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APPLYING LEAN-PRINCIPLES  
FOR ELECTRIC MOTORS PRODUC-  
TION

ABB Motors and Generators

Technology and Communication  
2014

## TIIVISTELMÄ

Tekijä	Sami Jaskari
Opinnäytetyön nimi	Lean-periaatteiden hyödyntäminen sähkömoottoreiden valmistuksessa
Vuosi	2014
Kieli	englanti
Sivumäärä	91 + 5 liitettä
Ohjaaja	Lotta Saarikoski

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Tämä opinnäytetyö tehtiin ABB Motors and Generators Vaasan yksikölle. Kyseisellä tehtaalla on päätetty ottaa Lean-periaatteet viitekehukseksi kehityshankkeille. Aiemmin on tehty kehityshanke suurien moottoreiden kokoonpanolinjalle, jossa ensimmäistä kertaa on käytetty Lean-periaatteita. Seuraava kehityshanke, joka tällä hetkellä on käynnissä, on pienmoottorien kokoonpanolinjan uudistaminen. Myös tässä projektissa Lean-periaatteet ovat apuna projektin tavoitteiden saavuttamisessa. Tämän opinnäytetyön on tarkoitus tutkia Leania, sekä sitä, miten Lean-periaatteita voidaan hyödyntää tässä kehitysprojektissa.

Opinnäytetyön teoreettinen viitekehys käsittelee puhtaasti Leania, sekä Leaniin liittyviä työkaluja. Tässä työssä tehtävinä oli osallistua kolmeen Kaizen-työpajaan ja dokumentoida työpajojen käyttö ABB Motorsissa. Toinen tehtävä oli tehdä ”benchmark” vierailu tehtaaseen, jossa Lean-periaatteet ovat olleet pidempään käytössä kuin ABB Motorsilla Vaasassa. Vierailusta tehtiin erillinen dokumentti ABB:n sisäiseen käyttöön. Kolmas tehtävä oli tutkia miten Lean-periaatteita voidaan hyödyntää pienmoottoritehtaan kehitysprojektissa.

Kehitysprojektissa on mahdollista käyttää useita Lean-työkaluja ja niitä tullaan myös käyttämään. Ehdotuksena tulevaisuuteen voidaan kuitenkin todeta, että enemmän tulisi jalkauttaa Lean-tietoutta myös työntekijöiden keskuuteen, sillä silloin yhtenäisen ”Lean-kulttuurin” kehittäminen työntekijöiden keskuuteen on mahdollista.

## ABSTRACT

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Title	Applying Lean-Principles for Electric Motors Production
Year	2014
Language	English
Pages	91 + 5 Appendices
Name of Supervisor	Lotta Saarikoski

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This thesis was done for the ABB Motors and Generators Vaasa –unit. In the factory the decision was made that the Lean-principles should be used for development projects. The first development project where Lean-principles were taken into use was the development project of the assembly line of large motors. Next, the assembly line of small motors is planned to be renewed and that project is currently running. The purpose of this thesis was to investigate the Lean-principles and that how those could be used in that small motor factory development project.

The theoretical section of this thesis handles of Lean and tools which are commonly used with Lean. The first task in this thesis was to participate in three different Kaizen-workshops and document the usage of these workshops in ABB Motors. The second task was to make a benchmarking visit to a company where the Lean-principles have been longer in use than in ABB Motors Vaasa. The separate report was made of that visit for ABB’s internal use. The third task was to investigate how the Lean-principles could be used to help to achieve the targets of the development project in the small motor factory.

Many different Lean-tools can be used in that development project. A proposal for the future next step would be to deploy the Lean awareness more also to the factory floor. When also the workers are committed to operate according to the Lean-principles, right kind of Lean-culture is automatically created among the workers and development of Lean strategy is then possible.

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**LIST OF ABBREVIATIONS**

4Q	= ABB's problem solving method
AL1	= Assembly line 1
AL2	= Assembly line 2
AL3	= Assembly line 3
AL10	= Assembly line 10
AL15	= Assembly line 15
AL25	= Assembly line 25
ASCC	= Advanced Supply Chain Collaborating. Collaborative commerce network between ABB companies and their suppliers
Hermes	= A tool for maintaining buffer agreements with suppliers, buffer levels are based on risk policy and calculated according to consumption and forecast data
MES	= Manufacturing Execution System
MSP	= Manufacturing Service Portal. Web portal for ABB subcontractors and business partners, linked to SAP
SAP	= Enterprise resource planning system (ERP-system)

# **1 INTRODUCTION**

## **1.1 Background of the Thesis**

This thesis was done to the ABB Motors and Generators Vaasa factory. There are currently running different long term processes which aim to raise the productivity in motor assembly lines. One part in this is the project Double whose main objective is to raise the productivity by 100% in the small frame sized motor factory. The whole concept of assembly lines in this factory will be renewed.

One part in the operation development was the decision to use the Lean-principles. The assembly line of the large frame sized motors (AL2) has been renewed earlier and that was the first development project where the Lean-principles were consciously taken into use. So at this point it seemed useful to investigate how the Lean-principles could be used also in the development project Double.

In the future, also the assembly line of the medium sized motors is meant to be renewed. After the reforms it is meant that three different lines operates in ABB Motors Vaasa factory, AL1 manufactures the medium sized motors, AL2 manufactures the large sized motors and the AL3 manufactures the small sized motors.

The objective of this thesis was to research how the Lean principles are currently used in ABB Motors and how they could be used in the development project Double. The objective was also to document the usage of Kaizen workshops in ABB Motors and make a benchmarking visit to a company where the Lean principles have been in use longer than in ABB Motors.

## **1.2 Scope of the Thesis**

The main focus in this thesis was in the operation in the small motor factory (AL3) because that is also scope in the Double project. The co-operation with suppliers is also included into the research because the small size motor factory

uses a lot of subcontractor network and it affects significantly to the operations. However, the supplier network and its improvements are handled only superficially because the deep analysis of the network is a very large project and the whole thesis could be done only on that topic.

### **1.3 Structure of This Report**

This report consists of eight chapters including this first introductory chapter. The second chapter gives a brief presentation about the company where this thesis is done. The whole ABB Group is presented so as the ABB's operation in Finland. This thesis was done to Motors and Generators unit, so it is also presented briefly in the second chapter. The third chapter presents the relevant theory of Lean management. Lean and its main principles are first defined generally. After that the certain most common Lean tools are presented.

In the fourth chapter the progress of the applied part of the thesis is described. The report of the applied part of the thesis begins in the fifth chapter. The usage of Kaizen workshops in ABB Motors Vaasa is presented. It includes the presentation of the whole concept of the workshops, including the preliminaries, three-day workshop and actions after the workshop. In the sixth chapter observations about the Lean benchmarking visit are reported briefly. The seventh chapter deals with the Double project. First, the project itself is presented and then the current situation and the background of the project are presented. Also the Value stream map is presented, as well as the wastes found in the Kaizen workshop in the assembly lines scoped in Double. The planned new lay-out is also presented and evaluated in that chapter. Finally, the usage of the possible Lean tools which could be used to help to achieve the objectives of the project is being evaluated, as well as the Lean methods with the suppliers. The final eighth chapter then summarises the report.

## **2 ABB GROUP PRESENTATION**

In this chapter the whole ABB Group and its operation in Finland are presented briefly, together with Motors and Generators unit, where this thesis was done. ABB has operations globally, which makes it very notable company all around.

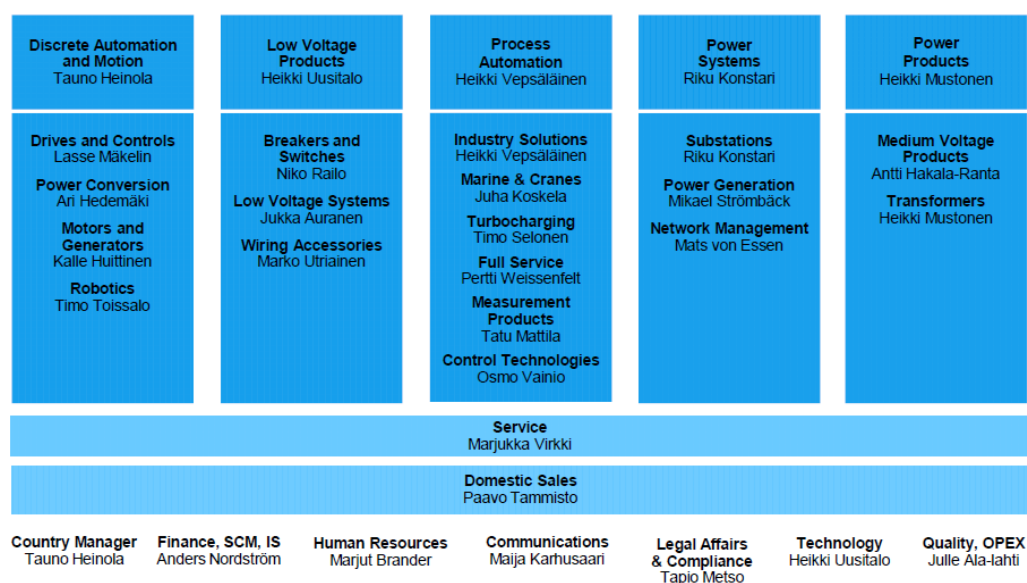
### **2.1 ABB Group**

ABB is a publicly owned company whose headquarters are located in Switzerland. ABB is a global leader in power and automation technologies. It holds a leading market positions in its main businesses. ABB was formed in 1988 when the Swiss BBC Brown Boveri and Swedish ASEA were merged. Now ABB has more than 150 000 employees and it has operations in more than 100 countries. Its revenues were 39 billion USD in year 2012. ABB's vision is to help their customers to use electrical power efficiently, to increase industrial productivity and to lower environmental impact in a sustainable way. (ABB Group 2013)

ABB is organized with five global divisions and they are: Power products, Power systems, Discrete automation and motion, Low voltage products and Process automation. The portfolio of ABB covers electrical equipment, automation, controls and instrumentation for power generation and industrial processes, power transmission, distribution solutions, low-voltage products, motors and drives, intelligent building systems, robots and robot systems and services to improve customers productivity and reliability. (ABB Group 2013)

### **2.2 ABB Ltd. Finland**

ABB has the major factories in Finland in Helsinki, Vaasa and Porvoo. ABB had about 6600 employees in Finland in 30 different localities in the year of 2012. The revenue in the same year was 2,4 billion euros. Figure 1 shows the organisation of ABB Finland. (ABB 2014a)



1.1.2014  
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January 7, 2014 | Slide 1



Figure 1. ABB Finland organisation. (ABB 2014b)

### 2.3 Motors and Generators

Motors and Generators unit belongs to the Discrete Automation and Motion division. Motors and Generators unit develops and manufactures electric motors and generators for industry and many other applications all over the world. The unit is specialised in the research and development of motors with high efficiency, and it is a forerunner in its field. In Finland, Motors and Generators have factories in Helsinki and Vaasa. The factory in Helsinki manufactures and sells among others high voltage motors, wind- and diesel generators and permanent magnet motors. The factory in Vaasa produces low voltage motors to the IEC standards. (ABB 2014c)

The assembly lines of motors are divided in two different factory buildings in ABB Motors Vaasa. One factory building, called MM-building, houses the assembly lines of the large and the medium sized motors. The assembly line of large sized motors is called AL2 and the assembly line of medium sized motors is called AL1. In another factory building, called KK-building, is located the assembly lines of the small motors. In the small motor factory building there are currently three different assembly lines AL10, AL15 and AL25 in operation. In the de-

velopment project Double all those three different lines located in KK-building are meant to be united to one assembly line, AL3. The assembly lines of the ABB Motors Vaasa and their locations are shown roughly in Figure 2.



Figure 2. Assembly lines in ABB Motors Vaasa.

### **3 THEORETICAL APPROACH TO LEAN**

In the next chapters the theoretical approach to this thesis is presented. First what Lean means generally is explained. After that issues which are relevant for defining Lean are presented. In the final chapter of this theoretical framework the most common tools which are used when the company is executing or trying to achieve the Lean operational strategy are explained.

#### **3.1 Lean Management**

The roots of Lean thinking come from Toyota's factories in Japan. Toyota itself calls this type of operation TPS (Toyota Production System). In past decades this type of operational management has been adopted also in many other industries. In the Lean-thinking the ideal situation is such where you can instantly meet the demands with producing perfect quality with good price and without waste. (Slack, Brandon-Jones & Johnston 2013)

Lean defines an operational strategy the core of which is to improve the flow efficiency. When the flow efficiency is at a high level there should be such actions all the time for the produced product which raise its value for the customer. Also, if the flow efficiency is high, the time spent from the order to the arrival of the product to the customer is short. When the company concentrates on the flow efficiency, it can reduce the additional work and remove the waste from the processes. When the amount of waste is reduced, also the resource efficiency usually improves, but Lean still always underlines the flow efficiency, not resource efficiency. (Modig & Åhlström 2013)

The philosophy of Lean could also be compacted to two pillars. The first one is: "The concept and practise of continuous improvement", and the second one is: "The power of respect for people". In Lean such a culture should be created in a company which consists of aiming at continuous improvement in every single process and people should be engaged to that. The only way to achieve this kind of culture is to respect other people and their opinions. The management should not push that culture to the workers. Instead of that the management should moti-

vate and encourage the workers to implement such a way of thinking that they themselves try to achieve the continuous improvement in their every-day job. Lean offers various tools what motivated and Lean-culture oriented workers first learn and then use those in their jobs. Lean is “continuous improvement through people”. Figure 3 shows the preferred way to achieving the Lean culture. (Koenigsaecker 2009)

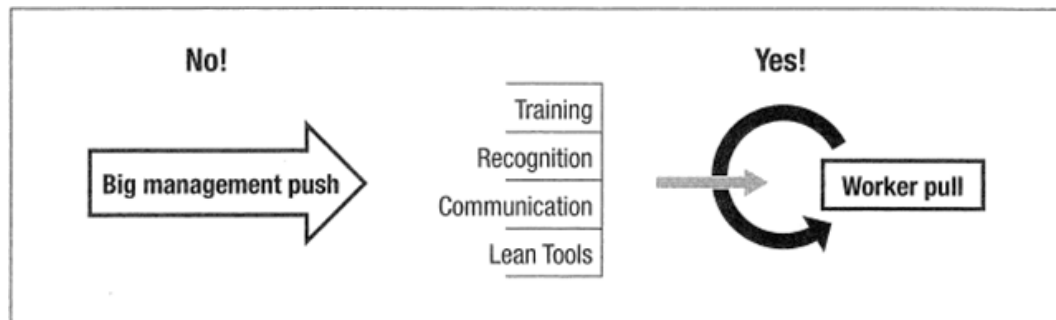


Figure 3. Two ways to commit Lean (Tapping, Luyester & Shuker 2002)

### 3.2 Five principles of Lean

In the next five chapters the five cornerstones of Lean-thinking are being presented.

#### 3.2.1 Focusing on Customer

The first cornerstone is the focus on the customer. First, it has to be defined what is the kind of action in the processes which raises the value of the product for the customer. Of course, also it has to be defined who is the customer of the process. The customer could be the end-user of the product, the next process, the next company in the delivery chain or the customer’s customer. (Bicheno 2000)

#### 3.2.2 Value Stream

Value stream should be mapped so that it can be figured out in which phases of the product’s moving through the processes the value-adding action is happening and where the waste can be found. With the help of this it is possible to concentrate to eliminate the waste. (Bicheno 2000)

### **3.2.3 Flow**

In Lean it is vital to create an unbroken product flow through the processes. The ideal is to create a one piece flow. Buffers and large batches should be avoided or at least those should be reduced actively. (Bicheno 2000)

### **3.2.4 Pull**

There should be production only in that level that customers order. It can be imagined that customer “pulls” the product through the whole production chain. There should be no overproduction because it is defined as waste. (Bicheno 2000)

### **3.2.5 Perfection**

When all of the four previous principles are adopted there should be an attempt to improve the operations continuously towards the perfection. The main goal is to get produced exactly what customers want, exactly when customers want, with a good price and with minimum waste. (Bicheno 2000)

## **3.3 Waste**

There are three different kinds of actions in processes when we look at the operations from the customer’s point of view. Those actions are value-adding, non-value-adding and non-value-adding but mandatory to complete the process. The non-value-adding operations are defined as waste. In Lean, waste is also often named as *muda*, as it is in Japanese language. There is an attempt in Lean to create an unbreakable chain between the value-adding operations. Non-value-adding operations should be eliminated from the production chain. And the non-value-adding but mandatory operations should be reduced to as minimal as possible.

Lean could also be defined with the help of this waste-notion. With this kind of definition Lean is such an operational strategy where you try to identify where waste can be found in production and how this waste can be eliminated. When evaluating the processes, there are two very demonstrative questions which help to determine if those operations are value-adding or not. These questions are:

- “If a customer saw me doing this step, would he or she be willing to pay me for it?”
- “If I did this step twice, would the customer’s pay be twice as much?”

If the answer for those questions are no, the process could be defined as waste. Those kinds of processes should be eliminated. (Koenigsaecker 2009)

According to Toyota Production System there can be seven different types of waste. Usually when speaking of waste these seven types of waste are meant. However, there exists still one more type of waste. This eighth type of waste is also an important factor even it is not usually being noticed. Below all the waste types, including this eighth waste, are explained.

