take in charge with the processes and the humans should do the rest of the work that remains (Frohm, Lindström and Bellgram, 2005).

The design and the change of the manufacturing system is complex procedure and it should be done in a structured and controlled way for the best desired output (Lindström, 2005). The linkages between the parts of the system are quite important and changing one factor of the system can influence other parts of the system.

Dynamo project goal is to establish strategies for the use of dynamic levels of automation (LoA) to increase manufacturing system robustness, and to provide industry with design, measurement, visualization and management tools for dynamic levels of automation in manufacturing.

A more complex representation of the Dynamo Project and the combination between the nine levels of automation and the allocation between the mechanical and informational task can be represented on the following figure 8. It combines the Mechanical Allocation of the LoA and the Information Part of the LoA.

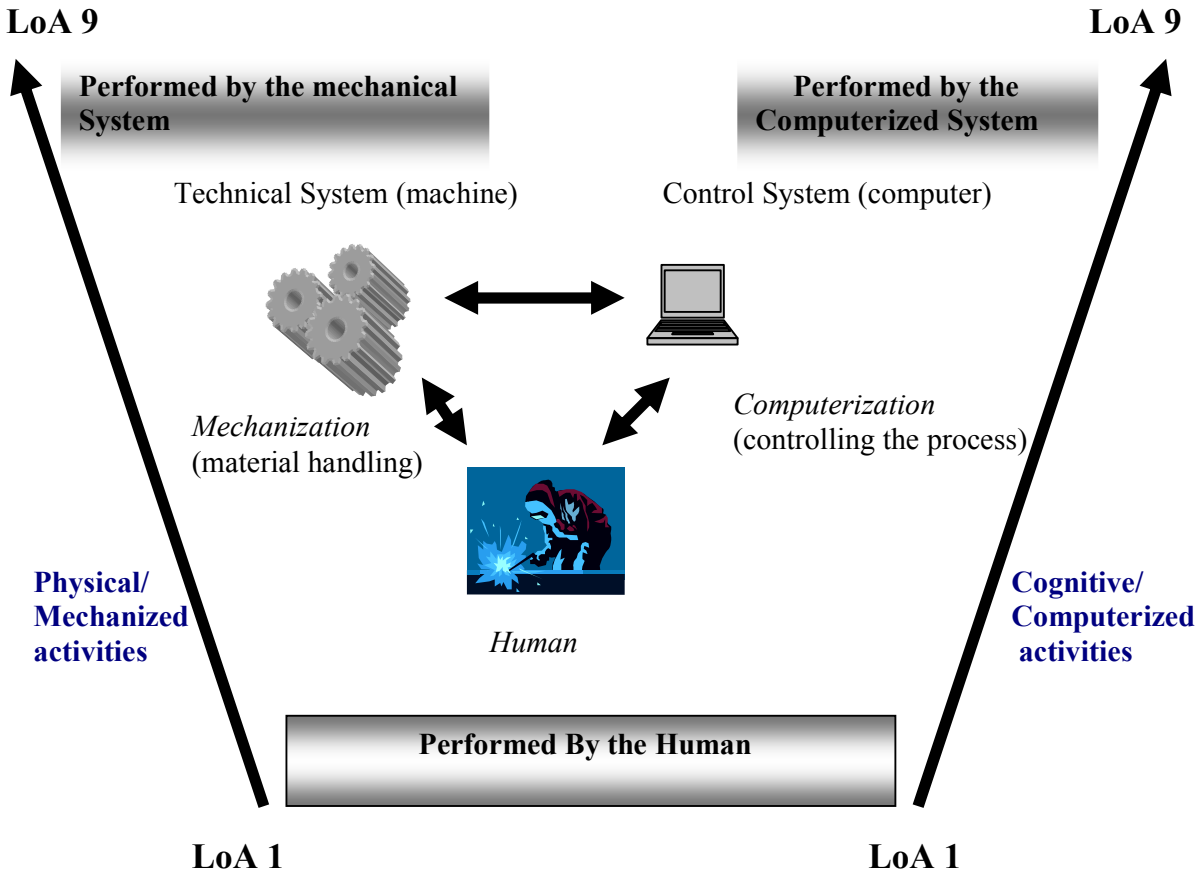


Figure 8. *Dynamo Project (2006-04-20) Connection between the LoA and the Task Allocations*

The perspectives in the following table 4 are useful for identifying the specific measures. It could be used for changing and improving the internal capabilities, and the internal worker's perspective related. Quality is an output parameter that could fit the performance measurements of the system. Other performance measures that are being highly considered are the cost, flexibility of the system, and time (Neely et, al, 1995).

Perspective	Measure
Internal worker	Safety, skills, capability of solving problems, teamwork, morale
Customer	Product quality, delivery and time
Shareholder	Cost, waste and reduction
Society	Continuous improvements, value adding

Table 6.*Performance measures (Granell, Frohm and Winroth, 2005).*

7.5 Survey Result Regarding the Automation Process

As being explained the in this paper the Delphi study is appropriate method for questioning experts or people working in separate areas. The main reason for questioning is the necessity for taking the appropriate decision whether to automate or not. The question was basically oriented in the field of the reason for automating one process. The following table represents the most important factors being placed when making the decision for automating one process. The top ones are quality, work environment and rationalization. Working environment is related to the internal perspective.

Parameters	Percentage Low to Very Low Degree	Percentage High to Very High Degree	Don't Know
Quality	4.8%	95.2%	
Work Environment	11.3%	88.7%	
Rationalization	14.5%	85.5%	
Financial	16.1%	83.8%	
Production Capacity	21.0%	79.1%	
Risk Analysis	24.2%	74.2%	
Volume	30.6%	69.3%	
Time Perspective	30.7%	66.1%	3.2%
Available workforce	58.1%	42%	

Table 7. *Questions about Automation (Granell, Frohm, Winroth, 2005).*

The material handling is playing a major role considering the automation level, because if the material handling is high then the manual part is low. The decisions regarding the automation are based in perspective, which processes should be automated and which shouldn't, because they are not appropriate. Tasks that are involved with bad ergonomic conditions are not suitable to be handled manually. The Delphi research being made regards questions related to the benefit of automation, the problems related to automation, and the definition of the LoA. The major benefits related to automation are cost savings, higher efficiency, increased competitiveness, and productivity. The most important reason regarding our survey is the improving of the working conditions, by eliminating the monotonous and physically difficult task involving great danger and hazardous work. The following table represents the survey study results.

Advantages	**High**	**Very High**
Increased efficiency	24%	98%
Improved quality	33%	91%
Increased productivity	19%	96%
Cost-cuts	35%	100%
Improvement of productivity	32%	93%
Decrease the number of employees	48%	88%
Better handling	37%	52%
Possibility for increase the volume	42%	87%
Improvement of the work environment	48%	93%

Table 8. *Automation Advantages (Linsdröm, Winroth, Stahre, 2005).*

The survey shows that the top 5 very high reasons for automation are cost saving, increase efficiency, increase productivity, improvement of working conditions, improvement of productivity.

The other research states that the other conclusion being made from another research questions is that the competence of the operators is quite important when considering automation of one production process.

Another research being made is regarding the tasks that are not suitable to be handled manually. It shows that there are some tasks that are not suitable to be performed manually. The Delphi study shows that the work in the hazardous environment is 97% or monotonous work and physically demanding working situations 94% are not suitable to be conducted manually. The following table 7 considers the results.

Not Suitable tasks for manual work	**High**	**Very High**
Heavily lifting or monotonous working operations	29%	93%
Hazardous tasks for the human	10%	98%
Big volumes	34%	81%
Demands for check of quality	40%	50%
Tasks that demand high accuracy	41%	67%
Tasks that demand high repentance	40%	89%

Table 9.*What tasks are not suitable to be performed manually (Lindström, Winroth, Stahre, 2005).*

Some of the survey results associated with the automation processes are not considered, because they are not in a close relationship with the project.

7.6 Theoretical conclusions and the real surrounding

Regarding the automation decisions over 95% of all the questions being asked considers the quality as the major aspect of the automation process. The quality is complex term, which relates to the type of process and the off line inspection. Our task relates quality as an important aspect of the reason for automating the process. Another very important aspect relates that the working environment leads to the need of automating the process, 89% answers that this is quite important; this issue is the primary issue in our study. Working environment is connected to the safety of workers and the improvement of the working conditions. As being investigated the Levels of Automation can be varied and adjust on a scale from 1 to 9. The measurement of the existing level of automation is preferable firstly to be measured and than to adjust a new one or change it. A controllable and adjustable level of automation could form an individual production system. One production system is formed by the capabilities and by the level of automation. The connection and the dependability between the capabilities of the system and the performance measurements are of a great importance for the overall output of the manufacturing system. The following figure 9

represents this dependence and the connection in between the system (Granell, Frohm and Winroth, 2005).