1. Overproduction: When producing products or parts which have not been ordered by the customer. Overproduction increases costs because more workers have to be hired and also large stock increases warehouse and transporting costs.
2. Waiting time: This means, for example, situation when workers have to wait the previous or next work phase to complete or if some delivery has to be waited. Also possible bottlenecks which can occur in the production process cause waiting time.
3. Unnecessary movement or transportation: This means, for example, transporting the unfinished products long distances or other types of inefficiency. Unnecessary movements happen also when parts or material are being transported back and forth between the storage and production.
4. Over-processing or faulty processing: It is unnecessary to do more or better quality than the customer requires. Producing “too good quality” causes inefficiency. Faulty processing or unnecessary work phases can be caused, for example, by poor product design or inappropriate tools in production.

5. Inventory: If there are too much raw materials, parts, unfinished products or finished goods in storage, the lead time could be stretched very long. That also causes obsolescence, damaged products, overall delay and additional costs for transportation and storage. Inventories can also hide many possible problems, such as unbalanced production, failures in products, delays together with downtime and long set up times for production machines.
6. Unnecessary motion: All the workers' unnecessary actions in their jobs are included in this waste type. That is for example searching for tools or parts.
7. Production defects: Producing faulty goods and repairing them are considered to belong to waste. All defected parts or products causes always unnecessary work and wasted time.
8. Waste of unused human talent: This happens if workers are not committed or listened. This causes the waste of time, ideas, skills, improvement and learning opportunities.

Overproduction is usually considered to be the most significant type of waste because most of the other wastes are caused because of it. When producing too much goods the storage and buffers increase. The storages can hide large amounts of faulty goods which are not noticed until those products either get back to the production process or when they are prepared for transportation. Overproduction can also even cause the lack of motivation to continuous improvement because everybody is thinking that one faulty product does not mean anything, because there are large amounts of new products in the storage for replacing that faulty product. It is also difficult and time-consuming to get on with variety in demands when there is plenty of one specific kind of product in stock. (Liker 2008)

### 3.4 Main Pillars of TPS

As said before, modern Lean thinking is based on the Toyota Production System. There are two main principles in which the TPS is based on: “Just in time” and “Jidoka”. Figure 4 shows the construction of the TPS.

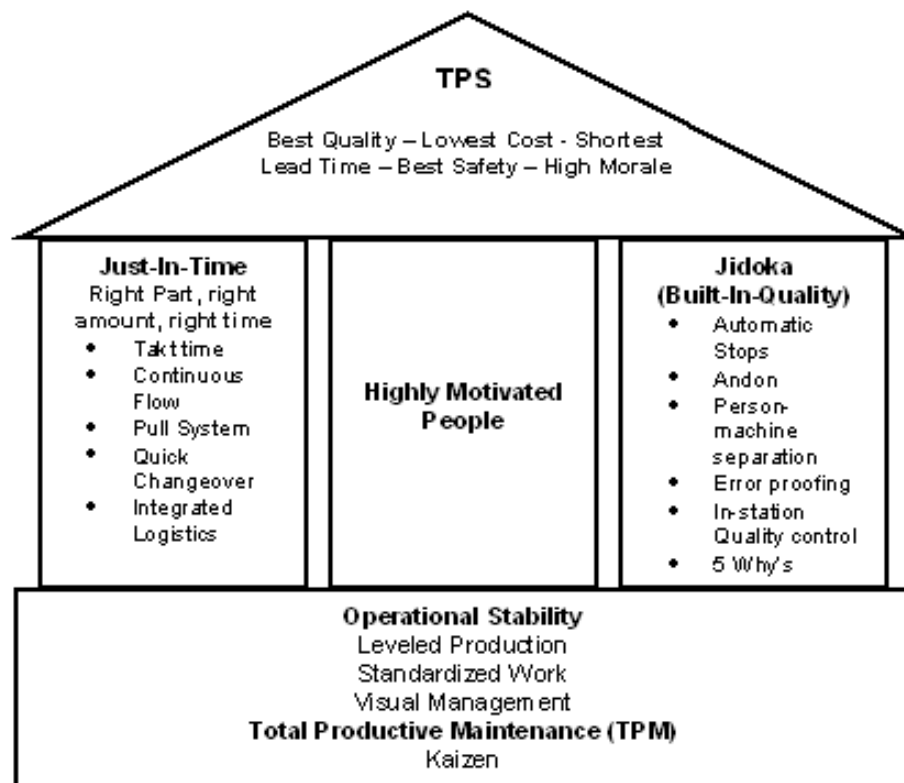


Figure 4. The construction of TPS. (EMS Consulting Group 2004)

The TPS is in many references shown as a house which consist of all the principles which are incorporated in the TPS. The construction of the TPS includes also other principles which allow the targets of the TPS to be reached. These targets are defined as a roof of the house in the figure, and they are best quality, lowest cost, shortest lead time, best safety and high morale. The operational stability, levelled production, standardized work, visual management, total productive maintenance and Kaizen in turn, form the base of the TPS house. Also as shown in the figure, the highly motivated people are also vital part in construction. It will be relevant to introduce these two main pillars "Just in time" and "Jidoka" more accurately next. Most of the other principles and tools are presented later in that thesis.

### **3.4.1 Just in Time**

Just in time (JIT) is the one main pillar in the TPS. Simply, JIT means that just the right amount of the right parts are delivered in the right place in just the right time. It is a set of principles, tools and procedures which enable that the small amounts of products or parts can be delivered with short lead times to the customer and to satisfy the customer's special needs and demands. With the help of JIT it is possible to effectively react to the daily variations in customer's demands. To ensure that JIT works perfectly it is important to keep in mind that the next process in the production is always the customer of the previous process. The previous process has always to produce for the next process what that next process needs and in the exact right time. With the help of this principle, it is tried to keep the buffers and storage levels at a low level. That is because big stock levels and buffers could hide the problems and production errors. (Liker 2008)

### **3.4.2 Jidoka**

The other main pillar in TPS is Jidoka. It means literally "automation with human touch". Basically Jidoka is about to build the quality in when producing the material. The thought in Jidoka is that the defected product should never be able to pass its way to the next phase. In Jidoka only the products with perfect quality are produced to the customer. Also the risk in which the customer – internal or external – gets the defected products which have not been noticed in the production must be eliminated. Jidoka is also about equipment and operations. They should be such that the workers are not strictly linked to the machines. Workers should be free most of the time to execute the value-adding work tasks. It is intended with the help of Jidoka to ensure that the machines do only value-adding activities, and also that the cycle times are shorter. With the help of Jidoka it is also possible to reduce the waiting, transportations, inspections and defects. (Tapping et al. 2002)

## **3.5 Value Stream Mapping**

Value stream mapping is used to define the current state of material and information flow in the production process. It is also used in planning to improve the

flows in order to make production more efficient in the future. To get mapping done well and accurately it is really important to go and collect all information concretely from the factory floor instead of collecting information from different old reports. The information collection is usually scoped either from inventing a new product to launching it, from raw-material arriving in the factory to shipment of the final product to a customer or from order's appearing to the system to when the customer has paid the finished order. Mapping helps to create a clear visual picture from the whole process chain, and helps in understanding the whole action better. It is also easy to identify waste and non-value adding activities in the production chain. The icons which are usually used in mapping are being presented and explained in Figure 5 below. (Tapping et al. 2002)

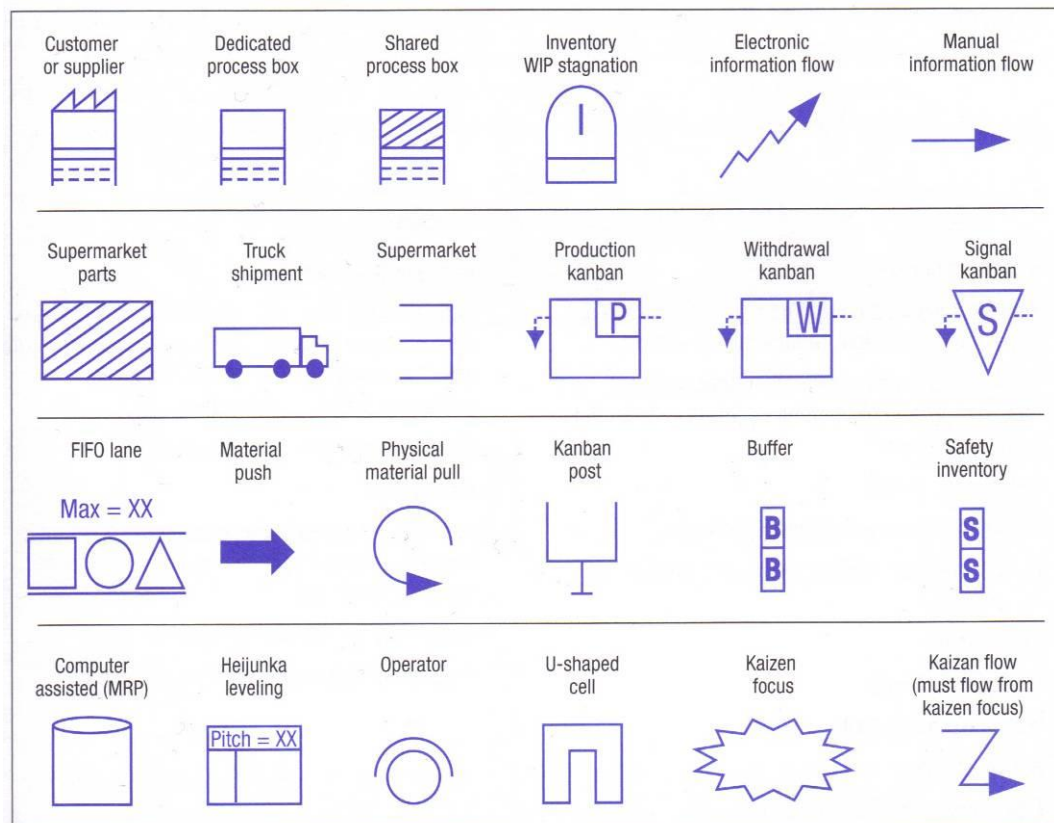


Figure 5. Value stream map icons (Tapping et al. 2002)

It is also important to concentrate on mapping how the information flows when the material flows between all the activities. This means practically how the pro-

duction scheduling is executed. Figure 6 shows an example of information flow map. (Tapping et al. 2002)

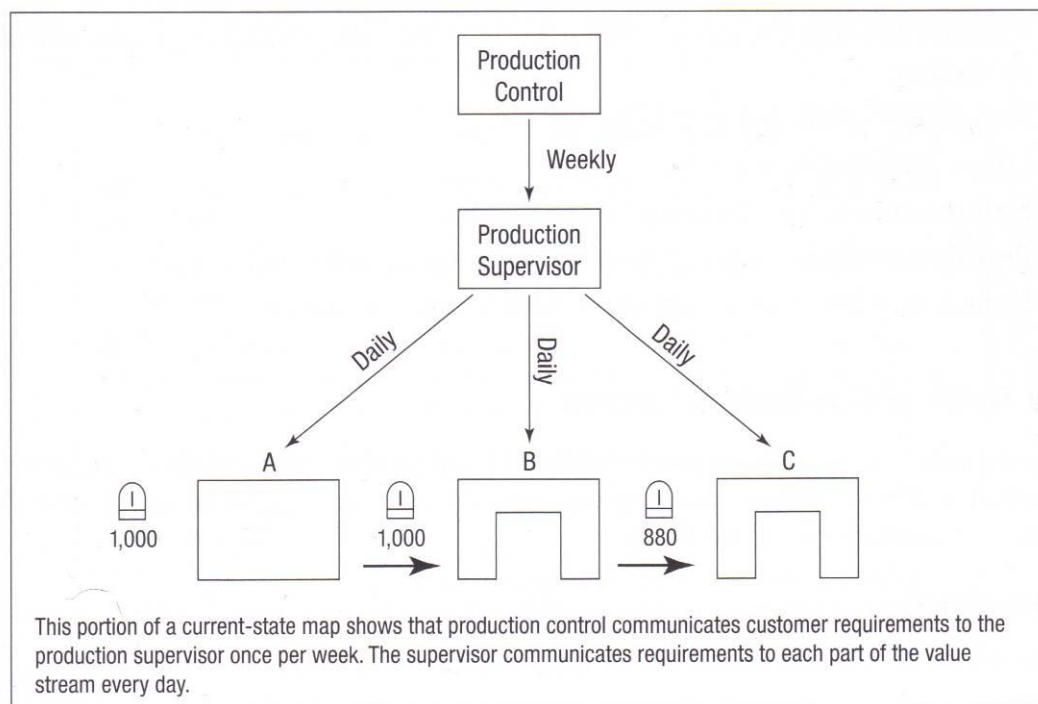


Figure 6. Information flow (Tapping et al. 2002)

The making of the current state map begins with marking the customer's symbol in the upper right corner of the map, the supplier's symbol in the upper left corner and the production control symbol in between those two. Below the customer's symbol then marked in the data box the customer's demands on every product are then marked in the data box. Next, below these symbols data from raw-materials supplies and final products shipments to customer is marked. That data also includes the frequency of those deliveries. Now the production process itself is marked below that delivery data. The first phase of production comes utmost left and the final phase comes utmost right on the map. Below each production phase all relevant data from phase is marked, such as the value-adding working time in phase which is usually the cycle time or the processing time. Also, in the upper right corner the shift time, all planned breaks and the daily available working time is now marked. After that, the information flow, both electronic and manual, in the process is marked on the map. In the information data the frequency of the information is also marked. Now the icon symbolising the production supervisor is

marked in middle of the map. After that, all the information flow is filled on the map all the way to the single processes. After that is done, the inventories and WIP should be marked in the map in right places between the processes with the quantities. Also the time WIP in hand in every phase should be marked in timeline in the bottom of the map. At the end also the push, pull and FIFO locations are marked in the map. A very simple example of the current state map is shown in Figure 7. (Tapping et al. 2002)

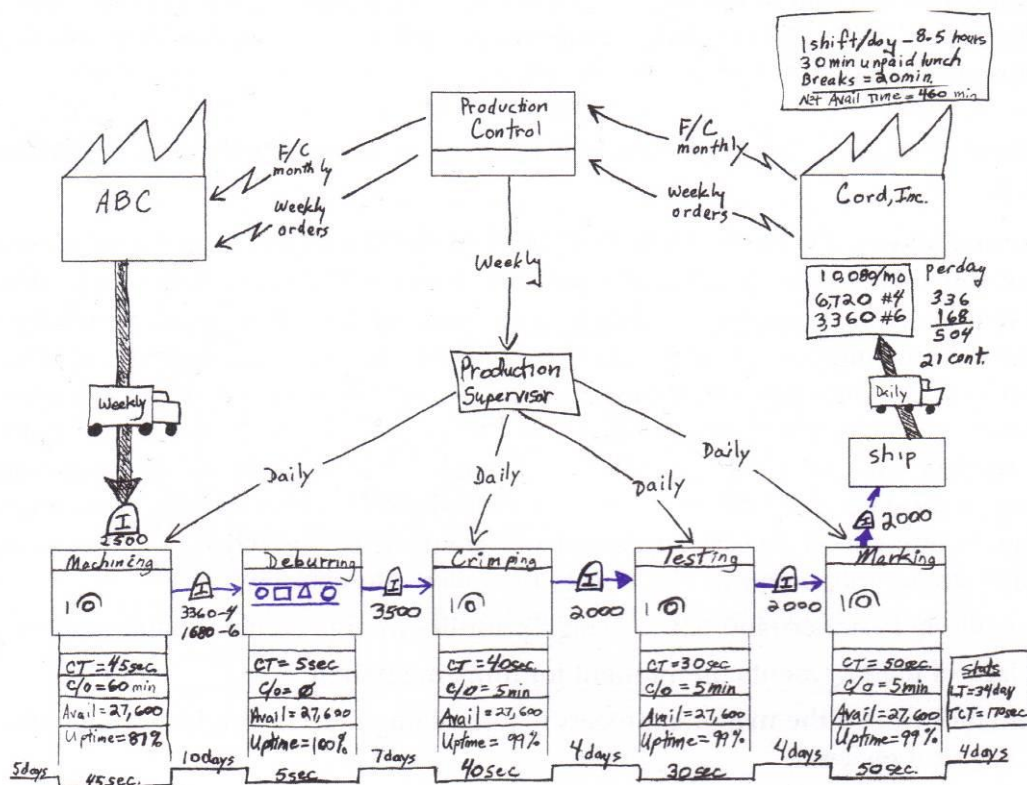


Figure 7. Current state map. (Tapping et al. 2002)

When planning the production improvements, the future state map is usually also made. It represents all the planned changes and improvements. That map shows the target where company wants to get. The making of the future state map consists as a matter of fact of three different phases. First, it must be defined and understood precisely what the customer wants. Second, the continuous flow should be improved so that the internal and external customers always get what they want in just the right time. And third, the work should be levelled so that the inventory and WIP could be reduced and because of that the tinier orders from the custom-

ers are possible. The making of this map is naturally based on the current state map. All the planned changes and for example the used Lean-tools are marked in the future state map. The future state map should be flexible so that if the plans change it is still easy to keep the map up-to-date. The future state map based on the current state map shown earlier in this chapter is shown in Figure 8. (Tapping et al. 2002)

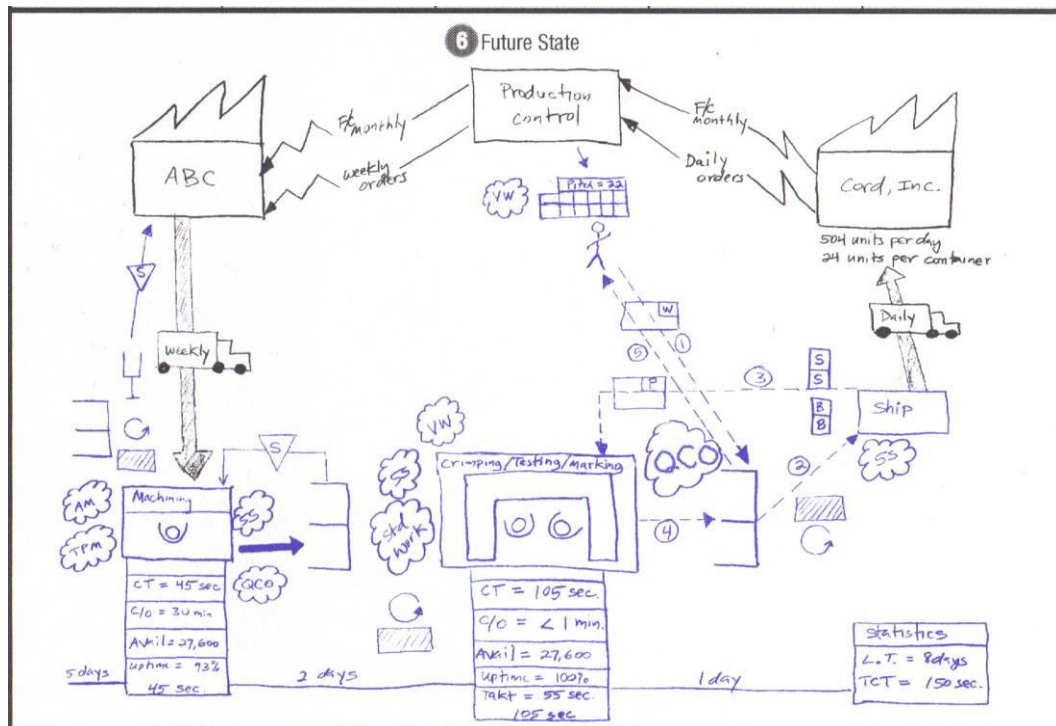


Figure 8. Future state map. (Tappin et al. 2002)

### 3.6 Lean Tools

Plenty of different tools are used for example in the Toyota Production system. Many of these tools are adopted in various ways in the companies which have wanted to commit themselves to the Lean strategy. In this chapter the most commonly used Lean-tools which have been observed to be very effective are presented. The goals of using these tools are to achieve the principles of Lean operational strategy which has been introduced earlier in chapter 3.

### 3.6.1 The Visual and Visual Management

One of the bases in Lean operational strategy is the well visible, visual operations. When the issues are made visual, it is much easier and quicker to understand the issues than for example just to read about the same issues. In Lean it is always tried to bring the information forward with visual methods. Also, in many Lean tools, the one purpose among all the others is to get all the possible problems or wastes quickly visible. There are many visual Lean tools, like for example Andon, 5S or Kanban which are explained later in this study. In Figure 9 one example of a well visually organised work area is shown.

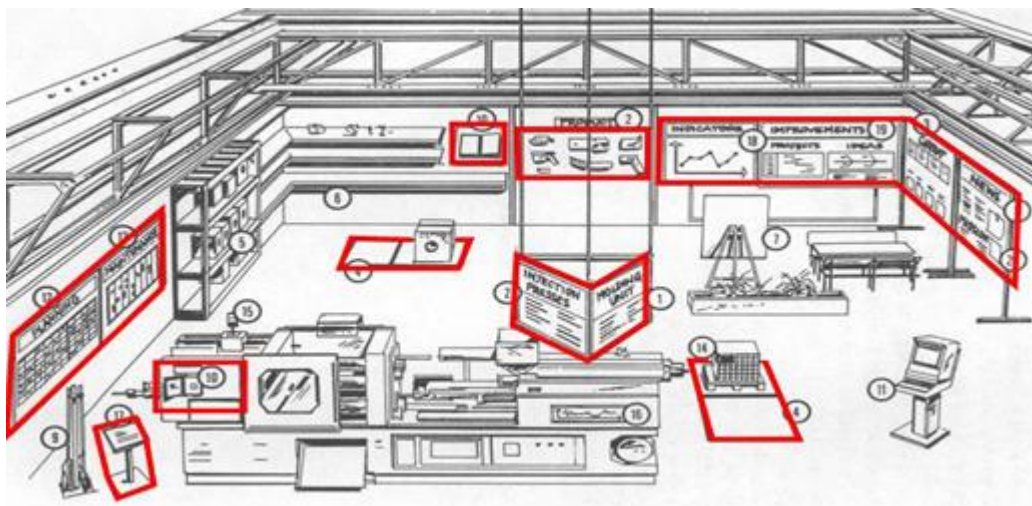


Figure 9. Visually organised working area. Everything is in its place. (VSI 2013)

In the visual management the indicator could be any kind of communication equipment which is used in work environment and it tells at one glance how the work is meant to be done or does it differ from the standard. Also, with the help of it, it is possible to inform the workers how their work is going. Visual indicators can also tell where the different goods belong to and how many goods belong in a certain place. Also the standardized way of working can be shown with the visual controllers, and what is the condition of ongoing work task and plenty of other information which is relevant to executing the job. In the biggest scale visual management means all kinds of “just-in-time” –information, where it is just in the right time just only the needed amount of information told. It is possible to ensure the rapid and proper execution of processes with the help of that. When the visual

methods are used, the workers have an opportunity to understand the overall view and the purpose of their jobs. Because of that they can better control their own jobs and duties. The good visual indicator should be such that it is immediately obvious what it represents. There should be no specific need to be familiar with it first. One example of a good visual indicator is shown in Figure 10 below, this cannot be misunderstood. (Liker 2008, Tapping et al. 2002)



Figure 10. Visual indicator at the airport. (Wrye 2013)

So, with the help of visibility it is among others tried to get to the situation where it is easy for workers to do the job assignments in the standardized way, and that all the equipment is in the right place, and also that the working environment is in every way clear and tidy. But above all the most important meaning of visibility is to get all the problems and deviations visible at one glance. In that situation it is possible to intervene immediately to those issues and as a final result, eliminate waste. For example, if the shapeliness of a specific tool is drawn in that place where it belongs, it is immediately noticed when that tool is not in its own place. Or for example, if storage levels are marked visually, it is possible at a single

glance to see if they are under the control. So it is immediately possible to intervene to the exceptional situations and start to find out the reasons which are caused those situations. (Liker 2008)

### 3.6.2 5S

5S is one of the tools which are used to eliminate waste. With the right use of 5S it is possible to eliminate waste which causes errors, defects or accidents in working environment. At the same time the visually pleasant and effectively working environment could be achieved. 5S is strongly the visual tool. With the help of it, it is also possible to get the problems visible, and with the right use of 5S it could also be the part of well-designed Lean-system's visual management. The 5 S's which belong to that tool are: Sort, Set in order, Shine, Standardize and Sustain, as shown in Figure 11. (Liker 2008)



Figure 11. Implementation of 5S. (Niftysol 2013)

Next, here is being explained what those 5 S's mean:

### **1. Sort**

First of all, all the goods located in working environment have to be looked over. All the goods and tools are divided into three different groups, those which are needed daily to produce value-adding work, those which are needed time to time and those which are never needed. Such goods which are never needed should be thrown away. Never used goods or tools causes only waste of time when the needed tool or particle have to be found among from all the countless amount of unnecessary things. Also the tools which are broken or not calibrated causes waste. They should be also thrown away or repaired if it is possible. (Liker 2008, Bicheno 2000)

### **2. Set in order – “A place for everything”**

When the tools and goods in working area are looked over and sorted those should be next organised logically. All the tools and goods which are used rarely should be located somewhere outside the working area. All the important tools which have been left in the working area are then organised based on that how often the worker uses that tool within the day. After the tools are organised a place for every tool must be marked so that this place is always the same. The places for tools and other goods lying on the floor should also be marked. When marking all the different places, there should be used various visual methods, like different colours or shapes to make it easier to find the right place for every particle. Workers should always be capable to instantly find each of the frequently used tool or part. With the help of good and right order it is possible to minimize all the unnecessary reaching, bending and walking around. (Liker 2008, Bicheno 2000)

### **3. Shine – Clean**

When the workplace is organised it is important to keep it tidy. There should be an attempt to keep everything clean and in right order with daily cleaning of the workplace. When acting like that it is possible to have a pleasant work-

ing environment and tools are always in at right places. With the active cleaning it is also possible to get all the potential deviations to be noticed easily. It is then possible to quickly intervene to abnormal conditions which could eventually do harm to quality or cause even machine failure. This is also a very important work safety issue. To this point of 5S belongs also all the possible daily minor service or inspections of production machines in which workers are capable. (Liker 2008, Bicheno 2000)

#### **4. Standardize**

With standardizing the three first points can be supported. That means creating different kinds of systems or operation guides. With the help of these it is possible to control and maintain all above principles. (Liker 2008)

#### **5. Sustain**

The most difficult with 5S is to sustain all the changes. The managers have a big role in sustaining because a culture has to be created where every working team should take care of the maintenance of their own environment. The automatic habit of following the right practices should be created which teams could continuously try to improve. One of the effective methods to sustain the 5S actions is to make regular inspections in workplaces by the managers. All these inspections should also be standardized. It has been proven to be quite effective that based on those inspections the best team could be rewarded in some way. This improves the workers' and teams' motivation to try continuously improve in the 5S actions. (Liker 2008)

### **3.6.3 Kanban**

The Kanban system is a very effective and simple way to implement the pull production control where only that amount what customer demands is produced, in accordance with one of the Lean principles. The example of pull system is shown in Figure 12 below. As it was noted before, the customer could be defined also as the following process of some specific other process. Kanban is a tool which at-

tempts to eliminate the overproduction and the waste what is caused because of that.

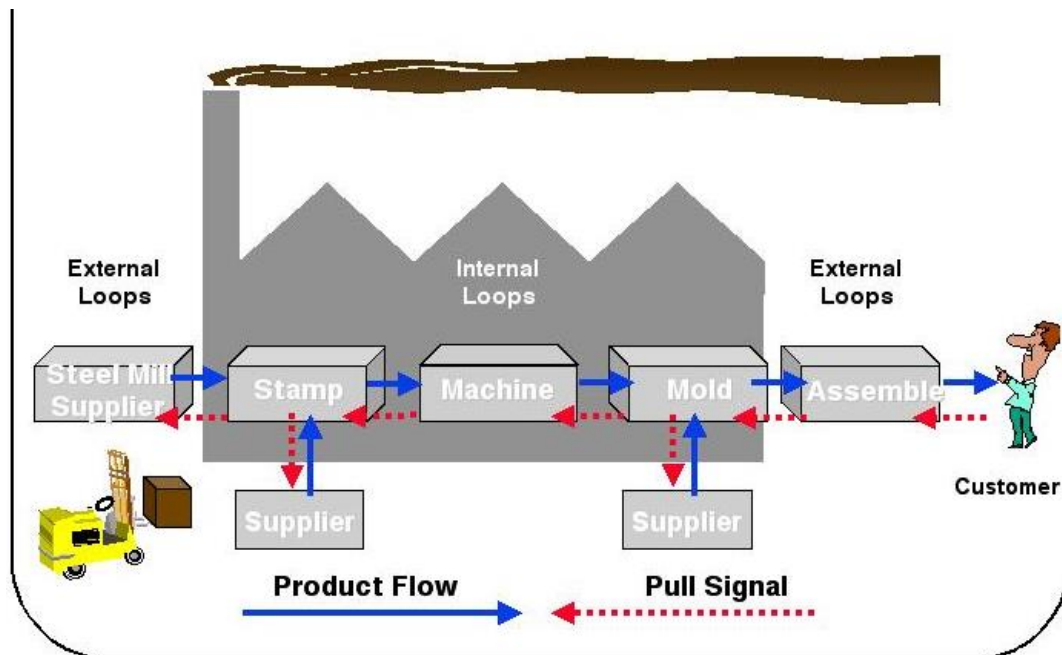


Figure 12. Example of pull control system. (Elsmar.com 2013)

Kanban is used in such kind of production phases where it is not possible to apply the smooth one-piece flow. These kinds of situations are formed, for example, then when there are various kinds of products and materials used in them and when the customers' demands are varying. The consumption of materials is not steady then and so the levels of storage are fluctuating considerably. The main idea in the Kanban system is to produce more parts in small storage according to how much the parts are consumed there. When acting like that it is possible to control the stock levels effectively and to keep them in a wanted level and to avoid the overproduction. If the traditional mass production push control system would be used in that kind of situation, there would be all kinds of parts in storages all the time according to schedules without depending on that how much those parts would be used. If the customers' demands are varying a lot that would cause eventually waste either because of overproduction or alternatively also running out of the parts, what causes unwanted waiting and delays. (Liker 2008)

The word Kanban itself means sign, board, poster, billboard, card, but it is generally interpreted as a signal. In the Kanban system the customer expresses with some signal (kanban) when he needs some specific commodity from the producer. This specific commodity is then produced to the customer according to the information that the signal (kanban) gives. One example of kanban card is shown in Figure 13. (Tapping et al. 2002)

Part Description				Part Number	
Smoke-shifter, left handed.				14613	
Qty	20	Lead Time	1 week	Order Date	9/3
Supplier	Acme Smoke-Shifter, LLC			Due Date	9/10
Planner	John R.		Card 1 of 2		
			Location	Rack 1B3	

Figure 13. Example of a kanban card. (Velaction 2013)

The most common examples of kanbans are cards or empty boxes. For example, in the production line some parts or group of parts could be marked with cards which include the specific information and amount about those parts. When this part or group of parts is used in production, the card is then sent to the parts supplier. This card then launches the actions in the supplier to get the right part produced and the right amount of parts according to that card to the customer. The customer in this case is the production line. That same card then also follows with those parts to the customer. The parts supplier could also have its own kanbans for the materials which are needed to produce the parts. This is what the pull control system is based on, information (kanbans) flows away from the customer in the production chain and the materials flow towards the customer. The other common way to implement the Kanban is the empty boxes. Specific information is marked in the boxes about what material box includes and how much it includes it. When the box runs empty, it will be shipped to the supplier. The supplier then fills the

box with that material what is defined in box and with quantity what is defined in box. Then the supplier ships the box back again to the customer. There can be either only one or several kanbans for the same product. The amount of kanbans should be planned and calculated separately for each product. (Bicheno 2000)

### 3.6.4 Andon

This tool is associated with quality and the principle of Jidoka. With the help of Andon it is tried to spotlight quality problems immediately. Also according to Andon's principle these problems must be intervened immediately, so that the production could continue without any breaks. Simply put, Andon means a visual indicator or controller which informs the staff about problems or defects in production with various signals. These signals could be for example different kinds of lights or voices, like shown in Figure 14. The purpose of Andon is to stop the progress of a defected product in the production chain. The other purpose is to launch the operations for resolving the causes for the problem and to eliminate that specific problem completely. (Koenigsaecker 2009)



Figure 14. Andon-lights. (Lean Sigma Supply Chain 2013)

With the help of Andon there is an attempt to reduce the quality issues permanently. Traditionally in mass production when problems occur, the faulty products are just put aside to wait the repair activities so that the production will not stop. But in Andon the main idea is that the faulty products are kept in the production line

and they are also repaired there immediately even if there is a danger that the line will eventually stop. That is because of that it raises the stress to seek out and resolve the cause of the defect causes carefully. When the causes are resolved, the same problem should never occur again in the future caused by the same issues. So, the main purpose with Andon is not just to repair the same problems again and again immediately, but to eliminate defects and errors permanently by eliminating their causes. (Koenigsaecker 2009, Liker 2008)

One clarifying and good example of using Andon is the Toyota's way to do that. In every workstation there is an Andon-button. When problem occurs in that workstation, the worker presses that buttons and yellow light appears above the workstation. The line still will not stop at that time yet. The yellow light is signal to the team leader that he has to react immediately to that problem, before that defected product moves to the next workstation. If the problem is impossible to be repaired within that time when the product is in that workstation, the product still does not move to the next work phase. In that situation the red light then lights up and the line stops automatically for that region where problem occurs. But if the problem is getting repaired, Andon is checked out and the stoppage of the line is cancelled. The causes of those problems should immediately be sought out and made the necessary repairing actions so that there would never be need to press the Andon button again because of the same problem. Usually there exists a small buffer of WIPs between the workstations. That is because when problem occurs in some workstation, other workstations could still operate normally for some period of time even after that. But eventually, if the problem is big and takes long time to repair, the operations at other workstations start also to be stopped from workstation to other. Still, the total stoppage of the whole line or the whole factory is very rare. Even if to keep buffers between the work phases is against the Lean principles, the SMALL buffers help to minimize the risk of loss of production when problems occur. (Liker 2008)

### **3.6.5 Heijunka**

Heijunka means production levelling. In Lean the products are made according to customer orders. So, it means that if work is always begun only when order ar-

rives the production is very uneven because of variations in the demand. Sometimes there could be plenty of work and the workers and machines are used with overcapacity. On the other hand, sometimes there are quieter seasons with not much work and the workers and machines are standing idle. Heijunka means to level that amount of work so that there would be always as even amount of work as possible. This is one of the trickiest principles to implement, because there should not be overproduction but still all the products should be delivered to the customer just in the right time and right amounts. (Bicheno 2000, Koenigsaecker 2009)

So, Heijunka does not make production based strictly on the actual customer demands because it could be varying a lot depending on time. Instead, in Heijunka, all the orders are taken within some specific time period to handling and then the orders are levelled so that there would be same production amounts and range daily. When acting like that it is also possible to standardize the job better because the same kinds of operations are repeated daily. (Koenigsaecker 2009)

Traditionally in mass production there is a habit to produce big amounts of one same kind of product at a time to the stock so they would be enough for the needs of a long time period. After that the machines and tools are set up so that it is possible to produce massive amounts of another product and so on. When acting like that, it is tried to minimize the production down time caused by machines and tools set-up times. That kind of action raises many problems and issues which are against the Lean principles. First of all, the stocks and the costs caused are really big then when large amounts of one product are produced and producing another product is just started. On the other hand, because of that the same product is not produced again until after a long period of time, it could even run short if the customers' needs change and there would be more orders of that product as expected. The purpose of Heijunka is to level the production volumes of every product so that some amount of every product is produced within some specific period of time (for example daily). These amounts are solved out so that orders from some period of time are levelled evenly within for example every day. So, every product is then produced daily according to the levelled schedules. (Liker 2008)

When acting in accordance with Heijunka's principles, it is possible to keep the stock levels low. There are also no big variations in stock levels when the production is smooth. In Figure 15 is shown the stock level variations compared with traditional mass production system and with when using Heijunka. Also the amount of work is even and no waste due to defects and overproduction is formed either in busy times, or in off-peak times because of needless waiting.