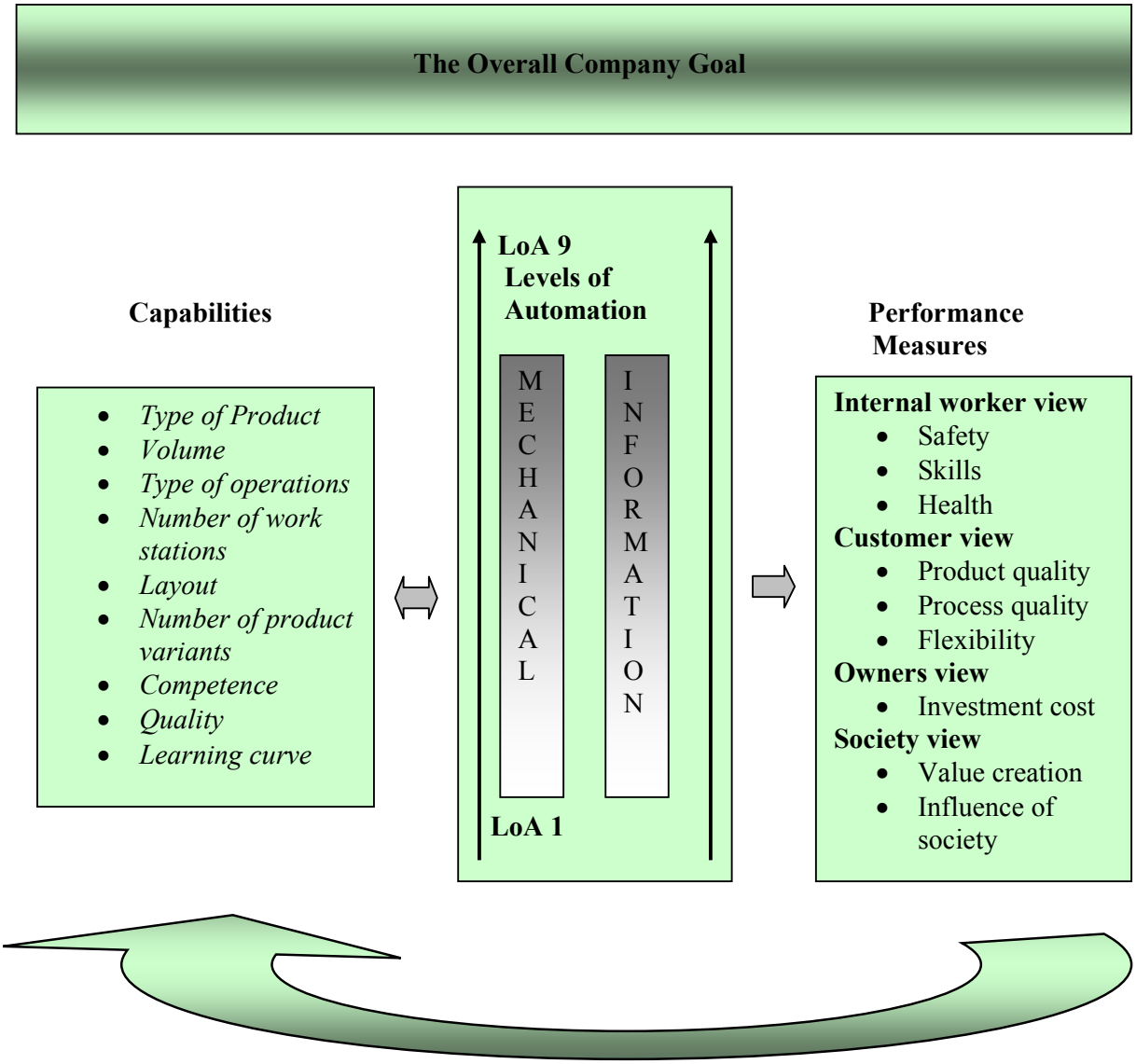


Figure 9. *A model for controlling levels of automation (Granell, Frohm and Winroth, 2005).*

It can be stated that the connection between the Performance Measures and the Capabilities is very essential in the manufacturing output of the company. The change in one of the Performance measures affects the capabilities and thus influences the LoA. All the connections should be taken into consideration, because the different aspects and views are important to be considered when making decisions about the investment of automation. The identification the capabilities of the system and the demanded performance help in finding out the right level of automation. As being stated earlier the choice of the right level of

automation affects the output and it in turns affect the manufacturing system. The LoA can either be implemented in the design stage and then being used during the process or being used as an adjustment method for maintaining the output variables of the system.

8. Project Goals

The main goals of the project and the automation of the facility are oriented in the reasons, why to change existing production system, and how will that affect the overall production capabilities and outputs. The following steps are representing the areas that are most important for those issues.

The most important consideration for the project is the working environment and how is it possible to change it and improve it. The concern is mostly oriented in how the working environment affects the worker's health and how that reflects in the production capabilities and the cost associated with this.

Reduction of cost is the other important goal that is oriented to improvement of the entire production. Reduction of cost in this research is oriented to the reduction of the workers cost, saving of energy and cost of material.

The improvement of the work process time, in other words, the lead time is primary objective for the project as well. "Time is money", when considering the automation time is the most important factor that is considered.

Waste of material is the last issue that has to be taken into consideration. When speaking about automation it is understand the presence of necessary equipment needed for the production process.

8.1 Analysis of the Project objective

- Improvement of the working environment conditions of the plant increases the human safety and the facility capabilities. Some areas of the manufacturing are associated with hazardous and dangerous work that increases some factors associated with the productivity, because that makes the workers suffer and that brings undesirable circumstances associated with the working processes. Diseases and injuries bring lack of important working personnel and that slows down the production processes. The cost lost and slowing down of orders is the typical outcome of lacking personnel.
- Reduction of the cost is a complex process, which is not linear. Reduction of cost associated with workers is the cost necessary to be predicted for salaries and expenditures associated with the staff. By improving the equipment in a way of automating it the number of workers decreases and the process demands less personnel. The necessity of well trained people increases as a result of this automation process. This leads to the demand of training working programs associated with the work. The cost for the working personnel increases, because of the demand of quality workers, educated, trained and having the necessary knowledge. In comparison with the demand of trained workers and the cost for them with the number of people needed, who are usually suffering from injuries and diseases the strategic orientation of the company should be mostly oriented in improving the existing environment and following the consequences. The cost for

energy and material is reduced with the implementation of modernized equipment that is more precise, accurate and effective.

- The equipment of the plant combines the modern technologies of robots and automatic navigation. As described earlier that improves the whole production process as it reduces the time necessary for that. High automation level increases the speed of the processes that is always true when the processes are quite alike, but at the same time it is not always true when the processes demand flexibility and the products differ from each other.
- Waste is associated with the levels of automation as well. Waste can be considered in two different ways. Firstly waste is the material, which hasn't been used on purpose, but has been wasted; it is part of the production process. When speaking about LoA waste can be regarded as the extended production quantity of the products, overproduction or excessive inventory, which can be controlled by the different levels of automation. Identifying the sources of waste in the product development can help the production with higher quality of the product. When the waste is considered, a well satisfactory analysis has been made and the automation has been considered.

The entire goals are associated with the improvement of the entire production and the introduction of new technologies and the right and appropriate level of automation is the key to successive production. Factory-in-Box has the ability and possibility to implement all the company goals in the desired overall improvement of the production plant and the capacity.

9. Varnas (Varnäsföretagen)

VARNÄSFÖRETAGEN AB

Varnäsföretagen is a Swedish company that is dealing with production of aluminum parts for different companies. The company is situated on different production plants that are shown on the following figure 10. This thesis concerns the one that is situated in Eskilstuna. It works and produces parts for VOLVO Company and other custom production companies. The company relies on quality, service and accurate delivery. The company is one of the leading suppliers of aluminum sand castings on the Nordic market. The top priorities that the company has are:

- high flexibility in customer contacts
- creative product development
- aluminum sand castings to your requirements
- long runs and high safety
- rapid switching between large and small consignments

Figure 10. *Location of the production plants*

The production at Eskilstuna foundry is characterized with the following specifications:

- Automatic high pressure molding.
- Electric melting plant.
- Heat treatment.
- Internal/external pattern production.
- Artificial flow/solidification facilities.

The company specializes in production of aluminum green sand casting and additional mechanical machining. Varnäsföretagen operate three plants with a shared computer system for material and production control. The earlier they begin to work with you, the greater the opportunities for shortening the lead time to the finished product. Effective communication with our customers provides your company with advantages such as creative product development, reduced development times and guaranteed quality. Quality and reliability give the best overall economy**.**

9.1. Company's Goal and Analytical Research

Company decides to change its current productivity as mentioned earlier and the main reasons for this have been discussed in the project goals. Since the company succeeds on the market there are outer attacks and reasons, which lead to change and implementation of automation and in this case Factory-in-a-box. The Box contains a mechanized automated robot, which is capable of manipulating and treating the cast materials. The concept for the box has been created under deep analytical work regarding the process itself as well as the appropriate automation level being considered. The concept of this work is the analytical consideration regarding the automation level existing in the different solutions being developed for the factory. The company demands the implementation of 2 identical boxes that would be operative and they will be working together when there is a high manufacturing capacity. The analytical work of the concepts will be graded according to the most appropriate goals of the company and the connection between the different levels of automation will be considered within the design and the work of the boxes. The boxes contain predetermined database for the different available products that the company produces. The automation within the boxes will be considered High to High LoA and as being described earlier an automation system that is with high level of automation has the ability to be varied by lowering the automation degree, the other way around is almost impossible, coming from a lower level to adjust and change the LoA according to the circumstances and demands.