Figure 15. Stock levels compared with traditional and levelled production. (Abilla 2013)

### 3.6.6 SMED

SMED or Single-Minute Exchange of Die is a Lean-tool which is used to try to reduce the time which is needed when changing the production machines and settings from one product to produce another product. That setting time is defined as time which is spent from the production of the last good product from the old batch to the production of the first good product from the new batch. The rapid machines setting are necessary to use Heijunka effectively. With the rapid setting time it is possible to produce small batches of a product and to keep the stock levels low. SMED is used if the machines or lines setting times are so long that they

inhibit the forming of a continuous flow when producing different kinds of products, and because of that it is not possible to meet the customers' demands perfectly. SMED is a set of theories and techniques which are used to keep the setting times as short as possible, to perform it under 10 minutes. (Tapping et al. 2002, Trevino 2005)

SMED is begun with mapping very carefully all the current processes needed to changing the set-ups. These processes are divided to internal set-up tasks and external set-up tasks. Internal set-up tasks could be executed only then when machine is stopped or turned off. External set-up tasks could be executed also at the same time when machine is running. The next phase is to try changing the internal tasks to external tasks as much as it is possible. Also the tools and parts needed for changing the set-ups location and storage should be planned very carefully so that it is possible to execute set-ups very effectively. (Tapping et al. 2002)

After that it has to be planned how to do all the remaining set-ups as effectively as possible. One way is to divide the procedures to parallel processes so that several workers could operate with set-ups at the same time. The mechanical design of all the parts should be such that there is no need to do any adjustments when replacing parts and also the replacement should be mechanised within the probabilities. Adjustments could also be reduced when using different kinds of stoppers or jigs when replacing parts. If there are some parts which need adjustments, they should be adjusted before installing to the machine. If there still is need to do any adjustments they should be done with accurate and quick digital measurement tools. Also the fastening of parts should be quick. There is a recommendation to use some other fastening methods than bolts if it is possible. The amount of replacement parts should also be minimized. That is possible to for example combine the parts to sub-assembly, and so that the whole assembly is then changed, as in the example shown in Figure 16. (Tapping et al. 2002, Trevino 2005)

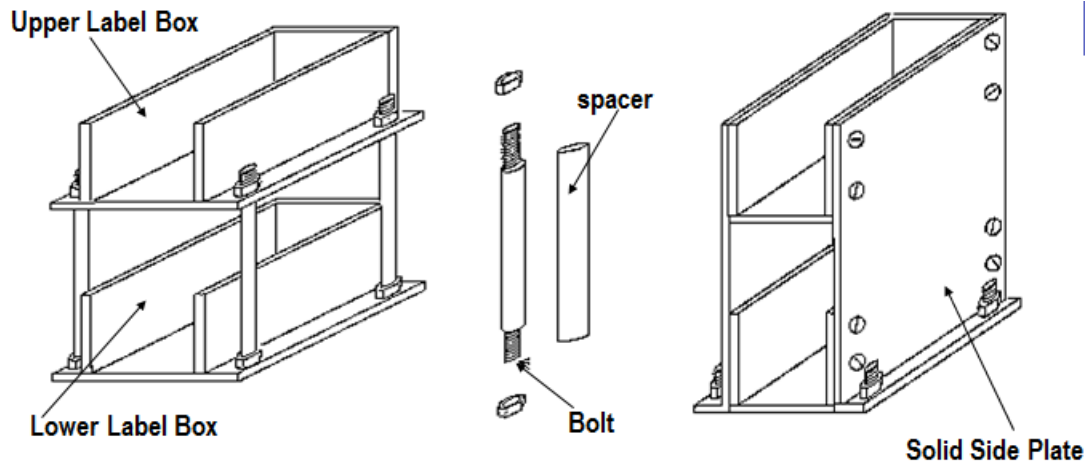


Figure 16. Example of combining parts. (Trevino 2005)

### 3.6.7 Takt Time

Takt time means the time interval of how frequently the factory must produce finished products to meet the customer's demands. When action is matched according to the takt time it is possible likely to match the same rhythm in production and in product sale. The takt time could be calculated for each product so that the weekly available production time is divided by the amount of the needed finished products, as illustrated in the following formula. (Tappin et al. 2002)

$$\text{Takt time} = \frac{\text{Available production time}}{\text{Total quantity required within that time}} \quad (1.)$$

The total production time available is calculated so that all lunch and coffee breaks, meetings and other possible situation when production is stalled are subtracted from the whole working time (for example 40h). According to this type of action it is therefore meant that after every takt time one new product should be finished on the production line. All operations should be matched to this time. The most ideal situation for one-piece flow would be that cycle times are matched very close to the takt time. So, this means that each work phase should also be finished every takt time and the product would be ready for the next work phase. If some work phase is quicker than others, a buffer (in other words overproduction) is raised after that work phase. Also if some work phase is slower than others it is defined as a bottleneck and it causes unnecessary waiting. Practically the cycle

times would be best to limit so that they would be a little shorter than the takt time, because then it is easier to get prepared to sudden problems, and it takes always at least a little time to move products to the next work phase. (Bicheno 2000, Liker 2008)

The takt time should be calculated again in every week because customers' demands could be varying. When actions are always synchronized to work with the takt time, it is possible to keep the stock levels as required. When implementing the takt time, it is sometimes also possible that some work phase speed should be lowered, even if it sounds quite strange. However, this usually shortens the products' lead times. This is because of the buffers do not rise anymore after that "too quick" work phase. So the products do not need to wait anymore so long in the buffers before moving to the next work phase. (Bicheno 2000)

### **3.6.8 Kaizen**

Kaizen is a Japanese term which means continuous improvement. It is an entire philosophy where different kinds of improvements are meant to be done continuously and actively no matter how small they would be. The purpose with continuous improvements is to try throughout time to reach the perfection state. Continuous improvements are needed because the customers' demands and standards are rising. With the help of Kaizen it is tried to eliminate all the non-value adding waste. There is an attempt to learn skills through individual persons to operate in groups by solving problems, documenting issues and improving processes, also collecting and analysing data. (Liker 2008)

In Kaizen, the decisions or proposals are made all the way from the factory floor workers to the top management. Open discussion is required and the whole groups' consensus before implementing any decisions. All persons have their own role with sustaining and implementing the Kaizen. The top management should take care of resources, strategy, operation methods and needed equipment for Kaizen to work. The middle management's duty is to follow and report of function and effectiveness for the program of continuous improvements, and also to take care of that the workers have the knowledge and sufficient education to use the

needed tools. The supervisors' duty, on the other hand, is to take into account all the workers' improvement suggestions and record them, and also take them forward to the management. The supervisors' duties are also to encourage workers positively and try to improve the communication in the working environment. And finally, the workers' duties are to make improvement suggestions, to learn to use the new operation methods and new tasks, and also to take part generally in action of continuous improvements both for individuals and in team. (Bicheno 2000, Liker 2008)

One of really effective Kaizen-tools is a Kaizen workshop, also called the Kaizen event. The purpose is to improve a process or work phase. The workshops themselves usually last from a couple of days to one week. But the whole concept is a long-term process. Before the workshop, the precise and accurate planning should be done about the execution of the workshop. The sustaining and monitoring of actions follows after the workshop, as like the continuous improving of those. The persons from management to workers connected to that specific process participate in the workshops. Also the customers and suppliers could participate in the workshops. According to Liker, the amount of persons should be limited to about 15 persons to ensure the smooth operation of workshop. In the workshops, the participants analyse the current process and creates a vision and planning for the implementation of improvements. And also the most important of all, the participants begin the implementing of the changes. (Koenigsaecker 2009)

### **3.6.9 Gemba**

Translating roughly from Japan, Gemba means the actual place where some specific action is happening. The term is used in Lean and generally in the improvement of operations, and it is meant that if there really is a desire to understand something, it must to be looked where the action is actually happening. Only in that way it is possible to notice where there would be room for improvements in operations, and what kind of improvement possibilities there would be. Generally in Lean, the implementing of "Gemba-walks" is supported to get the problems noticed. The Gemba-walk means that the leaders should regularly visit areas where the work is actually executed, and seek the waste and problems occurring

in the production. The concept of Gemba could also be used in the research and development site. It would be good if designers would visit there where the final product is actually used to develop their own improvement ideas to the product. (Slack et al. 2013)

It could be imagined that Gemba consists of four actuals: Go to the actual workplace, look at the actual process, observe what is actually happening and collect the actual data. When the resolving of the problems or making improvements in the company starts, the first thing to do is to go to the Gemba. It is forbidden to make decisions outside the action area or without seeing it. The decisions are also forbidden to be made based on only computer-aided simulations or calculations. The main idea in Gemba is that when the problems occur, the workers should not go to supervisors, but the supervisors should come to the workers and work area. (Bicheno 2000)

## 4 PROGRESS OF THE THESIS WORK

The applied part of this thesis started after getting familiar with the relevant theories of Lean management and different Lean tools and when the current situation of Lean in ABB Motors was mapped with the help of different reports and a Master's Thesis previously done about this issue. The first task was to participate in three Kaizen workshops so it could be seen how the Lean-principles are used in practise currently. One main objective of this thesis work was to document the progression and the usage of the Kaizen workshops.

The next phase in this thesis work was to make a benchmarking visit to a company where the Lean-principles have been longer in use than in ABB Motors. The objective was to make a report about the visit to help evaluating the differences and similarities of the Lean strategies and Lean tools used in both companies. The objective was also to collect experiences of different Lean tools used. The final phase of this thesis was to map and evaluate how the Lean-principles could be used in development project Double to help to achieve the objectives of the project. The main objectives of the Double project are to raise both the productivity and volumes of the small motor factory with 100%. The progress of this work is shown also in Figure 17.

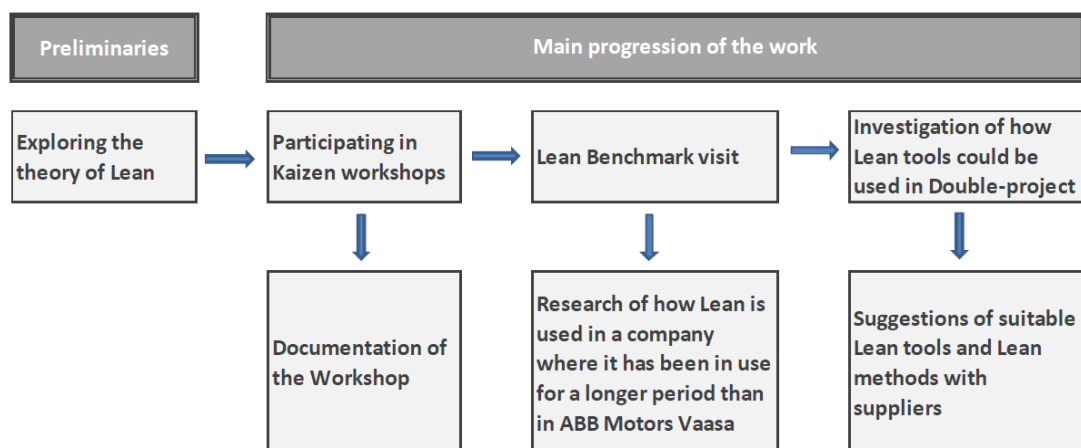


Figure 17. The progress of the thesis work.

## 5 KAIZEN WORKSHOP

One of the Lean tools used in ABB is the Kaizen workshops. A short theory of Kaizen workshops is presented in Chapter 3. One of the tasks in this thesis was to participate in workshops belonging to the project “Speed to win” and then to document the usage of the workshops. In this chapter it is explained how the Kaizen workshops are used in practise at ABB Motors.

### 5.1 Kaizen Workshops in ABB Motors

The workshop itself consists of total of three days at Motors Vaasa factory. The whole time which is needed to organize the workshop and sustain and track the results of the workshop is still much longer. The whole concept of the Kaizen workshop is presented in the next Figure 18.

Action	When	Notices
Settlement of the workshop	Min. -4 weeks	Contents, participants, time
Beginning of the collection of the data	-3 weeks	Relevant meters, process chart
Information to participants	-1 week	1 hour meeting
Workshop 3 days	0	
-Looking over the feedback -Launching the actions <ul style="list-style-type: none"> <li>• Priority (speed &amp; influence)</li> <li>• Suitability to scope</li> <li>• Does the action support the strategy</li> <li>• Bundling the actions - 4Qs</li> <li>• Information to other responsibility areas</li> </ul>	+1 week	3 hours meeting
-Workshop savings - calculation		
Assesment of the actions and the support	+12 weeks	-meters (superiors) -assessment (facilitators)

Figure 18. The concept of the Kaizen workshop.

The Kaizen workshops are implemented according to ABB’s 4Q problem solving system shown in Figure 19. That way of action consists of four different sections: Q1. Measure, Q2. Analyze, Q3. Improve, Q4. Sustain. Q1 is to map and measure the examined process accurately. Also the target conditions should be verified well. All measures should be done using Gemba. The preliminaries and the first

day of Kaizen workshop is basically the Q1. Q2 is to analyse and understand the gap between the current and target conditions. The root causes of the gap should be analysed to get the problems later eliminated. The second day of the workshop consists of the Q2. Q3 is to first generate the improvement solutions and to implement them in the pilot project. The third day of Kaizen workshop consists of the planning of the methods how problems noticed in Q2 could be solved and the situation improved. After the workshops the methods are implemented based on the plans done in the workshop. Q4 is to implement, standardize and sustain the new methods in processes. Q4 is implemented after the workshop. (D'Anci, 2012)

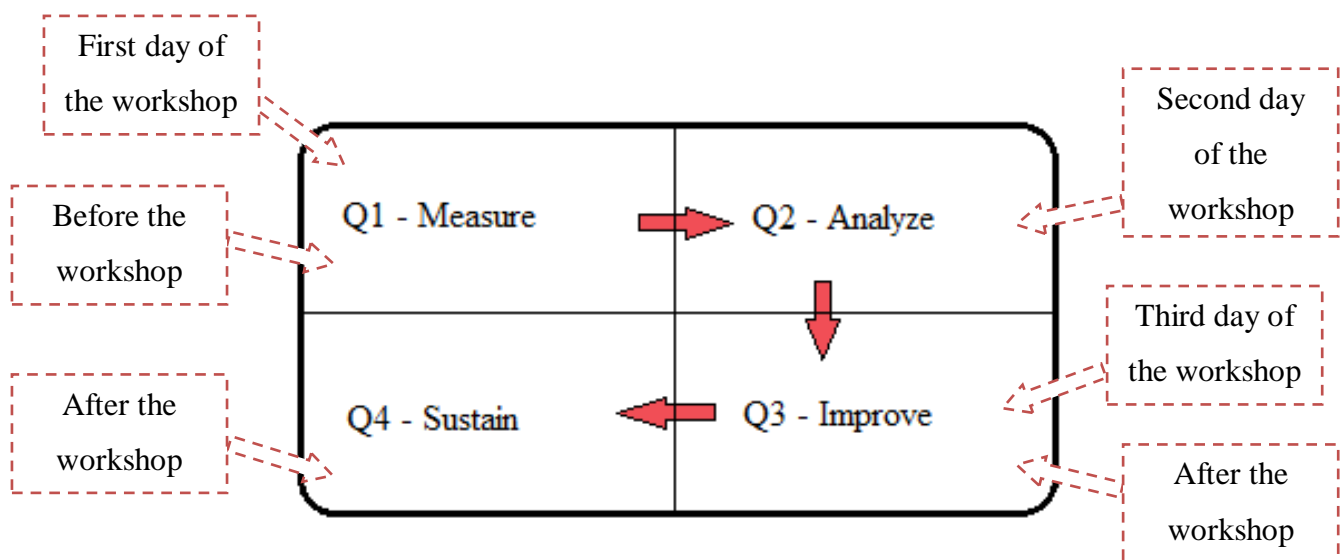


Figure 19. 4Q process related to the Kaizen workshops in ABB Motors.

## 5.2 Preliminaries

About four weeks before the workshop the first meeting is held. The participants of the workshop are agreed and planned. Usually the team in the workshop consists of two facilitators who are experts in the Kaizen actions and their task is to manage and control the workshops. Also the host of the workshop is selected and he is usually the manager of that department where this workshop belongs to. Other participants are the supervisors, foremen, various experts in that department and a couple of workers also always participate in the workshops. The total amount of participants is about ten people depending on the size of the department. In the first meeting also the contents and the date of workshop is agreed.

Approximately three weeks before the workshop, the collection of data is started. The whole process is tried to be documented as precisely as possible. Also all the relevant charts and meters are collected from that process. The material needed to collect can be seen in Appendix 1. The final preliminary is to keep the info about workshop about one week before the workshop. In that info meeting the participants of the workshop take part in. In that info it is told what the case in the workshop will be and what Kaizen workshop generally means.

### **5.3 Workshop**

The accurate agenda of the workshop can be seen in Appendix 2. The first day starts with a brief information about the project where the workshop belongs to and what the workshop consists of. After that, facilitators present the rules and targets of the workshop. The main targets of the workshops are to increase the productivity of the departments with methods introduced in the workshops. The methods used in the workshops are Gemba, identifying the waste, root-cause analysis and planning and later implementing the action plan. The other main target for the workshop is to commit the personnel to the project which the workshop is related to. In order to make the workshop to become a success, all participants should take part actively in issues during the workshop. The participants should be open minded and have a positive attitude towards the workshop. All the decisions made in the workshop should have all participants' consensus. And maybe the most important of all, all the participants in the workshop are equal even if they are managers or workers.

The next phase in the workshop is to map the current situation of the department and identify the problems there. This is started by looking into all data collected before the workshop. All the relevant data, including many kinds of meters and charts about the process, are collected on the walls of the workshop meeting room, as shown in Figure 20. With the lead of the facilitators all the meters and charts are gone over and it is cleared up what the charts actually means. At the same time when data is being discussed all the raised problems or other issues are written down on the blackboard, as shown in Figures 20 and 21. When the meters have been looked into and problems written down, there should be accurate image of

the current situation at the department. When the current situation is defined, suggestions are made related to issues which should be improved at the department in order to meet the targets defined at the beginning of the workshop.



Figure 20. Collected data of process.

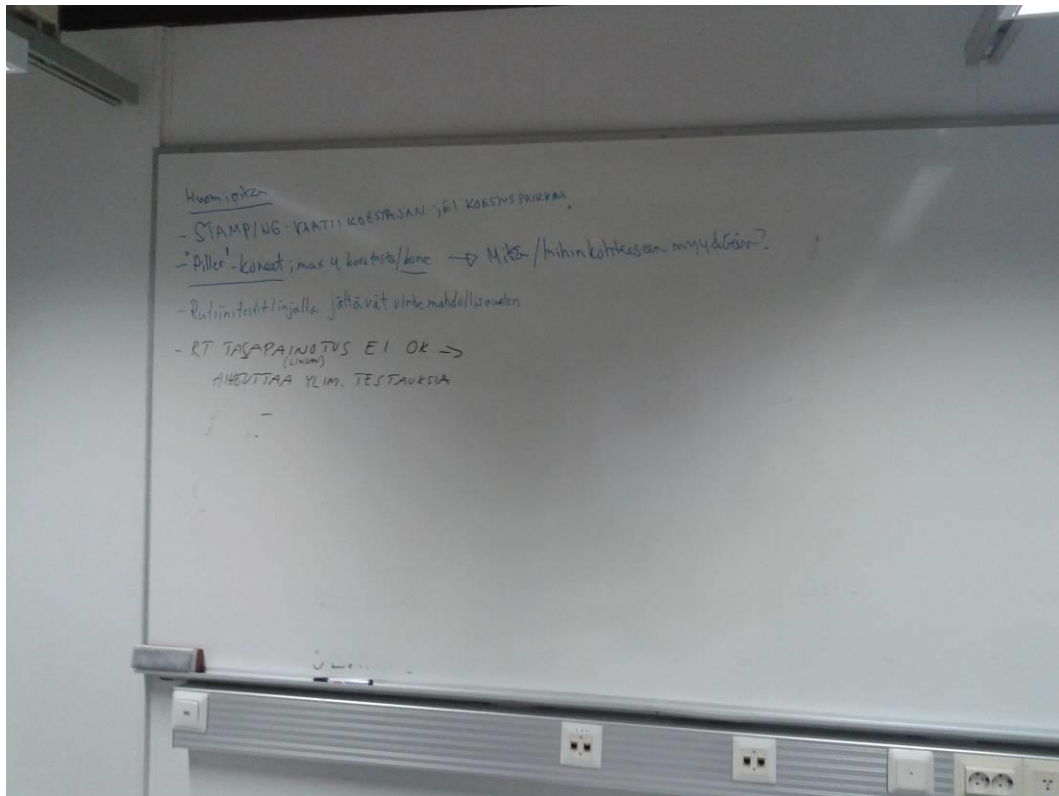


Figure 21. All the raising issues and problems are written down.

The next phase is to introduce the main theory related to the workshop to the participants. The facilitators give a presentation on that, as shown in Figure 22. The main theory of Lean and waste, Kaizen, 5S, root-cause analysis, visual management, inhibition of defects, SMED and Gemba are presented. This takes approximately little less than half a day.



Figure 22. Theory presentation.

The final task of the first day is to think about three or four most important issues which could increase the productivity most at the department. The issues are selected based on the notes written earlier that day. All participants could tell their own suggestions and finally when consensus has been reached, the issues are written down on the blackboard, as shown in Figure 23 below.



Figure 23. Three to four issues are selected to be improved.

The second day starts with a brief summary of the first day. If it is necessary the issues to be improved could be also defined more specifically. It is important to have all the participants' consensus about these issues. When the issues are clear, the whole workshop group is divided into teams so that every issue gets its own team to look over that issue. The team consists of 3-4 members and every team

should have a leader who also acts as a secretary to write down the team's observations.

Each team is meant to search and identify the waste and problems related to their own issue. The teams should go to the actual work place, in other words Gemba, to seek the problems and observe the actual process, as seen in Figure 24.



Figure 24. Teams are seeking the waste at Gemba.

When the wastes and problems are identified, the team should think about what causes the wastes. Each team makes a root-cause analysis to problems. Two different kinds of methods are presented during the first day in the theory presentation how to make the root-cause analysis, and they are fishbone diagram and 5\*Why. The main idea in both is similar, the problem or issue is first written down clearly. Then different problems or issues are listed what causes the main problem and so on. The analysis goes on as long as the root cause is finally identified. The next two Figures 25 and 26 shows the blank body of both analysing methods. The fishbone diagram also takes a part in what category the problems belong to, for example in materials or machines.

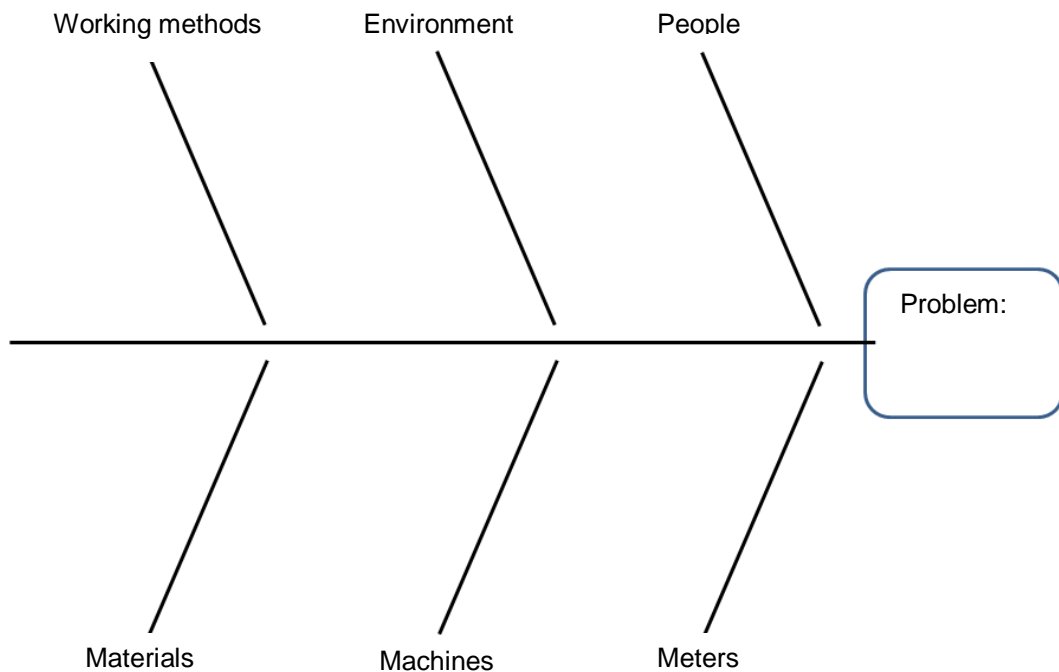


Figure 25. Root-cause analysis, Fishbone diagram

<b>Problem:</b>	
WHY?	
WHY?	
WHY?	
WHY?	
WHY?	
<b>How to repair?</b>	

Figure 26. Root-cause analysis, 5\*Why

After about half a day's independent working in teams all the teams are gathered in the same place and the current situation of teams' work is being presented. Figure 27 shows that situation. This is done to ensure that every team has understood

the purpose of these tasks and if someone has something to ask, it is then possible. After the short presentations of teams' work have been presented, the teams continue to finish the analysis during the rest of the second day if needed.



Figure 27. Teams gather to keep short presentations of current status of their work.

The third day starts also with a short review of the previous day and with presentations of third day's targets. The third day's main target is to make an action plan to increase the productivity. The teams get a blank body of action plan and that is also introduced to the teams when everyone is at the same place. The body of action plan can be seen in Appendix 3.

After everyone has a clear vision of what should be done next, the teams work independently again. Each team lists the problems found in the previous day into the action plans. The root-causes are also listed into the plan. Now, the teams' job is to invent the solution to solve the root-problems. The solution is also listed into the action plan. The teams should also think about the priorities of the solutions. Solutions should have three different levels of priority. The initial rough schedule

to implement the solutions is also listed into the action plan. The team also should think about who could be the responsible person on implementing each solution.

Again, when the teams are ready, all teams gather into the same room. Each team presents their own action plan to the others, as shown in Figure 28. Other participants could comment on the action plans because the expertise could be better in other teams on some topics. Changes and specifications to action plans are made if necessary. Finally the responsible persons are being thought in the most important topics.

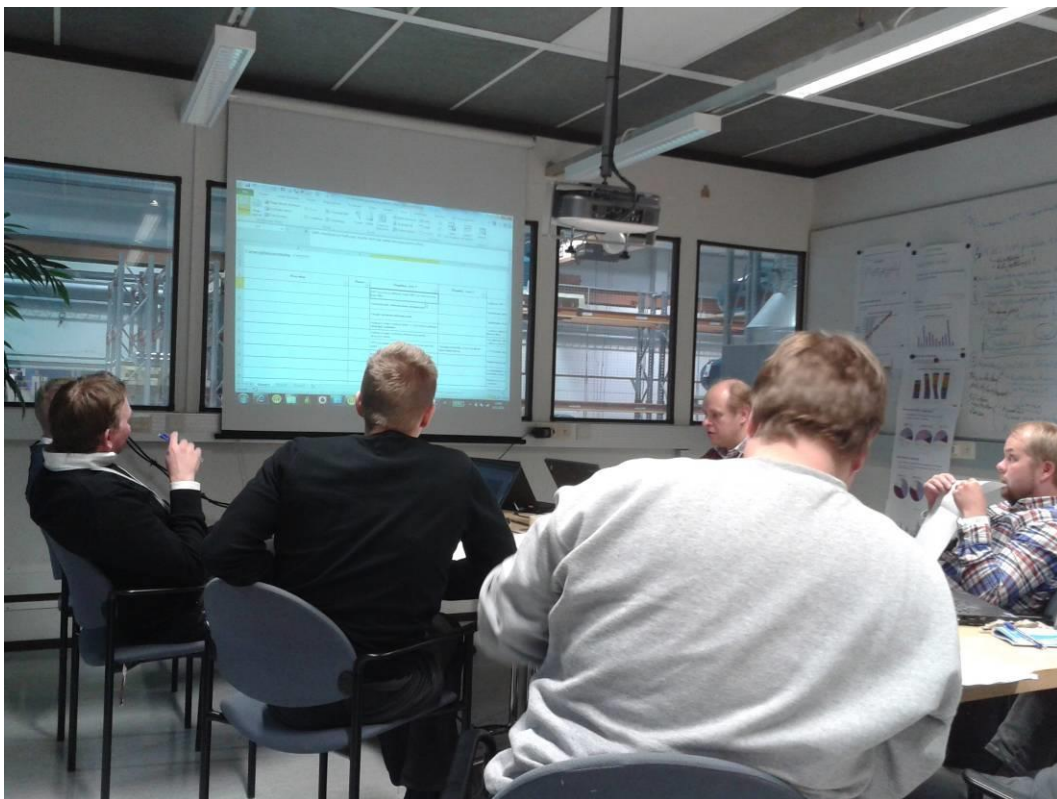


Figure 28. Each team presents their own action plan.

Finally, the feedback of the workshop is collected from the participants.

#### **5.4 After the Workshop**

After the workshop the action plans are defined more specifically with the persons related to each plan and action plans are finished. After about a one week of the workshop, the three hours meeting is held where it is decided how the implemen-

tation of the actions will be started according to the action plan. Then also calculations of the savings are made based on the action plans made in the workshops.

About three months after the workshop a meeting is held with the facilitators and department managers. At the meeting managers show the productivity meters and the effect of the workshop actions on them. The managers and facilitators evaluate together, how well the targets of the workshop have been met. The facilitators could give support to the managers if needed.

## **6 LEAN BENCHMARK**

One part in this thesis was to make a benchmarking visit to a company where the Lean strategy has been longer in use than in ABB Motors Vaasa factory. That benchmarked company operates in metal industry. In the company the hosts of the visit introduced how they are using the Lean operational strategy. With the help of that presentation and the benchmarking question list, the usage of Lean in that company was mapped and a separate report and material of the visit was made for the ABB internal use as one task in this thesis. A short summary of the general Lean thinking and the Lean tools used in company are presented also in this chapter. Benchmarking question list made in this work included questions about general usage of Lean and also about usage of some specific Lean tools. The person who hosted the visit and answered the questions was the development engineer in the benchmark company. The question list can be seen in Appendix 4.

### **6.1 Lean Culture**

People and the right attitude are on the central focus in the Lean operations in the company visited. The right Lean attitude is tried to achieve with different kinds of Lean trainings. All the employees have at least basic level Lean training. More in-depth training is organised if needed. Daily communication between managers and workers is regarded to be very important in order to create the right attitude. Also the achievements of the development processes and other activities made according to Lean are informed to the workers also. This is done, among others, with the help of a Lean-newsletter which is published roughly once per quarterly. It is important that all the employees understand and take the notice of the whole operation instead of concentrating only on their own operation.

Another central focus is to create a problem solving culture. The root-causes of the problems should be solved in-depth instead of doing only quick superficial repairs. One effective tool to implement that culture is the same kind of Kaizen workshops which are used also in ABB Motors, introduced more in-depth in Chapter 5. In workshops the problems and the root-causes are identified, action

plans to solve the issues are made and implementation of the actions and the results of the actions are followed.

## **6.2 Lean & Suppliers**

In the visited company different kinds of Lean programs are implemented with most significant suppliers. The company gives Lean trainings to these suppliers and tells about its operation methods to them. Also the Kaizen workshops are organized for these suppliers and problems are identified and solved in co-operation. This company strictly requires the perfect quality from the suppliers. All the defected parts are always claimed and shipped back to the supplier. So, the defected parts are not repaired by company's own workers.

## **6.3 Andon**

Andon is widely used in production in that company. In work phases there is possibility to make an Andon alarm with the Andon-button. This alarm goes to the supervisors. There is a possibility to make a few different kinds of alarms, for example, defected part, missing part or mistake in work performance. Andon problems are not handled exactly like in theory presented in Chapter 3. The issues are not always repaired or solved in the assembly line if the problem is big and solving takes a long time. Because of that there is no stress that the production could stop when problems occur.

## **6.4 Gemba**

Gemba is another tool which is much used in the target company. It is noticed to be very important that all the problems should be seen and inspected always in actual workplace before planning the solutions of these problems. There is also Gemba boards in work places where the different kinds of meters and relevant information about the processes are shown. Gemba meetings are held daily in front of these boards. The themes of these meetings vary according to the schedule and themes are, for example, quality, safety, and work situation. The participants are varying depending of the themes. With the help of these meetings the clear vision of the actual situation, targets and the wholeness is tried to be created to everyone.

## **6.5 SMED**

A couple of SMED projects are done in the target company. For example, in machining, the changing of the some machined parts is automatized with robots. Also, the 3D-CAM programs are used in machining so the machining programs are created automatically based on 3D-models when starting to machine a new kind of product. The machines set-up tasks which are impossible to automatize are tried to get to external tasks so that it would be possible to do these set-ups at the same time when the machine is running.

## **6.6 5S**

5S is used in the whole target factory. All the departments are implementing 5S in the way that they are noticed best. Some rules are common in the every department in implementation of 5S. Important in the sustaining of the 5S is the right attitude of the workers. The supervisors are also inspecting regularly the state of the 5S. One effective way to sustain the 5S is also regular auditions done by the persons from another department. The external person usually could identify the deviations more effectively than a person from the observed department. According to the experiments lots of unnecessary work and waste could be avoided with 5S.