The Dynamo projects concerns the different demonstrators that are regarding the different areas of investigation. The demonstrator #3 is regarding the foundry level application and the implementation of a box in the production system. Conceptual box that will be characterized as flexible, movable and dynamical, possessing the ability to be transportable and to manage with the different production demand as said a mobile production capacity on demand. The box is with a central placed robot with high capabilities and flexibilities. The concept demonstrator is oriented in the collaboration between the human operator and the computerized and mechanized robot. The robot and the whole equipment possess the ability of watching and inspecting the process and the details in the process. The concept is being made in order to satisfy the company's demands and to speed up the processes and increase

the most necessary and demanding aspects of the production system. Factory-in-a-box has the capability of execute the production demands with high accuracy, speed, precision and flexibility.

The concept relies on the ability to control the levels of automation in the process, which helps the system to handle with high production demands and complex tasks and unexpected conditions. The mutual interaction between the modern technological box and the human operator is the central idea that stands behind the success of the project.

The Demonstrator #3 as being said is regarding the treatment of cast materials of the foundry level application, due to some difficulties of the materials the box possess the high flexibility demand for switching from product to product. The sanding of the materials is the procedure that treats the parts and by that means achieve the necessary output. And the concept relies on the human operator and worker to treat some of the material, which varies much from the usual dimensions of the product. The following pictures show the materials that are treated after the foundry:

Details

The current analytical work will consider the different concepts that are proposed as a solution for the performance objectives that the company wants to change. The current

production system is used just to demonstrate the current existing working environment and the methods and technologies being used for that. It is seen that the current existing system is not appropriate for the growing competitive world market. Competing in the changing environment is a necessity that is related to acquiring and implementing new technologies and innovations in production systems.

Global competition and outsourcing creates a delicate and specific environment that place the surviving in the manufacturing harder and uncertain. That also provides opportunities for innovations and creation of new technologies, contributing to sustaining in the market.

Complex operations are usually associated with large number of workers handling with them, and these tasks can be associated with inappropriate working condition and environment, which lower the manufacturing output parameters and overall competitiveness on the market. Designing the system in a way that these obstacles can be overcome and the system improved by applying capability in changeability of the production system and effective adjustments during the production, that is becoming a necessity. This will lead to better competitiveness on the market, and improvement of overall manufacturing outputs.

The current working environment and the procedures that are used for the execution of all the tasks are demonstrated in the following pictures:

Material handling

Treating the materials

Treating the materials (cutting off)

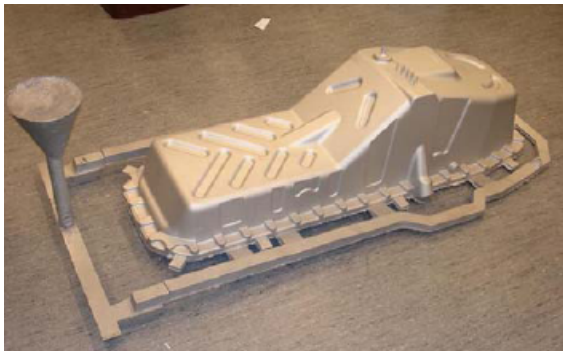
The transportation and the handling Of the materials

Transportation

The demonstrator #3 is oriented in the implementation of a complex Factory-in-a-Box that is created for treating and handling with the cast materials and the concept is oriented in treating the bodies for the different applications. The treatment of these parts is rather difficult, because it is followed by a complex treatment and operations. The weight of the bodies is rather high and the material handling is associated with usage of transportation system for it.

The following pictures demonstrate the look of the materials and their condition after they get out if the foundry. It is well seen the amount of work that is associated with this and the necessity for great treatment, and the removal of the unnecessary waste material.

Body



A container after found

The design of the concept is made for the specific production of this company demand the production of this part body for a vehicle and the motor tank. Never-the-less all the concepts are able to be changed and adjusted for a different specific part that is demanded to be produced. All the necessary components in the box have the ability to be reconfigured and adjusted depending on the type of parts. The following figure 11 represents a 3D model of the part that is taken under consideration developing the concepts and the demonstrator, a body for an automobile vehicle, which is used for big heavy trucks and also for the industry and motors.

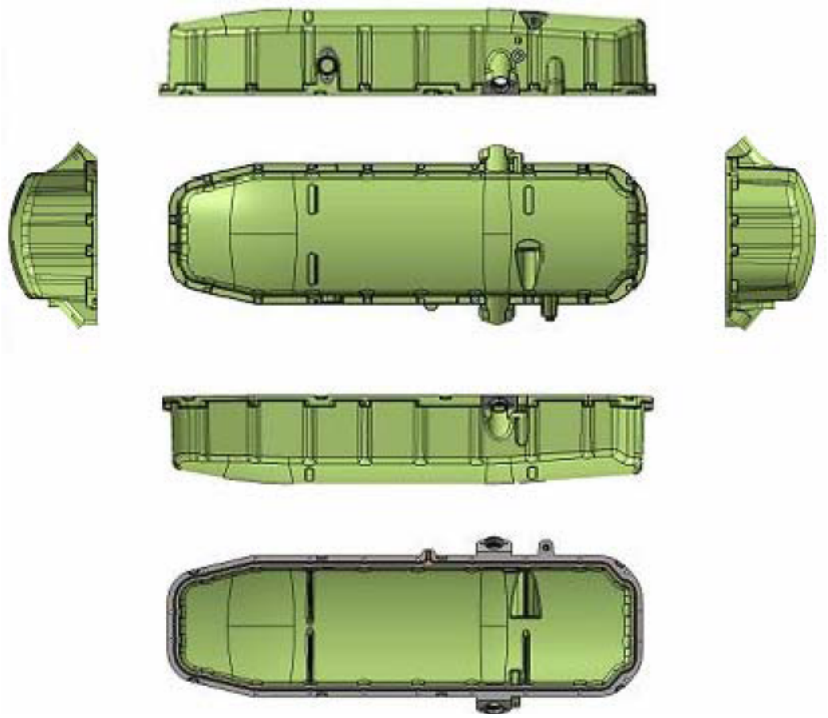


Figure 11.*Representing a 3D model of a body, corpus, and oil container*

The project Factory-in-a-Box and the demonstrator #3 will definitely increase the Swedish industrial production. It is a mobile, flexible and fast production system, which will push forward the speed of the work. The project is changing the current face and outlook of the processes in the manufacturing due to its mobility and resource capabilities. The off-line programming of the demonstrator and the box can be adjusted for different products.

The application of the demonstrator can be used to sand and treat materials from different foundry levels; the automation set is design with the possibility of choosing different products from the database. The monitoring and the computer abilities are predecessor for successive production. The human operator contributes to the overall process with his high skills and experience.

The idea that lies behind the project is the transportable abilities of the boxes and the transportability and flexibility that stand behind it. The production ability on demand and the characteristics that the concept possess set as a prerequisite for the company success. The following figure 11 represents the idea that stands behind the Factory-in-a-box, the flexible, transportable and compact production system. Figure 12 demonstrates the lay out of the boxes in the production line for the factory application.

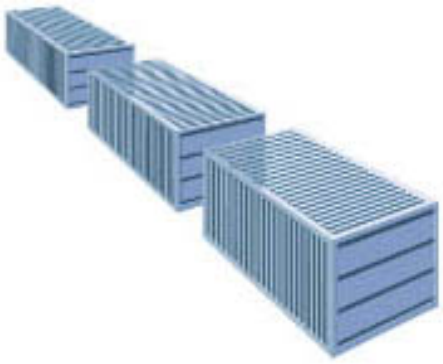


Figure 11. *Factory in a box representations*

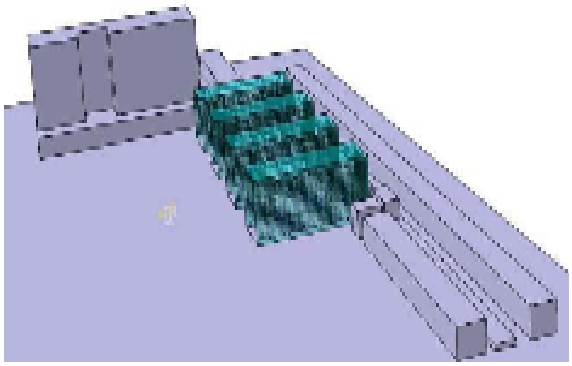


Figure 12. *Layout on a production line*

The current production system at the foundry level factory has certain imperfections and areas that are driving back the success of the company. As being discussed the working environment and the procedures are lacking certain characteristics that are not helping the good and overall manufacturing output of the company. The main project goal is to improve the working environment, by giving chance to the technology to handle with the hazardous and dangerous work, the human health and mood is a serious concern, when considering the foundry level. The thesis concerns the ability and the necessity of handling with the demands associated with the improvement and implementation of modernized system. It is a question of at what extend the system should be automated and how the different concepts respond to the demands of the entire goals. The collaboration between the human worker and the equipment are primary concerns necessary for the entire manufacturing output of the company.

10. Concepts

The preposition of four different concepts is taking place in the demonstrator #3.Based on similarities and differences this thesis is focused in finding out and analyzing the conceptual advantages and disadvantages from automation point of vies. The analysis will be oriented in finding out the appropriate concept and the connection between the equipment and the human operator. Material handling of the processes will be oriented in the close collaboration between the worker and the machine; it will not be oriented to the transportation of the products and their storage.