## **6.7 Just in Time**

Just in time (JIT) is tried to be implemented with kitting of the parts. Logistics employees are taking care of making the right sets of the parts and that the set would be in the right work place at the right time. The kitting is always done according to the order of the parts assembly. The set includes the modular parts, the bulk parts, such as screws and bolts are not included in the set.

## **6.8 Summary**

The general usage of the Lean strategy is quite similar in both ABB and company benchmarked. The same style of Kaizen workshops is in use in both of the companies and the same Lean tools are considered to be useful, such as Andon, Gem-

ba and 5S. However, the implementation of the Lean tools mentioned is more advanced in the company visited because the Lean have been longer in use there than in ABB Motors Vaasa.

The biggest difference between these two companies is that in the benchmarked company people are in a central role when thinking of the Lean strategy. That means that right kind of “Lean culture” and Lean awareness is first tried to create among the people before the Lean is largely started to implement. The experience there has shown that when doing like this, it have been easier to get the Lean operations going in the company and workers are more committed to it. In ABB Motors Vaasa there is room to spread Lean thinking among the factory workers. For example, the same kind of basic short (max. couple of hours) “Lean awareness” trainings could be organised to workers so that there would be at least basic level Lean awareness also on the factory floor. At this time only a few workers who participate in the Kaizen workshops get some kind of idea what Lean is. Lean trainings for workers could include basic level theory presentation of Lean and some Lean tools, for example 5S, Gemba, Kaizen and Andon. Also it would be demonstrative if these trainings would include also some short group exercises or simulations related to Lean.

Figure 29 shows the comparison of topics and their status in both companies.

Lean-tools	Benchmarked company	ABB Motors Vaasa
Andon	Used	Used little or piloted, but not largely implemented yet
Heijunka	Not used	Used little or piloted, but not largely implemented yet
Kaizen workshops	Used	Used
Gemba	Used	Used
SMED	Used little or piloted, but not largely implemented yet	Not used
5S	Used	Used little or piloted, but not largely implemented yet
JIT	Used	Used little or piloted, but not largely implemented yet
Takt time levelling	Used little or piloted, but not largely implemented yet	Not used
<b>Lean-culture</b>	Lean awareness for all workers	Lean awareness only for few workers who participate in Kaizen workshops

Not used  
 Used little or piloted, but not largely implemented yet  
 Used

Figure 29. Status of compared Lean topics in the benchmarked company and in ABB Motors Vaasa.

## 7 DOUBLE PROJECT

The Double project is part of a larger development project called “Speed to win”. Speed to win covers to improve the whole ABB Motors operations. The Double project concentrates only on the assembly line of the specific motors located in the Vaasa factory, and its objectives are specified differently than in Speed to win. The purpose of the Speed to win project is to improve the whole chain of processes needed to manufacture the finished motor all the way from the beginning. The main target is to get processes working more reliable, faster, collaboratively, capital and cost efficiently and resiliently. It means that at the end of the development project the on-time delivery rate should maintain the rate of at least 98%, the lead time should be reduced to 50%, the inventories should be reduced in total with 25%, the costs should be reduced in total with 10%, the productivity should be raised by 20% and there should be flexibility in production +/- 35%. There are many methods in all sections to try to achieve those objectives. In the production, for example, the Kaizen workshops, presented also in this thesis, are the one of the many other methods to achieving the goals.

As mentioned before, the Double project concentrates only on a small sized IEC Motors produced in the Vaasa factory. It consists of the frame sizes from 71 – 250. The frame size means the height of the motors from the bottom to the rotor shaft in mm. These motors are assembled in the same factory building and there are no assemblies of other frame sizes in that building.

The background to why this project was started is because it was noticed that there was low productivity in the value chain in the production of the smaller frame sizes. Also the profitability was quite low for these products. So, to get the wanted sales margin, the products should be sold in bigger amounts. It was also noticed that potential larger markets for the products exist and that has triggered this project. The scope in the project includes the reorganizing of the production lines and the factory logistics processes in small motor factory, and also to simplify the essential supplier processes relevant to the small motor factory.

The targets of the project are presented in Figure 30. The main targets of the project are to double the productivity and volume of the production of the motors in scope. It means that the productivity should be raised by 100% when viewing the produced pieces per hour. In volume it means that at the end of the project, in the frame sizes from 71 to 132, 600 pieces per week should be finished and in frame sizes from 160 to 250, 400 pieces per week should be finished. So, the total amount of these smaller frame sizes should be produced a total of 1000 pieces per week. When taking into account the targets from Speed to win, the fluctuation in the production should also be possible to vary +/- 35% depending on customers' demands. In volume it means that it should be possible to manufacture the total amount of 650 – 1350 motors per week depending on demands. The technical capacity should be based on these numbers. When closing the project, the lead time should be no more than 15 working days and the total throughput time should be 10 working days of that. Also the profit (EBIT DA %) of products should be raised by 65%. The inventory turnover should also be raised by 100% on the average.

<b>EBIT DA %</b>	<b>+ 65 %</b>
<b>Productivity [pcs/ hours]</b>	<b>+ 100 %</b>
<b>Double volume</b> 71-132 160-250	<b>600 pcs/week (2015)</b> <b>400 pcs/week</b>
<b>Fluctuations in production +/-35%</b> <b>Technical capacity based on that</b>	<b>650-1350pcs / week</b>
<b>Lead time /Delivery Time</b> <b>TTPT</b>	<b>15 working days</b> <b>10 working days</b>
<b>Inventory turnover</b>	<b>+ 100 % on the average</b>

Figure 30. Main targets of project Double.

There are two main action areas in the Double project to deal with. The first is production and factory logistics. There is an attempt to implement a new kind of flow concept in the small range motor factory, which enables the possibility to

produce volumes wanted. It means the total reorganisation of the factory lay-out. Also one topic is to examine how well the components setting or in other words kitting could work and support the targets of project. Also the automation possibilities are utilized in the project. The second main action area is suppliers. It is meant to redesign the supplier network and processes simpler and better flowing. Also the methods to develop co-operation with the selected and relevant suppliers are implemented within the project.

### **7.1 Current Situation**

At the time, three different assembly lines are operating in the small motor factory building which operation is meant to be improved. One of the lines, called AL10 manufactures the frame sizes 71 – 132, another line, called AL15, manufactures the sizes 160 – 250. The operation in third line, AL25, varies depending on situation. Currently it manufactures certain type of products belonging to AL15. The current layout is shown in Figure 31.



painting with small electric lift because the line will not continue straight to the painting. In the painting phase the not-painted parts are covered first and after that the painting itself is made in a specific painting cabin. After the painting, the motor goes to the automatic oven where the paint dries. From the oven, the motor comes to the final assembly phase. In the final assembly, all the rest parts are assembled to the motor, and after that the motor goes to the dispatch department. Also the final assembly lines are different to each of the lines. The operation sequence and methods are the same also in the line AL25, but there the line is straight all the way from the frame pressing to the final assembly. This is possible because volumes in that line are smaller than in the other two lines.

## **7.2 Current State Value Stream Map**

The current state Value stream map for AL10 and AL15 collected and made by project group can be seen in Appendix 5. One method to collect the actual data of the value-adding time and non-value-adding time for the processes was to use a video material of the actual work processes.

## **7.3 Future State Value Stream Map**

The future state Value stream map for the new AL3 was not made within the time of this thesis work, but Figure 32 shows the objectives for the future compared by the figures collected from the current state Value stream map.

		Current state				Future state	
		WIP		TPT			
Order handling		118		1,2			
Engineering		1705		21			
Production control		811		8,3			
<b>Summary - Office</b>		<b>2634</b>		<b>30,5</b>			
		AL10		AL15			
		WIP		TPT			
Supplier		903	15	794	20		
Assembly		142	2,4	135	3,4		
<b>Summary - Manufacturing</b>		<b>1045</b>	<b>17,4</b>	<b>929</b>	<b>23,4</b>		
<b>TTPT (SUMMARY - ALL)</b>		<b>3679</b>	<b>47,9</b>	<b>3563</b>	<b>53,9</b>		
<b>Total lead time/delivery time</b>						<b>15</b>	
						<b>The target of throughput time (working days)</b>	<b>Change</b>
						<b>2</b>	<b>-93 %</b>
						<b>AL3</b>	
						<b>The target of throughput time (working days)</b>	<b>Change</b>
						<b>8</b>	<b>-66 %</b>
						<b>10</b>	<b>-81 %</b>

WIP = Work in progress  
TPT = Throughput time (working days)  
TTPT = Total throughput time (working days)

Figure 32. Figures collected from the Value stream map.

#### 7.4 Wastes Found in Kaizen Workshop for Double

A Kaizen workshop was also organized to assembly lines scoped in Double. This workshop for assembly lines of frame sizes 71 – 250 lasted, as all the other workshops, three working days and the agenda was like described in Chapter 5. In this Chapter 7.4 it is collected what kinds of wastes were found in the workshop from the operation chain of these assembly lines and what are the root-causes for these wastes. Collected wastes are of the type which makes achieving the objectives of the Double project almost impossible and it would be vital first to eliminate these wastes.

Workers' waiting time, waste number two, was one of the wastes found in the workshop. Maybe the most significant factor which causes waiting is the automatic shelf where the workers order parts. The speed of that shelf is not high enough to serve smoothly all the activities ordered from it. Several work phases from all of the lines uses that shelf. Also the logistics are filling shelf all the time with parts arrived. Because the shelf is almost full all the time that also reduces its speed. Waiting is sometimes also caused because the buffer of WIPs between the work phases runs empty and the next work phase has to wait the previous work phase. This could also happen when the buffer is full and the previous work phase has to wait the next work phase. This kind of waiting is caused because some

types of motors need more time to become finished from some work phases. Also even in the “standard” motor, different work phases take different amount of time and in some situations this could cause some waiting but it is not so a significant factor. Quality issues are also sometimes causing waiting time for workers. This happens mainly in evening shifts when there is no quality engineer or supervisors to take a responsibility for these issues and motors have to be moved aside from the line and the next work phase could run out of work within that time.

Waste number three, unnecessary movement or transportation, could also be found from lines and it is one of the biggest wastes identified. Assembly line AL10 is split between the routine testing and the painting. The painter has to carry the motors with an electric lift from the routine testing to the painting. Even if this distance is not long this still causes the extra work. Also, motors from all the lines have to be carried to the packing place after the final assembly.

Over-processing or faulty processing issues occur also in lines. This is waste number four. Over-processing or faulty processing are caused by both in suppliers’ operation and in lines operation itself. One example on the suppliers’ faulty processing is that the bearing housings in the motor shields, which came from specific suppliers, nearly always has to be cleaned by workers in the line because there is dust born in machining. And one example of over-processing by the suppliers is that machined surfaces in some frames are protected with moisture-proof paint even if the frames are shipped in a moisture-proof package. That paint could sometimes cause problems when assembling the motor and then the paint has to be scratched off by line workers. Faulty processing occurs also in line operations, for example, sometimes greases used in the connection and pre-assembly are spread accidentally in surfaces meant to be painted and this causes problems and extra work in the painting phase.

Another large waste type found is the workers’ unnecessary movements. Some of the needed materials are far from the working area and some of the materials are difficult to reach or pick. For example, workers from the AL10 pre-assembly have to pick most of the rotors manually from the large shelf with electric lift. There are also some other parts in a couple of work phases which are not located near

the actual place where the part is needed. Unnecessary motion is also caused because sometimes workers have to search for the right part. All parts are not necessarily marked with an identification number or the location of the part is not marked precisely enough. Also some of the work places are quite messy and it is impossible to find all needed tools quickly.

Production defects are also some kind of problem with specific motor types. This is waste number seven. There are a few repeating quality issues in specific motor types whose parts come from the same suppliers. For example, some of the frames occasionally break when pressing the stator in the frame. And there is lots of thread faults in these same types of frames. It is possible that sometimes all the threads in the frame have to be re-threaded by line workers.

Unused human talent, eighth waste, can also be recognised. Some workers have the know-how and willingness to work also in other work phases but this is not utilized well. Maybe the biggest problem in that is that on the other hand, some workers do not want to do any other tasks than what they are now doing. This causes frustration in workers who wants the variation in their jobs.

The wastes of overproduction and inventories are not the problem in the small motor factory because all the motors are produced there according to the orders. No motors are manufactured to storage there.

Figure 33 shows the estimation of the relative amounts of each wastes identified in small motor factory.

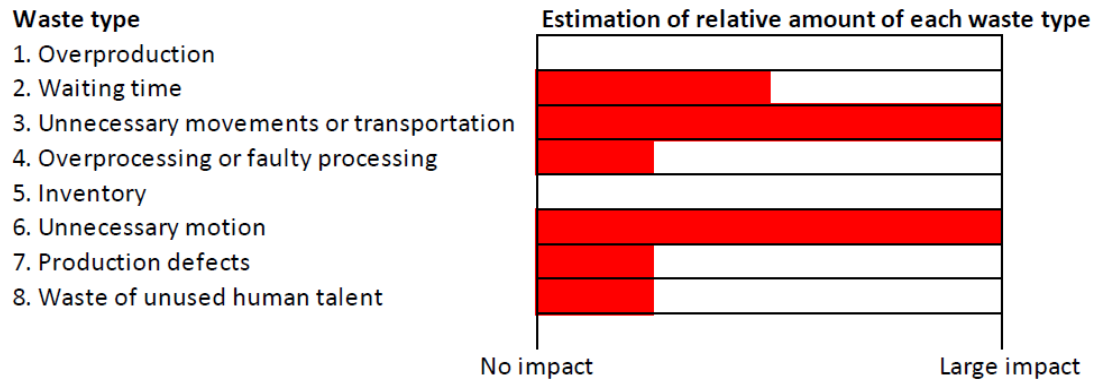


Figure 33. Estimation of relative amounts of wastes.

### 7.5 New lay-out

In this chapter the new concept of lay-out in the small motor factory planned by the project group members is presented. It is also evaluated how much and which of the found wastes could potentially be eliminated with this new kind of lay-out compared to the current lay-out. Figure 34 shows the planned new lay-out.

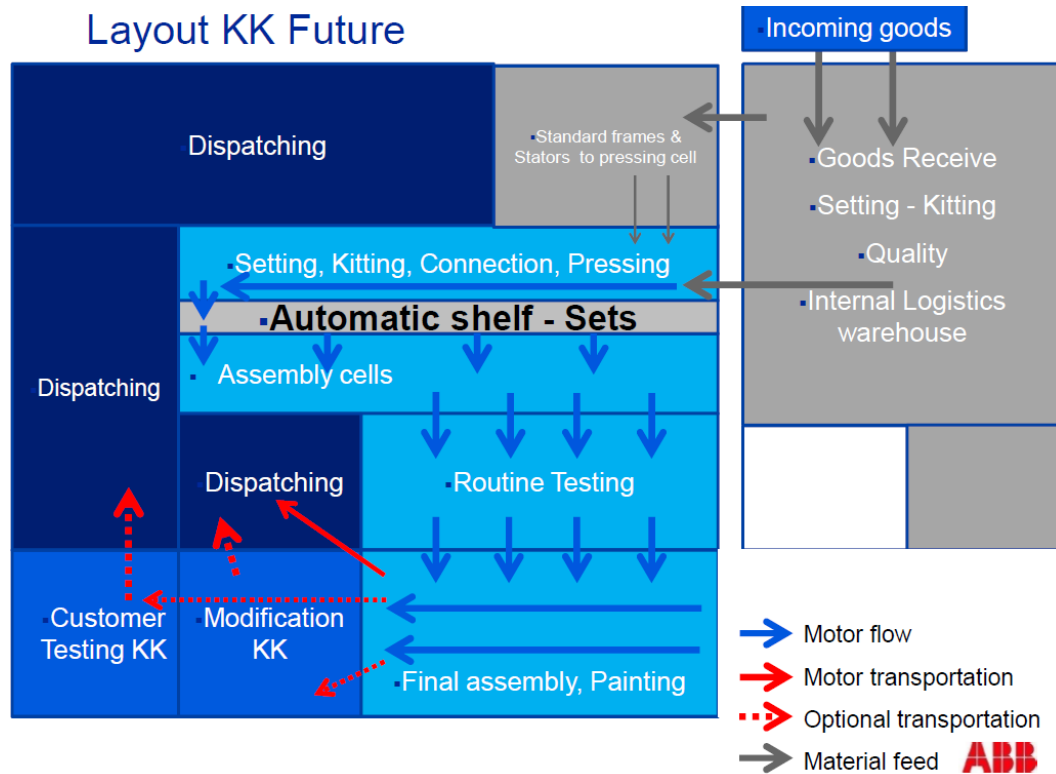


Figure 34. The new concept of lay-out in the small motor factory.

Compared to the current lay-out all the three different assembly lines are meant to be combined to one line of work cells, called AL3. The incoming goods are first received in section shown in Figure 34. In this section, also the kitting of the materials is done by logistics workers. The needed quality inspections are also executed here and logistics internal storage is held. The material sets are then forwarded to the frame pressing cells. The standard frames and stators are fed directly to the cell so they are not included in the material set. When the stator is pressed into the frame the material set is forwarded to the connection. After the connection the material sets are complemented and then the completed sets including the connected motor and all the needed parts are moved to the automatic shelf. Pre-assembly workers then order the needed sets into their cells and the pre-assembly is then done. The pre-assembled motors then move to the routine testing cell and after passing the test to the painting cell. When the paint is dried in the oven, the motor goes to the final assembly. After the final assembly, the motors go either directly to the dispatch department, or, if needed, to the modification department, or to the new additional testing department. Compared to the current

situation, if the additional testing is demanded from the customer, the motors are moved to another factory building for the testing before the new layout.

Unnecessary movements or transportation could be avoided significantly with this new layout. First of all, the line would not split in any phase. All the cells are in the right sequence, followed the previous cell and the motors do not need to move long distances between the working cells. Also, because of the new additional testing phase in the small motor factory, the motors do not need to be transported to another factory building for testing anymore.

Unnecessary movements of workers could also be avoided quite well with this new lay-out. For example, as mentioned before the current situation where the pre-assembly workers have to search and pick the rotors manually with an electric lift could be avoided. In the new kind of operation the right rotor is included in the material set which workers order from the automatic shelf. This applies also to many other parts which now have to be picked far from the work place.

Waiting time is also possible to be reduced significantly with this new way of operation. The automatic shelf is planned mainly to be used as a storage of the sets of the connected motors and the needed parts. That causes that the number of the orders from the shelf and the filling of the shelf are reduced significantly and so the operation of the shelf is more simple and long queues of the orders from the shelf exists no more. So the automatic shelf could operate more quickly. Also waiting time caused by varying working times between the different kinds of motors could be reduced. Because there are cells which includes a couple of the parallel work stations, the one motor which needs more time to finish does not slow down the whole operation of the line.

## **7.6 Lean Tools in Double**

This chapter includes the evaluation of which Lean tools could be used in the small motor factory. There is also an evaluation which wastes could be possibly eliminated with the help of those tools.

### 7.6.1 5S

In the new lay-out all the work places should be planned so that 5S could be taken into use. At the same time when the new lay-out concept is adopted, 5S could be implemented in all of the work places. It is important to use the same standards in 5S which is used already in the new assembly line of large motors in other Motors Vaasa factory building. Most of the unnecessary movements could be eliminated with the right use of 5S. All the locations of the needed parts should be planned and located so that they are near the actual work place. As determined in the Kaizen workshop, all the parts are not necessarily marked with an identification number. It has to be made clear that all the parts from the suppliers or from own manufacturing must be marked clearly so workers do not have to, for example, first print the drawings of the part before they can pick the right part. Figure 35 shows the worst example of untidy shelf in the small motor factory where all the parts are not marked clearly. It is impossible to find the needed particle quickly.



Figure 35. Current state of some of the shelves.

Very important and the most difficult in 5S is to sustain the right order and tidy work places. Without sustaining the improvements of 5S the work places could after a while relapse to the same situation as shown in Figure 36. It is not very pleasant to work in these kinds of work places, and it is also not so good advertisement, for example, to the customer who is visiting the factory. The right kind of attitude should be created among workers where the sustaining the tidy work places is obvious. Good help to creating that attitude could be regular 5S auditions. Maybe it would be effective if the persons working in that other factory building do the auditions regularly. Of course, the own line supervisors have to follow the situation daily.

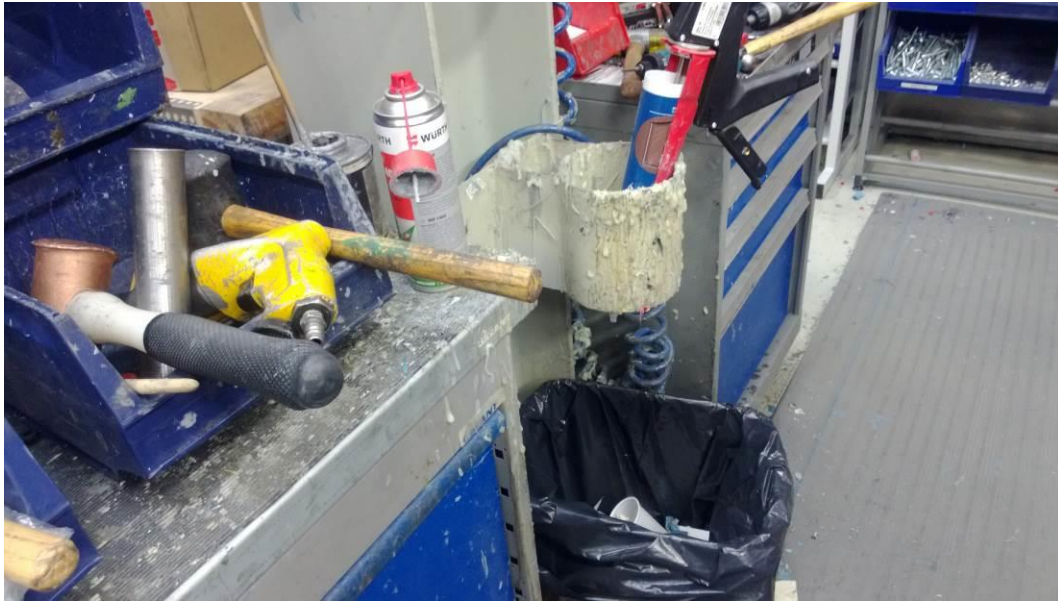


Figure 36. Messy and dirty workplace.

Figure 37 shows the results which could be achieved with the use of 5S. The picture is taken from the ABB's other department where the 5S project is already done. The worker can easily find the needed tools and put them back in the right place because all the places of tools are marked clearly. In the figure it can also be seen that there is a photograph where the right and wanted order in that workplace is shown. That photograph operates as a standard of 5S.



Figure 37. The results of 5S.

### 7.6.2 Gemba

The Gemba-walks have already been started in the small motor factory. In the small motor factory there is now Gemba-boards installed where all the workers and managers can see the situation of the assembly lines. The blank body of the assembly line AL15 board can be seen in Figure 38. The updated information is written to boards before the Gemba-walks.

<b>ABB</b>	<b>ASSEMBLY AL15</b>				<b>WEEK</b>				<b>Week Target</b>			
	h/pcs this Week				Finished this Week							
	h/pcs prev. Week				Finished prev. Week							
	<b>Monday</b>		<b>Tuesday</b>		<b>Wednesday</b>		<b>Thursday</b>		<b>Friday</b>		<b>Saturday</b>	<b>Sunday</b>
<b>Shift</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>2</b>		
<b>Finished pcs</b>												
<b>Finished pcs overall</b>												
<b>h/pcs in day</b>												
<b>The delays for the customer</b>												
<b>Stopped motors</b>												
<b>Missing parts etc.</b>												

Figure 38. Gemba-board.

The Gemba-walks are held currently twice a week in the small motor factory. The manufacturing manager of the small motor factory hosts the Gemba-walks there. The other participants in the Gemba-walks are the supervisors and logistics, quality and design engineers. The Gemba-group takes a round in all work phases in the assembly lines. All the stopped motors in lines can be seen effectively during the walk. Workers can also tell the Gemba-group if there are some other problems in work phases. When there are stopped motors or other problems the right person for each issue can immediately take responsibility for solving the problems. The Gemba-walks have been found to be effective way to see the actual problems in the actual work places and problems could rapidly be solved because of that.

Figure 39 shows the targets and guidelines of the Gemba-walks in ABB Motors.

## Gemba-walks in the production Target "Flow according to plans"

- Ensure the daily target volume and productivity
- Check the stopped orders – the ownership & the actions
- Lead the bottlenecks – instant, repairing actions
- Communicate – between the departments and internal

Take attention in the deviations

Figure 39. Targets of the Gemba-walks in ABB Motors.

### 7.6.3 Andon

Andon is taken into use in the development project done previously for the large motor line. It could be taken in use also in the small motor factory within the Double project. In the large motor line, MES-screens have been installed in production work phases and the same system is planned to be taken in use also in the small motor factory. From there the worker can, for example, easily and quickly search and look the work guides and drawings. This MES-system is also used with Andon. Three different kinds of Andon alarms can be done; quality issues, abnormal transportation and machine breakdown or missing operator.

When the quality issue which affects the Takt time is noticed in the line, the worker opens the notification in the MES and it goes to the quality engineer's work queue in SAP and also the notice for that is sent by e-mail. The notified motor is then changed to the PAUSE-status. All the motors with the PAUSE-status are shown in the MES-screen and the supervisors follow the screen also. The quality engineer is responsible that the solution is found to the issue and the supervisor takes care of that the solutions are made as quickly as possible.

The same kind of MES shortcut is planned to be created also for the abnormal logistics transports. It would be needed because approximately 10% of transports are the kind that there is no transfer order for them. The objective is that the PC in the forklift shows automatically updated work queue including the abnormal transports. Tasks can be taken into the queue for example from the MES-system.

In machine breakdown –issues the operation is quite similar to as with in quality issues. When a machine breakdown happens, the motor status changes to PAUSE and the worker either makes a repair request in the Arrows system or informs the supervisor to do that. With missing operator –issues the objective is that with the help of the MES –screen shown in Chapter 7.6.8 the workers independently move to the work phase where the operator is needed. That would need multi-skill training to the workers and rules should be defined precisely in which situation and what would be the WIP values of the work phase when workers should move to different work phases.

With the help of data collected from the MES-system the effects of the actions can be followed in many ways. One method is to follow how long in total the different Andon issues take to solve. That data could be collected based on that how long the motors have been in the PAUSE status in total. Figure 40 shows the graph about weekly total durations of the PAUSED motors in the large motor assembly line. It can be seen from the graph that the average trend of the duration of Andon issues, excluding weeks 8 and 11, has been decreasing.

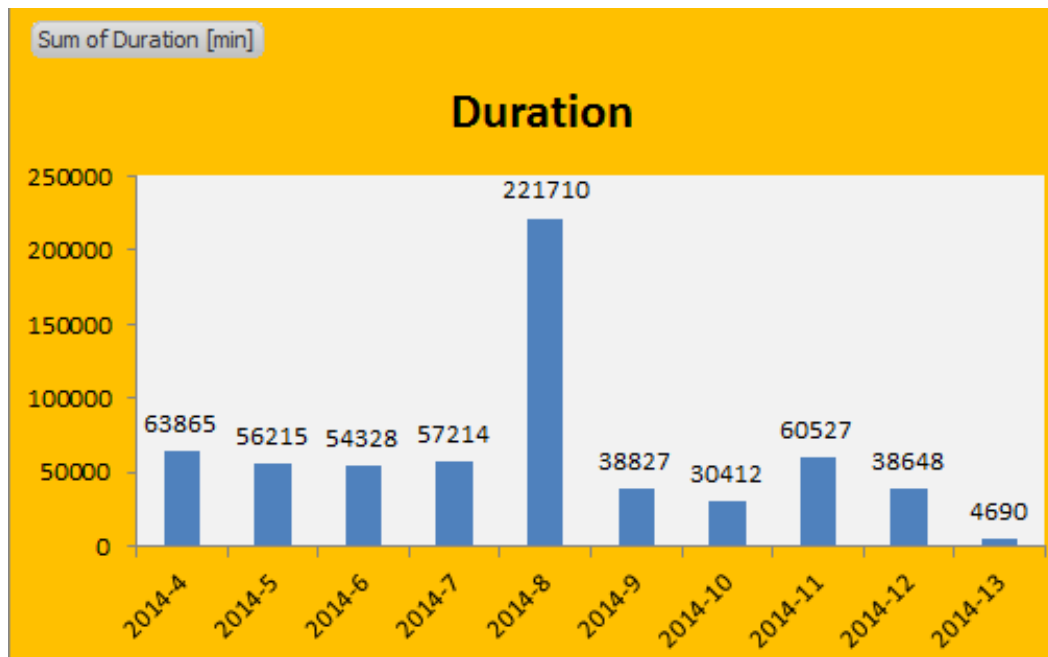


Figure 40. Total duration of Andon issues in assembly line.

#### 7.6.4 Just in Time (JIT)

In the future JIT is meant to be implemented mostly by material kitting. In this project it is planned that all the materials needed for motors are meant to be placed on a pallet and so the materials follow always with the motor and they are at the right place at the right time. That kind of complete setting of the all parts has not previously been in use in the Motors Vaasa factory. In the previously renewed large motor assembly line only some of the parts are included in the set. It would be good to investigate carefully if it is best to include all the parts in the set or is it best to leave some bulk parts out of the set. A good method to investigate this would be making some pilots first with sets including the all parts and sets including all but the bulk parts. In ABB Motors factory in Poland almost full setting is used. There all but bulk parts are included in the set. The example of sets there is presented in Figure 41.



Figure 41. Material sets in ABB Motors Poland factory.

### 7.6.5 Kanban

Kanban is currently widely in use at ABB Motors. In assembly line AL3 the needed scope of the Kanban depends on how high is the materials setting level. If it is decided that all the parts are included in the sets there is no need for internal Kanban for feeding the parts to the assembly line. In turn, if some bulk parts are left outside the set, Kanban is a simple way to handle the feeding of the parts to the assembly line. For example, there could be two boxes near the work place including the same bulk part where the amount of the material is marked. When the other box runs empty, the empty box is collected at some precise place where also all other empty boxes are collected. For some time interval the person responsible for those goes and fills the boxes from the warehouse and takes the full boxes again in the right place. Of course the line worker could also fill the empty box, but then the production idles in that work place and non-value-added time increases. It would be best if for example a logistics worker is responsible for filling the boxes.

The usage of Kanban with the suppliers is the different case than the internal Kanban. Currently Kanban is used with specific supplied parts where it is possi-

ble. It should be mapped if it is possible to expand the usage of Kanban. It is obvious that Kanban does not work with special parts which are made due to order.

Figure 42 clarifies in which kind of products Kanban is currently used in ABB Robotics. The figure is based on ABC/XYZ –analysis. The vertical axis describes how big the value of consumption of the materials is. Letter A means big value, C low value and B is between those. The horizontal axis describes the regularity of demand. Letter X means that material is regularly demanded, letter Z means that material is rarely demanded and Y is between those. It can be seen from the figure that most regularly demanded materials whose value is not preferably the highest suits best for Kanban. A few examples of that kinds of parts which are handled currently with Kanban in the ABB Motors are different kinds of terminal parts or valve discs the number of which is high but value is only a couple of euros per piece.

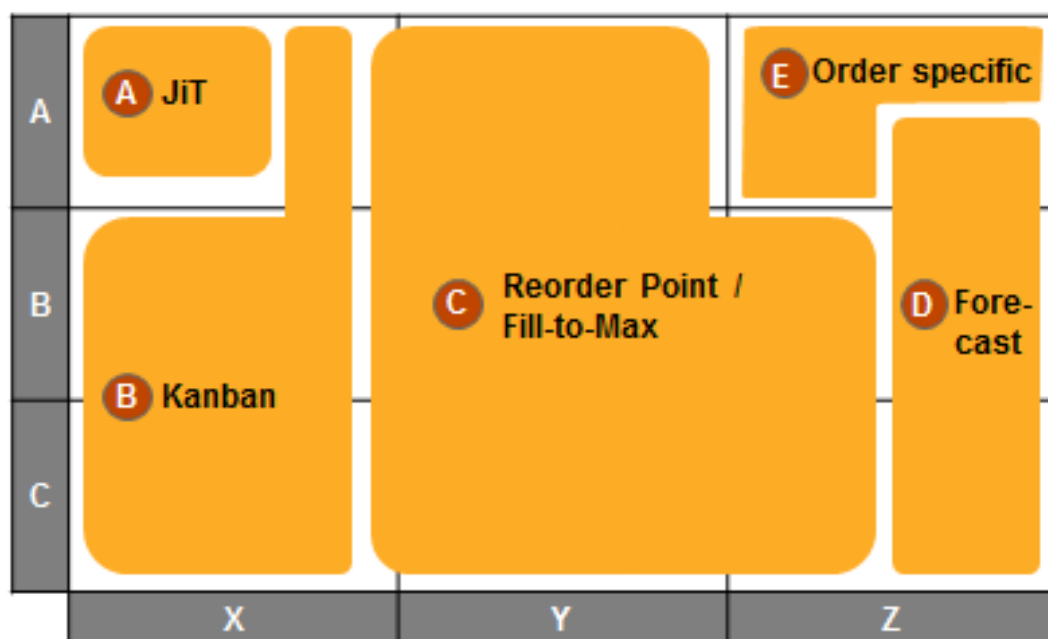


Figure 42. The usage of Kanban.

### 7.6.6 Heijunka

One challenge in the production is that the product mix can be varying daily a lot. For example, on some day there can be lots of motors in the work queue needing

much a longer production time than the standard motors and in some day there are only standard motors. This makes a lot fluctuation in the production volumes daily. Production levelling, Heijunka, should be used to smooth the daily variations in the production volumes. For example, the weekly orders could be levelled during the weekdays evenly so that there is the same kind of product mixes every day in that week. This means that motors which need longer production times are levelled evenly in the production so there would not be the situation where a big lot of these motors are released to the production at the same time and then they “freeze” the production in some sections and affects the volume of the whole line negatively. When product mixes are evened out daily the line could operate more effectively.

Currently Heijunka is under investigation in ABB Motors and a Master’s thesis is previously done on that topic. The essential proposals and results of that research were that three different main sections could be improved to level the production and they were: evening the daily load, reducing the throughput time in the assembly and making capacity more flexible. Table 1 shows the main results of the Master’s thesis to better level the production.

Table 1. Proposals to use Heijunka effectively. (Aitonurmi 2013)

<b>Smooth daily load</b>	<b>Reducing the assembly throughput times</b>	<b>Flexible capacity</b>
Uniformity of the production release	Defining the rules of the fine load	Reducing the significance of the time buffer
Take a notice of manufacturing of special stators, rotors or frames in time model or production releasing	Ensure the quality	Taking a notice of holiday times

### 7.6.7 Takt Time

Different work phases do not meet the Takt time. For example, the frame pressing phase is quicker than the connection phase. If there were a one-piece flow line these work phases would be levelled to meet the Takt time. But in that situation planned in the small motor factory that the line consist of different cells instead of one-piece flow line, the work phases themselves are not needed to meet the Takt time. Instead, the operation of the cells should be levelled to meet the Takt time. It means that from the cell, one work phase should be completed in every Takt time. That kind of levelling could be done with varying the capacity of the cells, simply more workers there where the operation takes longer time and less there where operation is shorter.

Figure 43 shows the current cycle times in each work phase in AL10. Huge difference can be seen between the cycle times of each work phase. The current Takt time of line AL10 is calculated to be 14 minutes. The Takt time is calculated so that the daily available production time is divided by the amount of the needed finished products within the day, like shown in formula 2. Available production time is 7 hours per shift and production line operates in two shifts and daily needed amount of the motors is 60 pieces.

$$\text{Takt time} = \frac{2 \cdot 7 \cdot 60 \text{ min}}{60} = 14 \text{ min} \quad (2.)$$

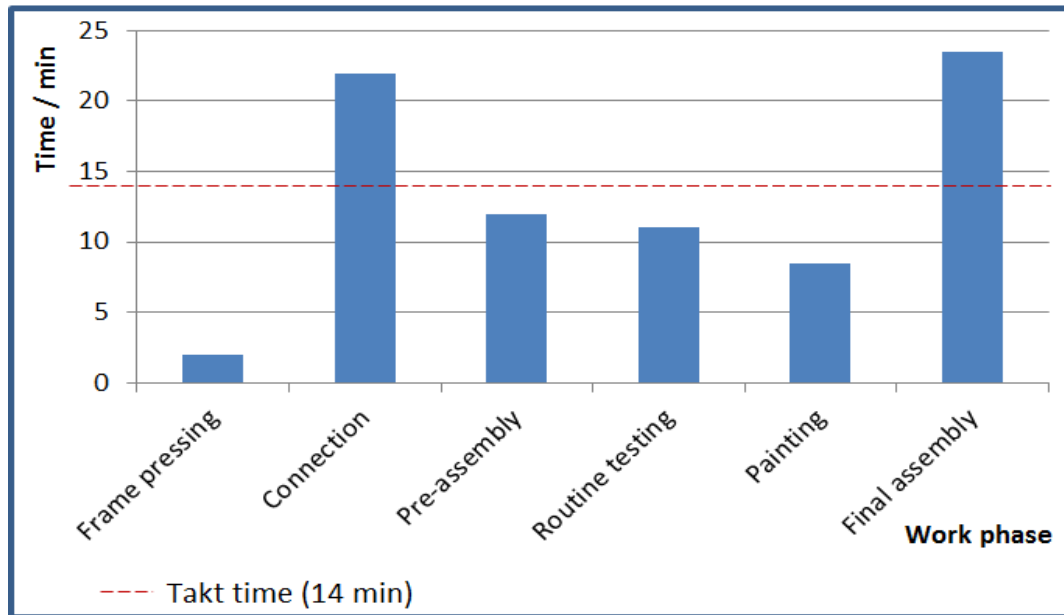


Figure 43. Current cycle times in AL10.

### 7.6.8 Visual Management

5S and the Gemba-boards are part of the visual management which could be used in the small motor factory. The other part of the visual management would be the visual guides for the workers. For example, in the work places there could be example pictures of some of the most critical work operations. In the pictures the right looking product after the work could be shown and possibly the most common defects of the work. Then the defects could better be avoided.

Also the factory standard is a part of the visual management. Among other things, the factory standard in ABB Motors Vaasa includes the rules of usage of the floor marks and their standardized colours. These marks operate also as guides for factory workers and are part of the visual management. Figures 44, 45 and 46 show examples of factory standard in ABB Motors.



Figure 44. The places of trash bins are marked with yellow squares.



Figure 45. Green colour on the floor indicates outgoing goods.



Figure 46. Blue colour on the floor indicates incoming goods.

In the small motor factory the visual screen of the situation of the assembly line could also be installed in the production. The same kind of MES -screen is also used in the new large motor assembly line. The screen is shown in Figure 47. The screen shows the current situation of the whole line and also the situation in each work phase. The main message which is possible to perceive quickly is that when there is green colour the situation is as planned, when colour is red the work phase is left behind from the planned schedule or the WIP -value is too low, and when the colour is yellow the situation is not as good as it should be but not yet as alarming as with red colour. The purple colour indicates that WIP-value is higher than planned or the production is ahead of schedule. An ideal situation would be that workers independently move to the work phase where the red colour is indicated if their own work phase is indicated as green or purple. That, however, needs more multi-skill trainings to workers to operate and move between the different work phases, and currently that is not in a good state.

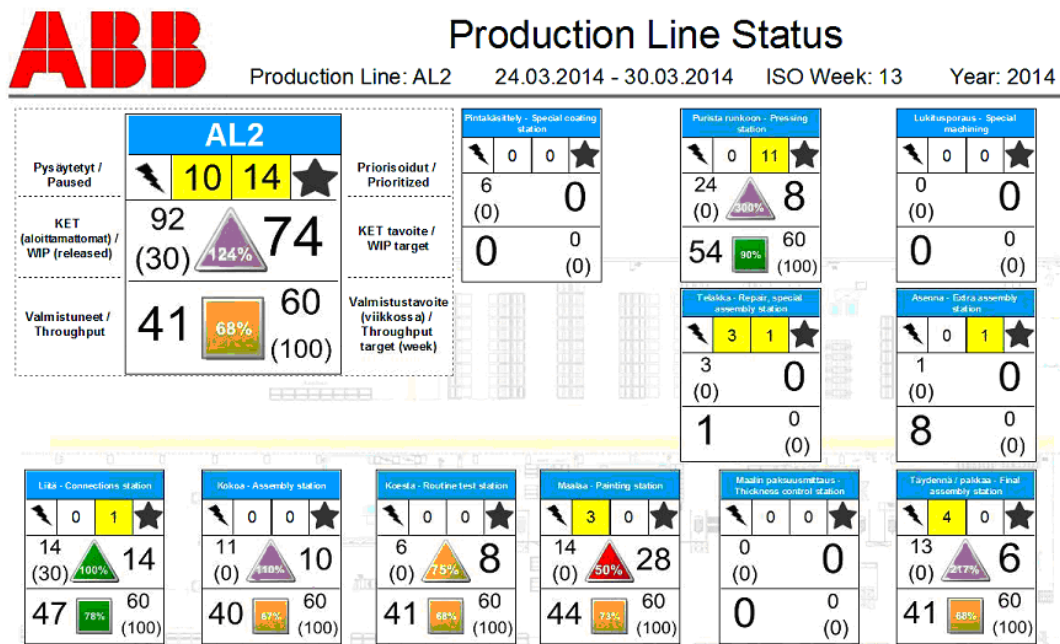


Figure 47. Informative MES -screen.

### 7.6.9 Suppliers and Lean

There are many different parts suppliers for small motor factory. The complexity of the suppliers' chain, especially in cast parts and in rotors and stators, is one of the challenges when raising the volumes so significantly as in this project. It would be good to map if there is a possibility to reduce the number of the suppliers. The co-operation should be deepening with a few of the most important suppliers. Different kinds of Lean-programs could be organised with these suppliers, as has been done in the company benchmarked in Chapter 4. The ABB's Kaizen workshops could be organised with the suppliers. There the problems preventing the production of the needed volume of parts could be identified and solutions could be planned to solve them in co-operation. Lean trainings are also a good method to organise with the suppliers if some of them are not so familiar with the Lean principles.

Also a tight line with the quality of supplied parts should be used. All the defected parts should be claimed and not be repaired in the assembly line, as is the habit

now. Eventually this forces the suppliers to concentrate more carefully on the quality and the right processing of the parts and then the over-processing or faulty processing issues could better be avoided.

The observations made in the Double project are that the cast parts supply network should be managed by the pull control and the role in forecasting should be reduced and the demand information should be shared more widely in the supply network. The stators and the rotors supply network should be organised so that ABB Motors Finland factory do not anymore operate as a distributor for some specific components but the suppliers themselves either manufacture or buy the components directly. Also, the volume and the products should be more effectively shared to the suppliers and the component manufacturing should be intensified. The opportunities of the delivery methods should also be planned with the suppliers. It would be good if the suppliers could deliver the parts as ready sets because the kitting is meant to be started in the small motor factory. Also, it would be good if some of the parts could be delivered as a pre-assembly, or in other words as a module, if it is possible. Some of the suppliers could operate as a module factory. Table 2 collects the observations about developing the supplier network.

Table 2. Observations made for developing the supplier network in project Double.

<b>Supplier network of casted parts</b>	<b>Supplier network of stators and rotors</b>	<b>Delivery methods of suppliers</b>	<b>Processes and tools</b>
Pull control	Not anymore operation as a distributor	Material sets	MSP
Reducing the role in forecasting	Sharing the volumes and products among suppliers	Pre-assemblies	ASCC & Hermes
Sharing the demand information for suppliers	Intensifying the component manufacturing		Supplier portal (Sharepoint)

## 8 SUMMARY

ABB Motors has decided to start to use the Lean-principles as a one part in the operations development. Before, one development project where the large motor assembly line was renewed was implemented after that decision and Lean-principles is started to take in use there. At this time the development project Double is started to renew the whole small motor factory to raise both the volumes and the productivity by 100%. The Lean-principles are also guidelines in that project. This thesis was done because the experiences of the Lean-principles needed to be documented so it is possible to improve the actions in the development projects in the future.

This thesis starts with the theory of the Lean-principles. That section should give a good theoretical basis to what the Lean management means and what the most used tools in Lean are. The theory of these Lean-tools is also presented. A benchmarking visit was made within this thesis and the objective of the visit was to map how the Lean strategy is used in a metal industry company where the Lean has been in use for a longer period than in the ABB Motors. The most significant difference between the companies was how well the Lean strategy is deployed on the factory floor. In the benchmarked company all workers has had Lean awareness training so they are at least somehow familiar with Lean. That awareness could also be spread among the workers in ABB Motors so it would be easier to try to create the right kind of attitude among the workers.

The Double project is implemented at the small motor factory, so its current situation and wastes found there is mapped and presented in this thesis. The planned future state of the small motor factory is also presented, including the evaluation of the new planned lay-out. It is evaluated how well the wastes could be eliminated with this new lay-out and other renewals planned. The final section of this thesis summarises which Lean tools are planned to be used or which could be used to support the achievement of the objectives of the development project Double and how the co-operation with suppliers could be improved.

A proposal for the future is that the Lean way of thinking should be more deployed on the factory floor to commit the workers to operate according the Lean-principles. The ideal situation would be that the improvements not only happen in Kaizen workshops but also in everyday job workers actively try to maintain the habit of doing the continuous improvements. Basic Lean trainings could be organised to all workers. Also the managers' right attitude is in the key role of creating the right kind of Lean culture.

In the future, SMED projects could be implemented in the component factory so the set-up times for manufacturing machines could be reduced. With quick set-ups it is possible to manufacture smaller batches of parts depending on the demand. Currently there is a habit to produce large batches of parts at the time to stock because the set-up times are not so quick to do. When the batches are smaller, then it is possible to take the Heijunka in better use in the component factory. Heijunka could also be used more effectively in every department to level the production. It would be good to evaluate if the production could be evened out also with Takt time –thinking. Some simulations could be used to investigate if the production is more productive and quicker when all the work phases are levelled just the same as the Takt time is.

Figure 48 shows a Lean roadmap for proposed guidelines to the future when developing the Lean strategy further in ABB Motors Vaasa. The figure is made according to the “roadmap” presentation method of strategies which ABB uses.

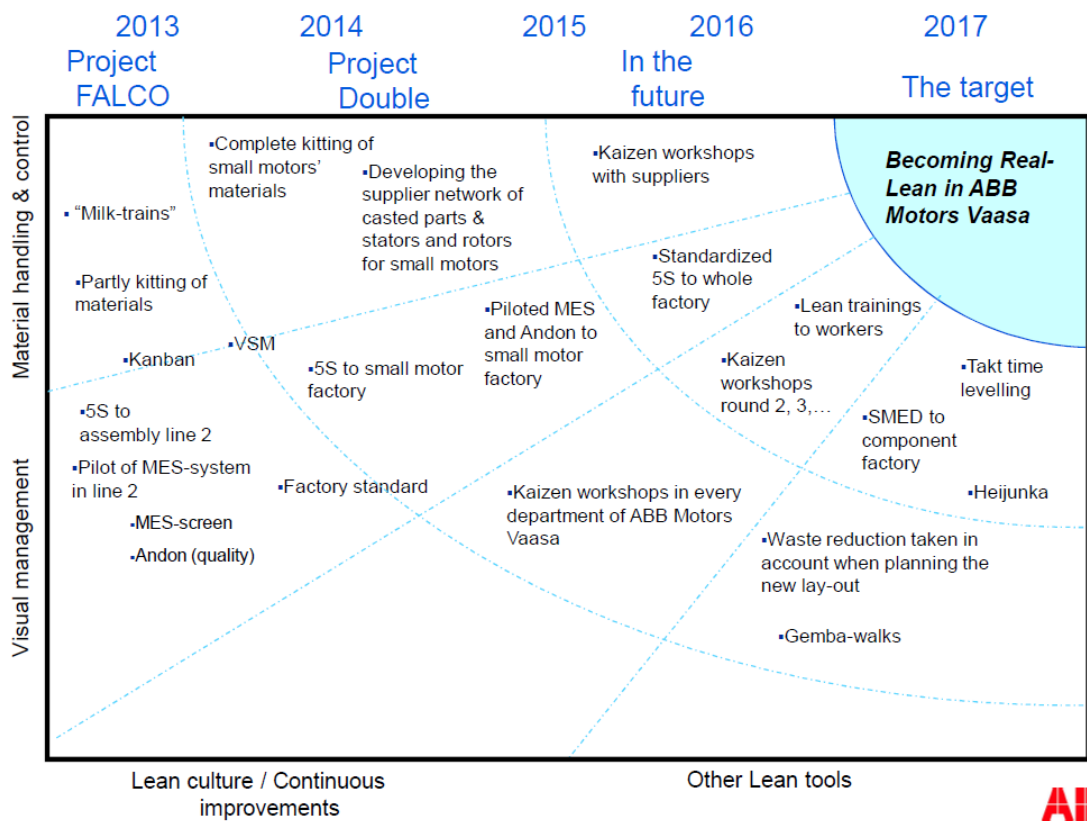


Figure 48. Lean roadmap.

In the roadmap there is a summary of Lean methods used in the previous development project FALCO and the current project Double, also proposals for the future are collected there. The final target is shown in the upper right corner of the figure.

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## The meters of the workshop

General	Machines	People
Volume/week (last 52 weeks)	OEE (usability, performance)	Multi-skilling table
Hours/week (last 52 weeks)	Set-up times	Time research outcomes
The quality deviations (notification, FPY)		
Persons and shifts		
The production reliability of the department The delays		
Lead times (departmental)		
Load/Capacity		
The lack of materials		

+ process charts, VSM etc.

**1<sup>st</sup> day of the Workshop****9.00 - The targets and the rules of the Workshop**

Looking over the meters and the current state of the productivity, setting the targets of the productivity.

What is Kaizen?

What means Waste?

**11.30 – 12.30 Lunch break**

Basics of the 5S

Root-cause-analysis: 5\*Why & Fishbone-diagram

**Coffee break**

Visual management and Preventing the defects (Poka Yoke)

Shortening the set-up times (SMED)

Forming the Gemba –teams and defining the issues for the 2<sup>nd</sup> day

**15.30 – 15.45 The summary of the 1<sup>st</sup> day****2<sup>nd</sup> day of the Workshop****9.00 - The summary of the 1<sup>st</sup> day and the targets of the 2<sup>nd</sup> day**

Identifying the wastes in Gemba –teams:

Team 1, Team 2 & Team 3

**11.30 – 12.30 Lunch break**

Each team's presentations of the identified wastes

**Coffee break**

Teams identify the root-causes of the most significant wastes

**15.30 – 15.45 The summary of the 2<sup>nd</sup> day**

**3<sup>rd</sup> day of the Workshop**

**9.00 -                                    The summary of the 2<sup>nd</sup> day and the targets of the 3<sup>rd</sup> day**

Creating the action plan in teams

**11.30 – 12.30                    Lunch break**

The creation of the action plan CONTINUES

The presentation of the action plan of every team (~30 min/team)

**Coffee break**

The summary of the workshop & agreement of the following the actions

**15.30 – 15.45                    Collecting the feedback about the workshop**



**Lean Benchmarking Question List**

In which Lean section are concentrated the most?

Why?

What are the results?

How Lean is implemented with suppliers?

Is these next Lean tools implemented / in use?

- Andon/Jidoka
- Heijunka
- Gemba
- SMED

How those are implemented?

What are the experiences of those?

Is the 5S in use at the whole factory?

How the sustaining of 5S is organized?

How the JIT is tried to be implemented?

Not published in this version of thesis.