10.1 Concept #1

The first concept is focused in the modularity, simplicity and robustness of the processes. The automation process is relatively low and requires the operator's availability, placing of the part in the fixtures and tampering from the fixture at the output of the box, taking the product off. Figure 13 represents the robot concept.

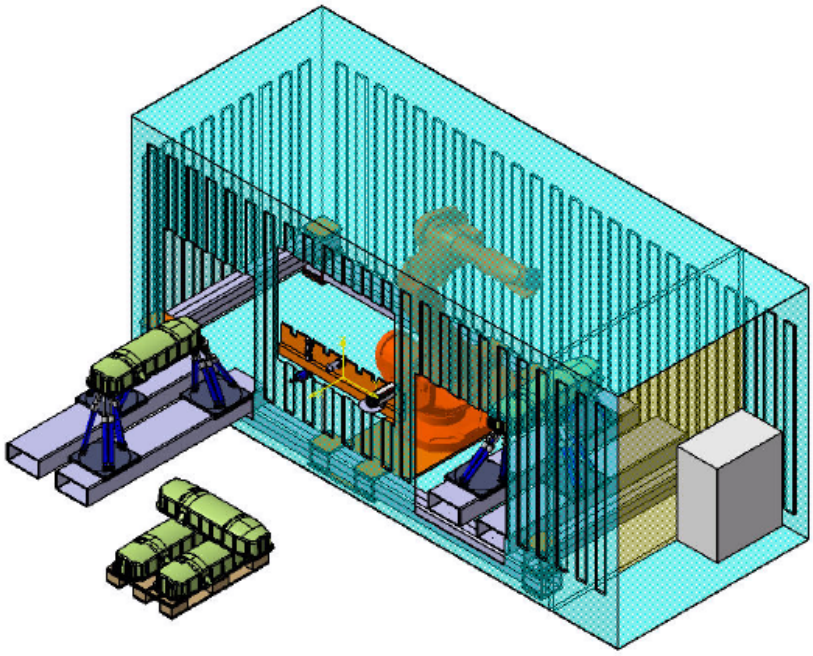


Figure 13. *View over the Concept #1*

10.1.1 Principle of operation

The process begins as the operator begins with the selection of the program that will be used according to the product that will be worked at. The hexagonal fixtures are positioned and they are in and off the box, when loading and unloading, their position is made from the robot. The hexagonal set, which slides out of the box, is ready for positioning of the

containers on the top. After this depending on the type of the product everything is calculated, the position and everything and after this the treatment of the product begins. The first treatment is with a routing file, where the angels are cleared. After this the process can continue with the removal of the other things and the air channels. After the treatment of the product and during the process the operator has placed another product on the other side of the box and prepares the next container, placing it on the fixtures. After one slipping the process begins again, but this time from the other side of the box. Then the operator removes the ready fixture.

It can be seen on the following figure 14 the layout of the process.

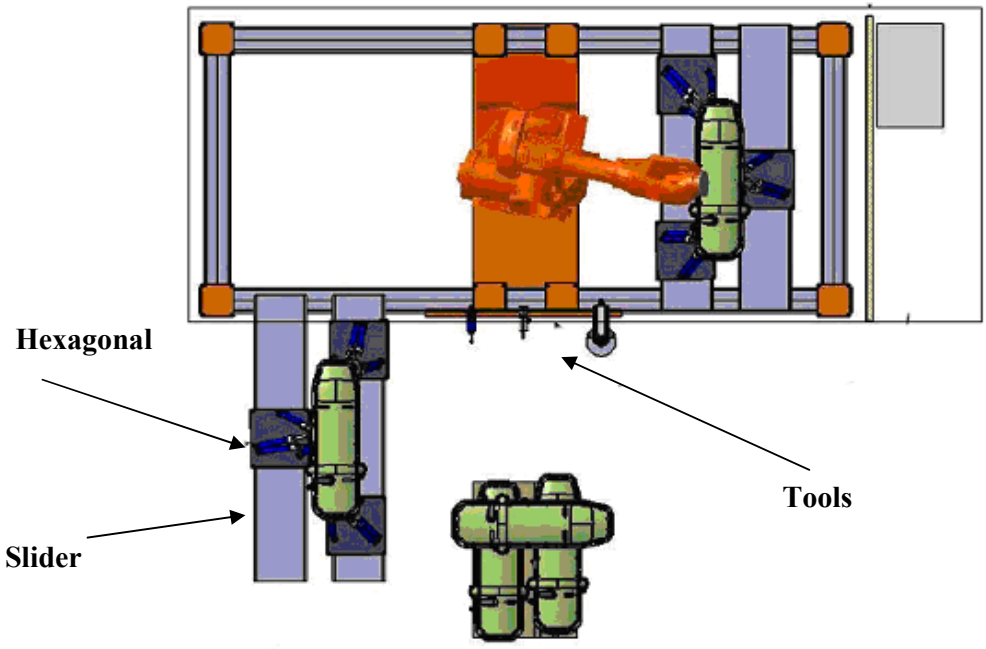


Figure 14. *Layout of the concept #1*

10.2 Concept #2

The concept #2 is oriented in the focus of functionality, simplicity and robustness and it relies upon the technical support of the material handling, the level of automation is low. The thought about the solution of the problem is to focus on a well known technique that has been experienced in order to get good functionality without problems. The following figure 15 shows the concept.

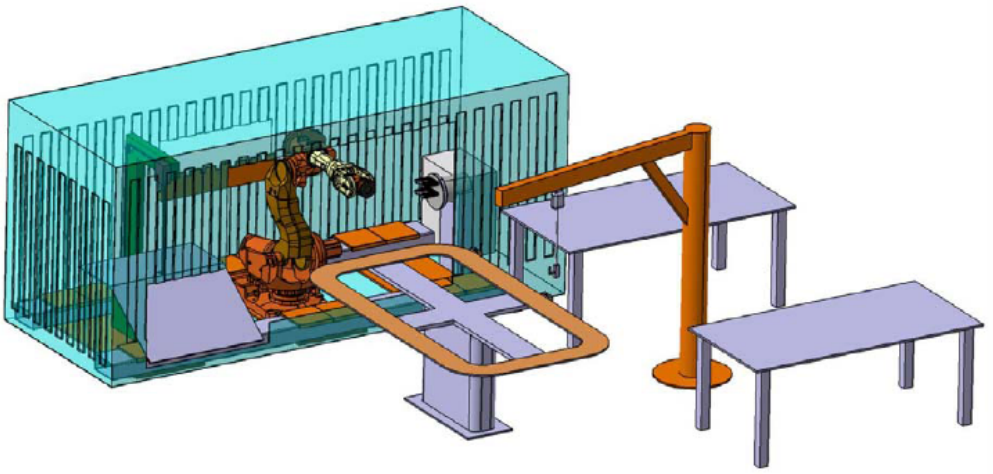


Figure 15. *View over the Concept #2*

10.2.1 Principle of operation

The operator with the help of the crane takes one griping device and places it on the table, where the untreated materials are and the parts are tighten up. After this the operator hangs up the griping device with the details and place it on the transport line, where it is hanged and left to wait in line. The next step is oriented in the robot placing the material on the fixture, then goes to the tooling place and takes the necessary tool, and then the treatment starts with the actual outer edges. When the operation is done the robot leaves the tool and goes to the griping device and brings back the details back to the transport line. After this operation the operator takes the ready details and places them back on the table where the finished details are. After the griping device is free the process starts from the beginning.

The following figure 16 shows the griping device that is in this concept

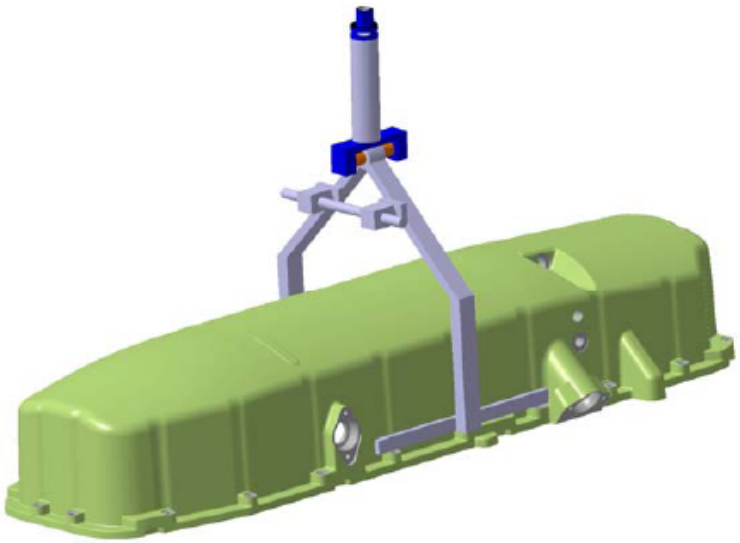


Figure 16.*Griping device with an attached container*

The following figure 17 represents the layout of the Concept #2

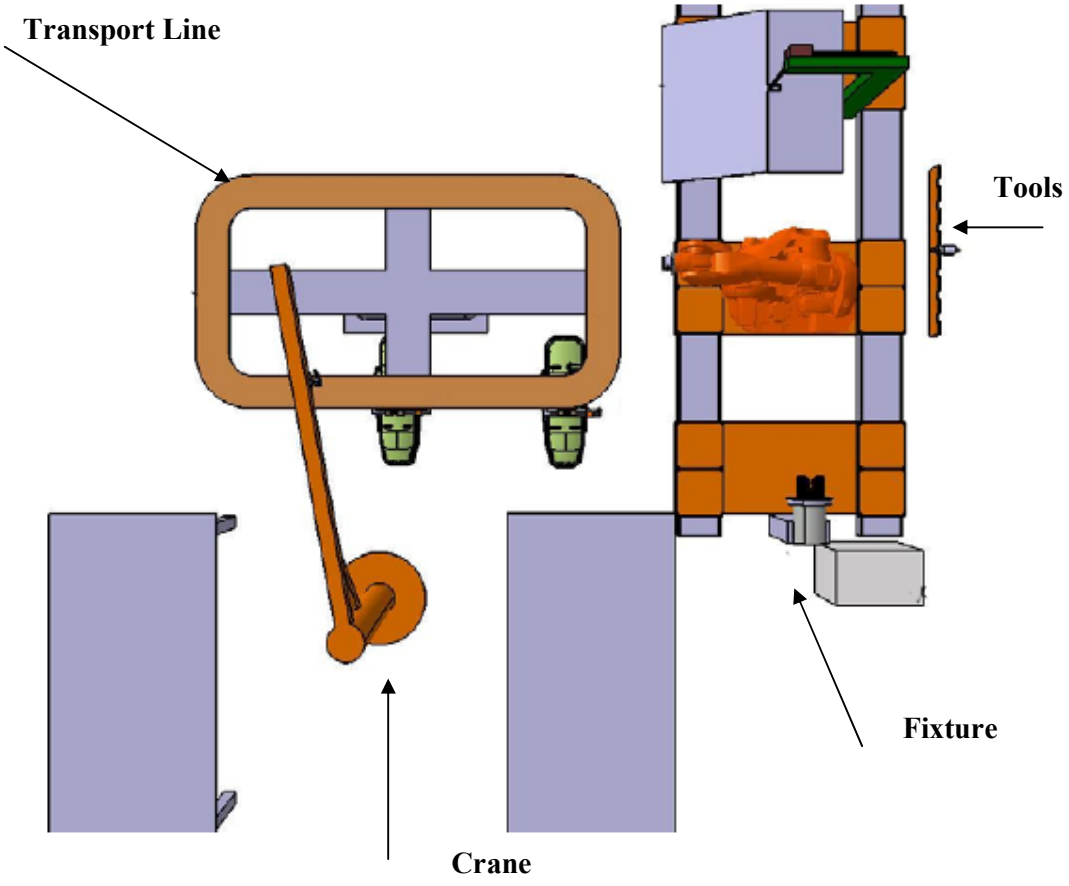


Figure 17. *Layout of the concept #2*

The concept #2 has an alternative variant. The two concepts are identical, but the only difference lies on the fact that the fixture is replaced with a faster one. The slipping machine part and the storage tool place are removed. In this case the time for changing the tools is reduced. The time that is saved for this type of operation at the same time can be lost, but all the operations should be performed. This type of operation with the faster slip is cheaper than the fixture, this is another advantage. The storage tools place and the fixture are not standards elements and usually they have to be produced individually. The following figure 18 and figure 19 represents respectively the concept #2a and its layout.

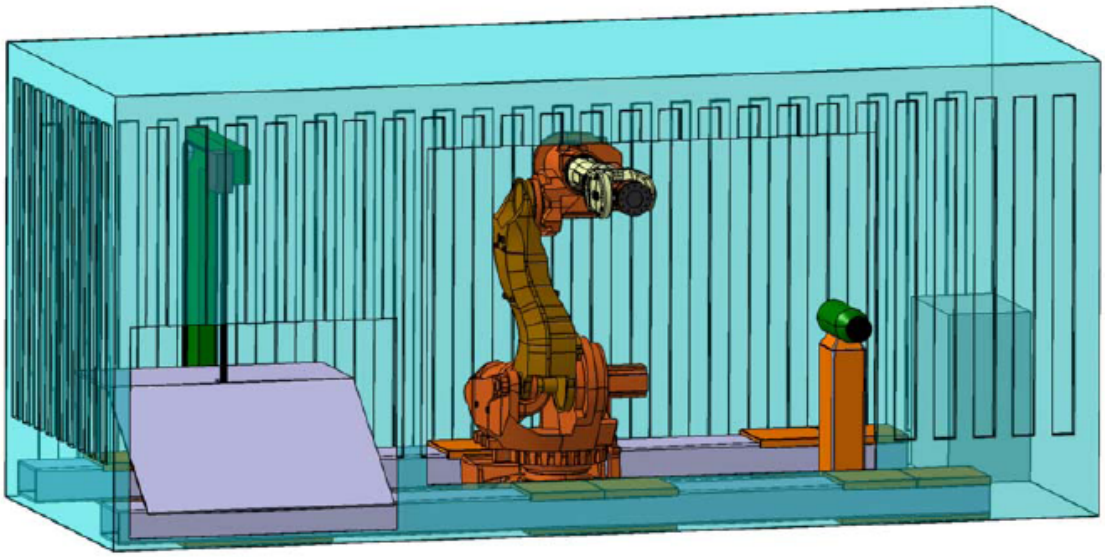


Figure 18. *Alternative Concept #2a*

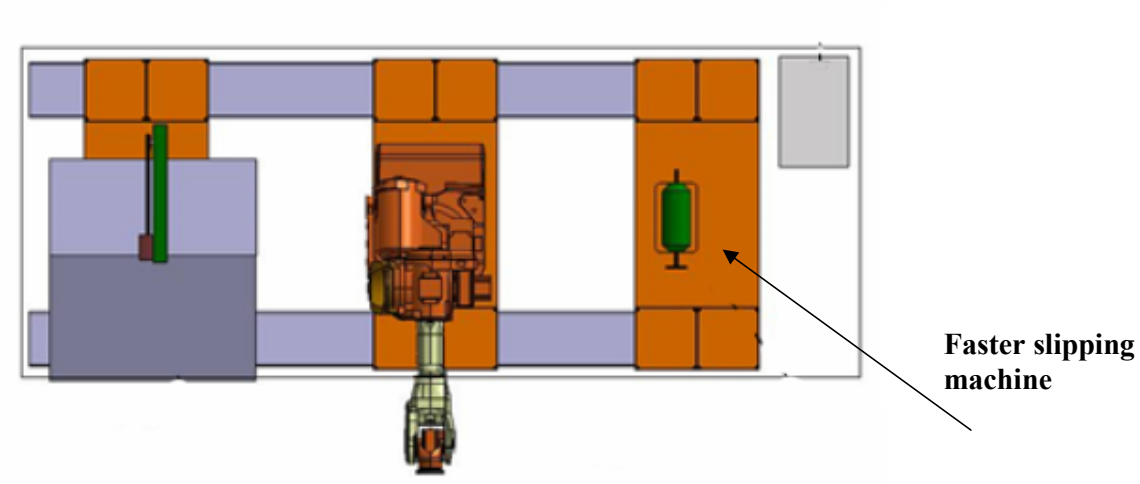


Figure 19. *Layout of the Concept #2a*

10.3 Concept #3

This concept is focused on the fast rechangeability and reconfigurability of the equipment, due to the high need of treatment. The automation is relatively high, which needs the necessary equipment.

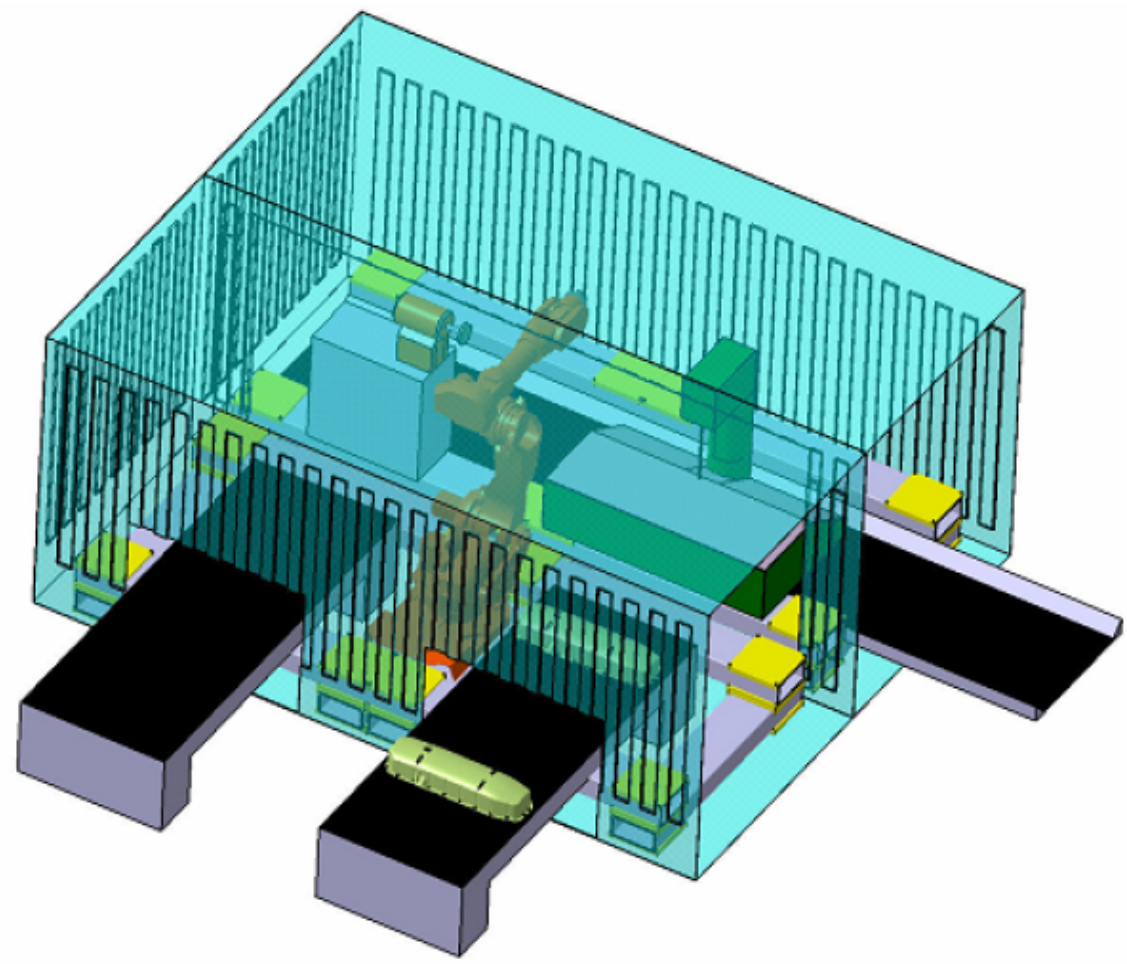


Figure 20. *View over the Concept #3*

10.3.1 Principle of operation

The process begins as the operators place the details on the transportable line and observe the details whether they are laid down properly. When the part is on its way on the transportable line the part is placed over the inspection of one camera, which identifies the outer edges of the part. When that is done the next step is the robot to take the part and place

it against the band saw. When the operation is done the robot place the part on one or more cutting mills. Then the element is placed on the outgoing line and the process can start from the beginning.

The following figure 21 represents the layout of the process.

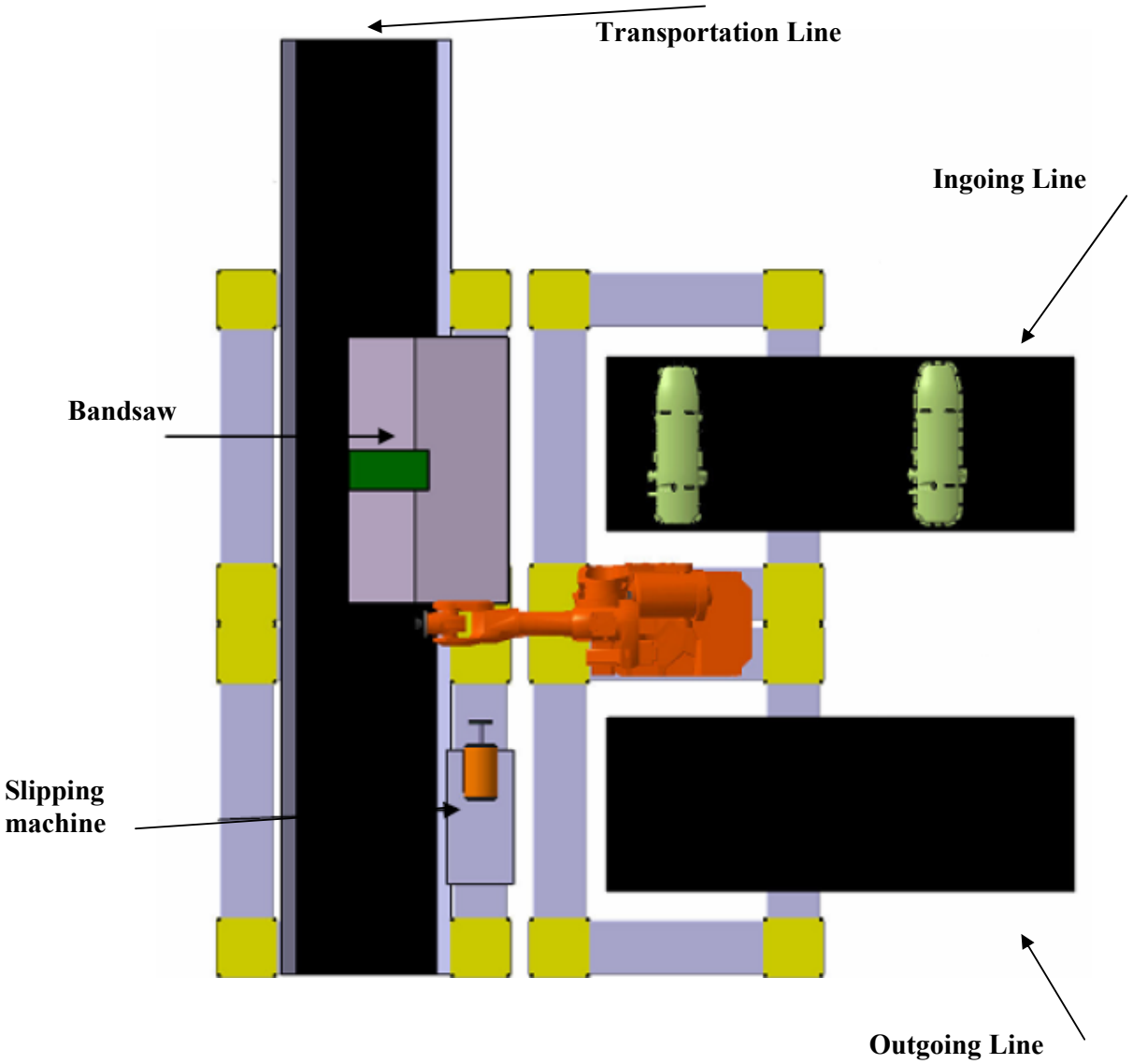


Figure 21. *Layout of the Concept #3*

The concept #3 has an alternative variant. In order to be possible the functionality of the material positioning to be functional better it is important to place better when they go to the box. As being explained the concept uses a camera, but at the same time there are other methods, which are possible for this purpose. One case is the operators look over the process and its ability of vigilance. One way is to change the ingoing line with a sliding one just as in

concept #1, with a scan device. And the operator is responsible for the correct positioning of the part, like in a fixture of a hexagonal. So the detail is placed in the box and the treatment begins.

10.4 Concept #4

Concept #4 is characterized with high technological alternatives, where the flexibility, speed and the high level of automation are important factors. The concept is created based on the principle of creation of automobiles and observing with a camera in order to control the position of the instruments.

The following figure 22 demonstrates the Concept #4

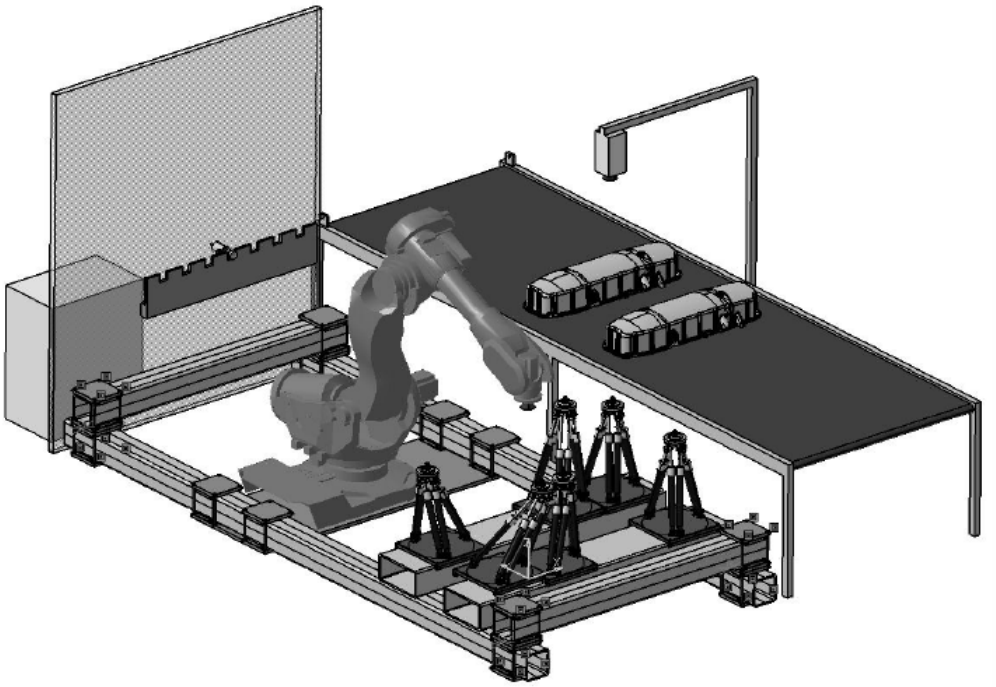


Figure 22. *View over the Concept #4*

10.4.1 Principle of operation

The process begins with the operators positioning of the parts on the transport line, the part is moved forth and back, where the photocells are, before the opening of the box, where the robot is. When it stands the usage of a 3-D camera takes place in order to position the part in the correct manner. Before every new batch there is a need of positioning of the hexagonal in the space so that it is possible to fix the part. When the position is estimated and everything is in correct position the work can continue. Then the part is attached with the help of a vacuum gripping device or with a standard gripping device. Then the robot places the parts in the flexible fixture and changes the necessary instrument for the specific operation of the treatment. After the treatment the robot places the parts on the transport line, so that the cycle is full.

On figure 23 it is shown the layout of the Concept #4

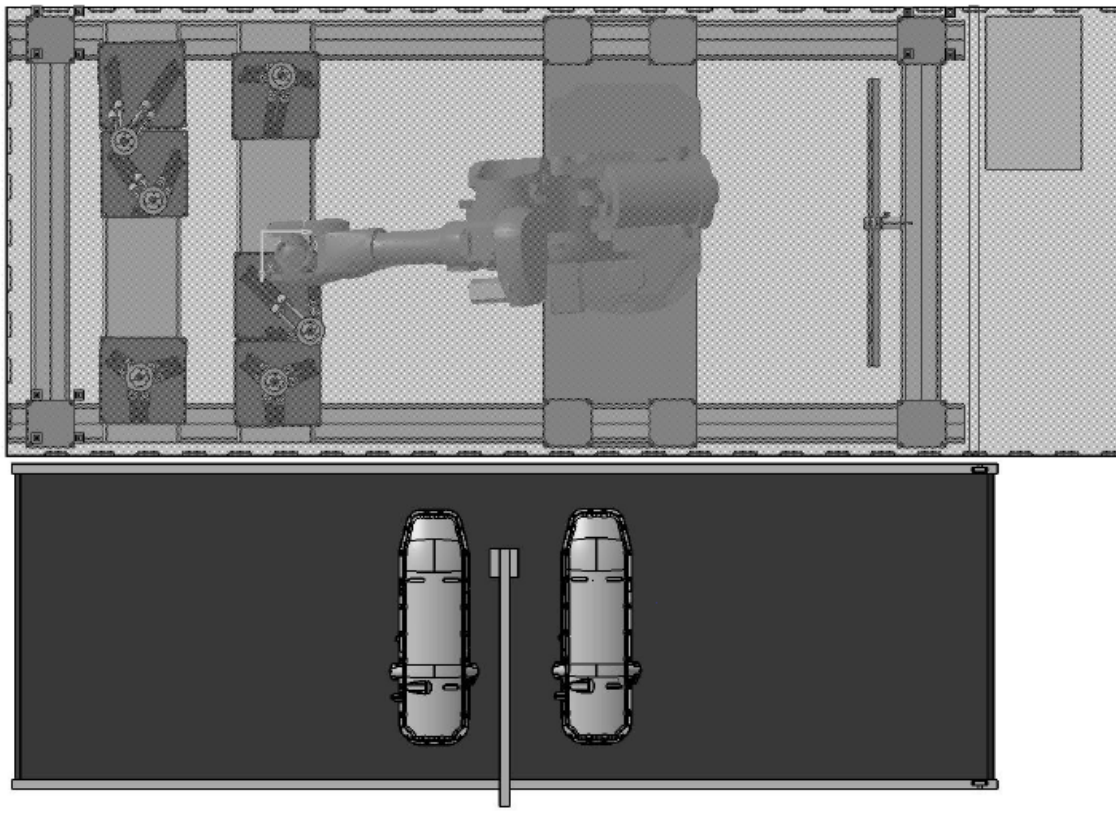


Figure 23 *Layout of the Concept #4*

An alternative variant exists regarding this concept. One of the variants is that the hexagons are placed on the other side of the container, this follows that the space will be emptied and as well the cutting forces will be lower, so in this case a usage of smaller robot is possible of type IRB 4400. The two robots can work parallel with each other, for example one of them is cutting, while the other the smaller one is sawing. When cutting during some process the smaller robot can hold what has been cutting, in order to sort it at the appropriate space. The disadvantage of this alternative concept is that the parts that are hanged on the wall can be down from themselves, after certain time.

The following figure 24 demonstrates the alternative Concept #4a:

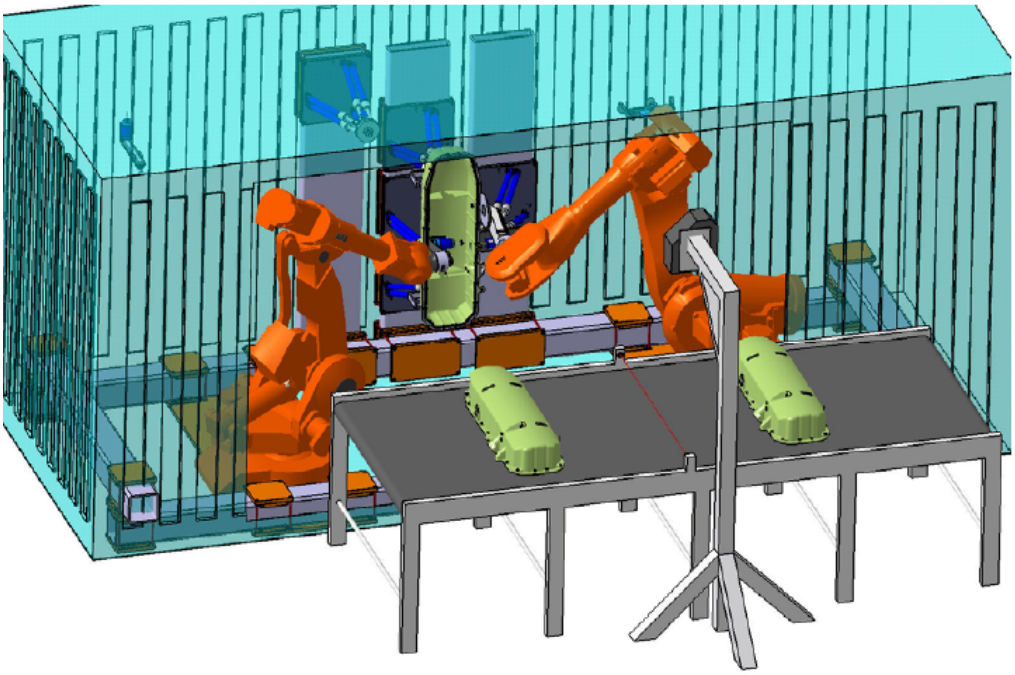


Figure 24.*Variant of the Concept #4a*

10.5 Evaluation

All the methods have been created in order to satisfy certain demands and criteria. The method differ from each other and regarding this thesis it is important to distinguish ,which methods are more oriented to the high automation and lower human participation and ,which are more manually oriented with the decrease of the automation presence. All of the concepts include the mutual collaboration between the human operators and the machines.
The concepts will be graded according to their automation level. The purpose is not oriented in making the necessary decision it considers the analysis of the concepts and their

advantages and disadvantages. The importance of automation and to what extend that is necessary.

When evaluating the different concepts different evaluation methods and techniques can be used for this purpose. The scoring is oriented in arranging the different concepts and accepting the most appropriate one. The scoring should be done according to the *Levels of Automation* and the next one will be made according to the *company's goals*.

The following tables will grade the different concepts with respect to their possibilities and capabilities. Table 10 grades the different concepts according to their design. Table 11 grades the concepts according to their functionality. The usage of these tables is because they are closely related to the analysis concerned in this paper. The score is from 1 to 4, and on the first row is the average score of the different grading. The score has been made according to the characteristics that the DYNAMO project relies on and they are made regarding the different demands and criteria Rapport i TMPS 07 Produktionssystem – projektkurs, varterminen (2006).

Table 10 *Rapport (2006), Grading*

	Concepts						
	1	**2**	**2a**	**3**	**3a**	**4**	**4a**
Design (average)	*3.0*	*2.33*	*2.33*	*1.67*	*1.67*	*2.67*	*2.67*
Concept needing evacuation	*3.0*	*3.0*	*3.0*	*2.0*	*2.0*	*3.0*	*3.0*
Flexible concept having the integration with the surroundings	*4.0*	*2.0*	*2.0*	*2.0*	*2.0*	*3.0*	*3.0*
Concept that is transportable within company's building	*2.0*	*2.0*	*2.0*	*1.0*	*1.0*	*2.0*	*2.0*

Table 11 *Rapport (2006), Grading*

	Concepts						
	1	**2**	**2a**	**3**	**3a**	**4**	**4a**
Functionality (average)	*3.33*	*3.0*	*3.0*	*3.0*	*3.0*	*3.67*	*3.67*
From product to suspecting	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*	*4.0*	*4.0*
Concepts possessing clarity in many processes	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*
Concepts possessing clarity in many products	*4.0*	*3.0*	*3.0*	*3.0*	*3.0*	*4.0*	*4.0*

11. Grading and connection between the different concepts and the levels of automation

As being described earlier the levels of automation can be used for positioning the best and the most appropriate level of automation for one production system. To what extend it works and to what extend it should work in order to achieve the best manufacturing output and collaboration between the machinery and the workers in the system. The separation between the material handling and the automation of the system in case of the separation between the mechanization and the computerized activities that are basically performed by the automation system is the separation of the grading that will be made. Every concept has high automation level, said to be High Loa, but at the same time the levels differ form concept to concept. The material handling is different for the different concepts, and some of the concepts demands high operators skill and attention when handling the details and preparing the set for production. The classification of the level of the automation for the different concepts will be made with respect to table 5, where the different levels are represented varying form lowest to highest level with respect form 1 to 9. The table 12 grades the different concepts according to their performance and principle of operation.

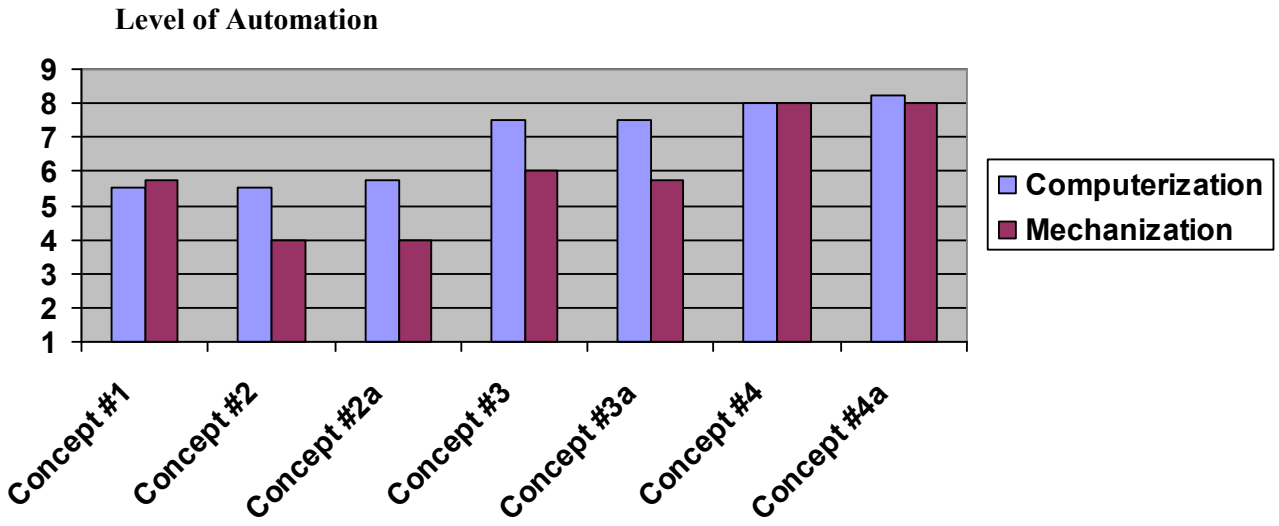
LoA	Computerized/Cognitive Tasks/ Activities	Mechanized/Physical Tasks/ Activities
1	The human produce the options, decide and execute the option without any assistance of the computer.	Total manual physical work, no physical tools are used, only human muscular strength.
2	The computer presents all suitable options; the human can choose and execute one of the options.	Manual physical need support of static hand tool.
3	The computer suggest a number of options, the human can choose and execute one of the options.	Method physical work with support of a static of a dynamic tool.
4	The computer produces a number of options and recommends one of them; the human can then choose to execute that option.	Manual physical work with support of an automated hand tool.
5	The computer suggest one option, the human can decide, and the computer execute the decision	Controlling of machine/robot on site that execute the task.
6	The computer suggest one option, decide and execute the option, the human is always informed.	Supervision of machine/robot on site that execute the task.
7	The computer suggests one option, decide and execute the option, the human is always informed if the human demands information.	Supervision and control of one or many machines/robots from a central control-room.
8	The computer suggests one option, decide and execute the option, the human is only performed if the computer demands that the human should be informed.	Automated physical work by machine/robot, the human is only involved when the machine needs assistance.
9	The computer suggests one option decide and execute the option without any assistance of the human.	Total automated physical work, the machine/robot solves the problem by itself when they emerge. The human are never involved.

Table 4. *"Copy" Level of Automation - Dynamo Project*

Concept	Computerized/Cognitive Tasks/ Activities	Mechanized/Physical Tasks/ Activities	Combination Automation Level (average)
Concept #1	5.5	5.75	5.625
Concept #2	5.5	4	4.75
Concept #2a	5.75	4	4.875
Concept #3	7.5	6	6.75
Concept #3a	7.5	5.75	6.625
Concept #4	8	8	8
Concept #4a	8.25	8	8.125

Table 12. *Grading of the Different Concepts, Task Allocation, Combination of the Activities*

The grading will be represented in the following graph 1.The purpose of the graph is graphically better visualization of the *Levels of Automation*.



Graph 1.*Graphical Representation of the Grading*

Table 13 will represent the grading that will be made according to the company's main objectives and goals that are necessary to be fulfilled in order to accept the most appropriate concept that is proposed. The criteria that have been represented in table 10 and 11 are those that are based on the need of the customers and closely connected to the aim of the Factory-in-a-Box project. The criteria are summarized and have to be considered in taking the evaluation concept. All the concepts differ from one to another and they satisfy different production demands, all of them are similar in one sense that they have been created for

satisfying the company's demands. The best concept should be accepted according to the appropriate Levels of Automation, which the company needs and it should be connected with accordance with the entire goals of the company, satisfying the project main goals, which have been discussed in Section 8.
Brief summary is listed below:

Leading Goals of the Project:
1. *Work Environment*
2. *Reduction of the cost*
   - *workers cost*
   - *saving energy*
   - *cost of material*
3. *Reduction of work process time*
4. *Waste of material*

According to the company's overall goal the different concepts satisfy all the criteria and are appropriate for the improvement of the company's strategy and the whole production system satisfying all the internal and external demands for successive manufacturing. As being discussed the main objective of the project is satisfaction and improvement of the working environment, which is a primary goal. The speed of the different processes is increased, the time necessary for the execution of all the processes and the treatment of the materials is decreased, the reduction of process time, lead process time reduction. The precision of the whole equipment will reduce the waste of material, which saves material and money.

12. Conclusion

The combination of human and automation control is the most desirable output for one automation design, characterizing it with flexibility and completeness.

The motivation behind the automation is to make the system simpler and cheaper to engineer. A second is to relieve the human operator, the reduction in the workload. And the most important thing is to make the system safer.

Creativity and innovation in new technology, which reflects to developing a new alternative system of production with different and new parameters, which are related to flexibility and dynamicity with close collaboration with humans within the production system, which are unachievable by fully automating the process is the essential step in this paper.

The purpose of the automation system is to perform and evaluate all the necessary tasks more efficiently, more reliably and more precise with higher accuracy then the human worker itself.

It should be stated that the automation has its limits and they should be considered very carefully, when analyzing different systems with the important connection between the price for the whole production and the safety of the system. The results of all the researches and investigations conclude that the driving force that stands for automating the processes is providing possibilities for increased efficiency and productivity. Automation is reducing the cost, increasing efficiency, productivity leading to overall company competitiveness on the more demanding market.

The most important factor in acknowledging the implementation of automation is the improvement of the work-environment by improving the conditions, hazardous work and eliminating monotony as well as saving physical demanding work.

After the study and the research it can be concluded that the work in hazardous environment, monotonous, and physical tasks are not appropriate to be conducted manually.

LoA is focusing on replacing of the human cognitive processes, the execution of the physical activities such as the mechanization. Automation is appropriate in speeding up the information flow and gives the opportunity is observing and controlling the processes. The most important aspect in the research is the ability of achieving a balanced manufacturing system, where the proper mix of necessary operators managing with the processes as well as the technological equipment necessary for obtaining the highest outputs of the productivity without loosing the quality and the human presence in the processes. The separation of the tasks between the information and control and the physical tasks is primary issue of the research and it is regarded according to the level of automation from the total manual work to the fully automated.

The presence of these concepts in this paper demonstrate the ability to choose the most appropriate one that reflects the most perfectly the company main goals and objectives. According to the author of this paper concept #3 and its alternative variant concept #3a are the most suitable ones for the company's decision, never-the-less all the concepts are appropriate depending on the area they are applied to, but the combination of manual and automated tasks is mostly considered in concept #3, which is the outcome of this research.

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15. Appendix

This chapter will list the technical parts and models considering the equipment used in the different automation concepts proposed.

The first proposed concept has the following components:

- Industrial robot ABB model IRB 6600
- Robot frame – BoxJoint
- Tools – Coromant Capto
- Hexagonal connection Capto – connection, fixtures coordinate with the help of the industrial robot

The second proposed concept has the following components:

- Industrial robot ABB model IRB 6600
- Robot frame – BoxJoint
- Gripping device Capto-coupling

The third proposed concept has the following components:

- Industrial robot ABB model IRB 6600
- Robot frame – BoxJoint
- 3D camera

The fourth proposed concept has the following components:

- Industrial robot ABB model IRB 6600
- Industrial robot ABB model IRB 4400
- Robot frame – BoxJoint
- Tools – Coromant Capto
- Capto-coupling
- 3D camera
- Hexagonal connection Capto – connection, fixtures coordinate with the help of the industrial robot

Sponsoring Companies: