LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
School of Technology
LUT Mechanical Engineering

Jaakko Warén

LEAN DAILY MANAGEMENT, VISUAL MANAGEMENT AND CONTINUOUS IMPROVEMENT

Examiners: Professor Juha Varis
M. Sc. Janne Kauppi

TIIVISTELMÄ

Tekijä: Warén, Jaakko Juhani

Työn nimi: Päivittäinen lean johtaminen, visuaalinen johtaminen ja jatkuva parantaminen

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Diplomityö oli osa lean -filosofian käyttöönottoprojektia, joka aloitettiin Outotecin Lappeenrannan tehtaalla alkuvuonna 2013. Tämän työn tavoitteena oli luoda ja esittää käyttöönotettavaksi lean -ajattelun mukaisia työkaluja päivittäiseen johtamiseen, visuaaliseen johtamiseen ja jatkuvaan parantamiseen. Diplomityö oli "ulkopuolisen" näkemys, eli syvällistä ymmärrystä prosesseista ei hankittu.

Työn tuloksena kehitettiin kaksi erillistä päivittäisen johtamisen taulua; yksi rinnakkaisille prosesseille, ja toinen peräkkäisille prosesseille. Lisäksi kehitettiin kehys jatkuvalle parantamiselle, johtajien standardoidulle työlle sekä tehtävien seurannalle. Kehitetyt työkalut ovat muodoltaan yleismaailmallisia ja ne tukevat työskentelyä lean ympäristössä. Työkalut ovat visuaalisia ja oikein käytettynä ne luovat pohjan, jolta jatkuvaa parantamista voidaan tehdä.

Lean filosofia korostaa vallitsevan tilanteen syvällistä ymmärtämistä. Olisi lean ajattelyn vastaista ottaa sokeasti käyttöön tai kopioida työkaluja jotka on kehitetty jossain toisessa toimintaympäristössä. Tässä työssä esiteltyjä työkaluja tulee tarkastella kriittisesti ja Outotecin työntekijöiden tulee kehittää niitä edelleen ja muokata niitä sopimaan oman näkemyksensä mukaan.

ABSTRACT

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This thesis was part of lean adaptation project started at Outotec Lappeenranta factory in early 2013. The purpose of this thesis was to develop and propose lean tools that could be used in daily management, visual management and continuous improvement. This thesis was "outsiders" view, and as such, did not study the current processes deeply.

As result of this thesis, two different Daily Management -boards were designed, one for parallel processes and one for sequential processes. In addition, methods of doing continuous improvement and daily task accountability were framed and standard work for the leaders outlined. The tools presented in this thesis are general tools which support work in lean environment. They are visual and, if used correctly, they provide a basis from which continuous improvement can be done.

Lean philosophy emphasizes the deep understanding of the current situation and it would be against the lean principles to blindly implement anything developed "on the outside". The tools presented should be reviewed and modified further by the people working on the factory floor.

ACKNOWLEDGEMENTS

I would like to thank Mikko Tykkyläinen from Outotec for the opportunity to write this thesis and for his support during the process. I would also like to thank professor Juha Varis for his advice and support.

During the writing process I received many ideas, insights and advice from numerous people at Outotec. The results of the thesis would have been greatly different without all the discussions. Thank you all.

During my years in Lappeenranta many of my fellow students have claimed to graduate before me. Many of them have been right. Now, finally, it is my turn to graduate. During my stay, I have learned to know tons of people and I want to thank everyone for all the memories.

Jaakko Warén
Lappeenranta. September 12th 2013

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TERMS AND ABBREVIATIONS

Gemba	Japanese: the place where work actually happens
Jidoka	Autonomation
JIT	Just-In-Time
Kaizen	Continuous Improvement
LCA	Life cycle assessment
LEI	Lean Enterprise Institute
Muda	Japanese term for “waste”
Mura	Japanese term for “Unevenness”
Muri	Japanese term for “overburdening”
NNVA	Necessary but Non-Value Adding -activities
NVA	Non-Value Adding -activities
TPS	Toyota Production System
VA	Value Adding -activities
WIP	Work-in-process

1 INTRODUCTION

The climate change, peak oil, the need for water efficiency, economic growth of the middle-class in developing countries and weakening ore deposits are just a few of the great global challenges that society at large and companies worldwide need to face in the next decades. Also, as the economic situation in developing countries gets better, many companies have to face fierce competition by new rising companies as well as the existing ones. Companies need constantly to try to find an edge over each other just to survive. The truth is that companies need to do better and better all the time in several dimensions (economically, environmentally, socially etc.). To survive in this challenging and ever changing world companies need to constantly find ways of doing business in a way that is more sustainable, more efficient and more agile.

In another challenging time, the decades after the Second World War, Japanese car manufacturers also had to find ways of coping in a difficult situation with scarce resources and hard competition. Their solution to these problems was lean manufacturing philosophy.

The ideas behind lean manufacturing philosophy have not been outdated and lean manufacturing philosophy is either being used in, or is being introduced to countless companies all around the world. To fulfill its mission, technology company Outotec Oyj has also started a lean adaptation project that will make it possible to satisfy its customers' needs more efficiently, with even better quality and do it more sustainably.

1.1 Outotec Oyj and Outotec (Filters) Oy

Outotec Oyj (later Outotec) is a technology company that provides leading technology solutions to minerals and metals industries along with innovative solutions to for example industrial water treatment industry and chemical industry. (Outotec, 2013a.)

Outotec started as part of Outokumpu Group and was then known as Outokumpu Technology. It grew strongly during several decades both organically and through acquisitions and mergers. In 2006 Outokumpu decided to focus on its stainless steel business and sold all other businesses including Outokumpu Technology. After the demerger the newly formed company then changed its name to Outotec Oyj in year 2007. Outotec filled a hole in its product portfolio in 2010 when it acquired the filtration business of Larox thus forming Outotec (Filters) Oy. (Outotec, 2013b.)

1.1.1 Mission and Values

Outotec emphasizes sustainability and lets it show in its mission “Sustainable use of Earth's natural resources”. The core value derived from the mission is “Committed to Sustainability”. Commitment is to be understood along three dimensions: environmentally, socially and economically. Linked to the core value are the additional values of “Aspiring for Excellence”, “Creating Leading Technologies” and “Building Business Together” (Figure 1). (Outotec, 2013c.)

Figure 1. Outotec’s values (Outotec, 2013c).

1.1.2 Strategy

Strategy of Outotec is built upon its values and mission (Figure 2). To be able to deliver the customer promise of delivering the best return on customer investment with minimized ecological impact, Outotec aims to be global technology and innovation leader. Focus points in strategy are life cycle solutions, innovative solutions for adjacent industries and improving cost effectiveness and scalability. (Outotec, 2012d.)

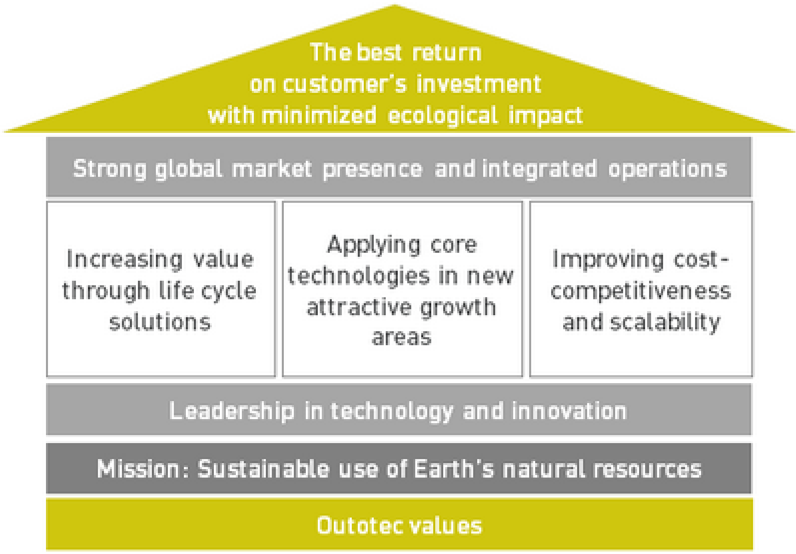


Figure 2. Outotec´s Strategy (Outotec, 2012d).

In a recent article in Finnish investment magazine Arvopaperi, CEO of Outotec Pertti Korhonen emphasized that Outotecs mission is not just empty talk. Company's responsibility towards the community should go beyond just making the shareowners richer in short term. Korhonen said he believes that with responsible actions towards the society at large Outotec can create better business and in the end achieve better financial results. He also said that many investors and portfolio managers have already shown interest towards how environmental issues are handled and have strict criteria when choosing stocks in their portfolios. (Melander, 2013, 35.)

1.2 Frame of reference for the thesis

This thesis is part of a lean adaptation project (O'Lean) done in Outotec (Filters)' Lappeenranta manufacturing site. The long term goal of the O'Lean is to transform all Outotec manufacturing and project management to function according to lean philosophy.

The objective of this thesis was to create and propose methods and tools for daily management in production, visual management and continuous improvement based on lean philosophy presented in such a general way, that they could be adapted in any Outotec (manufacturing) facility around the world.

This thesis was "outsiders" view. No in-depth knowledge of the processes was acquired and processes were observed only on the surface and from the "outside". As an outsider ´s view, this thesis will without a doubt have elements that do not work in the real world environment. On the other hand being an outsider meant not having had close relation to any old working habits. Also, the results do not directly influence the work of the writer so an open mind could be kept. The results of the thesis were presented to the leaders at Outotec (filters)' manufacturing and they will develop the tools further and modify them to fit the real situation.

Lean adaptation projects often start with value stream mapping and implementation of 5S. The starting assumption for this thesis was that 5S has already been implemented and value stream has been mapped. In the real world these processes have been done parallel to this thesis. Visual management was considered mainly from daily management point of view and many otherwise good visual lean elements have been left out. Some potential visual elements will be presented in the theory part, but the results part will only focus on the daily management tools that were developed. It should however be noted, that visual elements should be implemented where ever possible – everywhere. Also, because both 5S and value stream mapping are such essential elements to lean philosophy both of them will be shortly introduced in the theory part of the thesis. They will however be excluded from the results part.

There are tools that are essential to lean management and important for further research and successful lean journey but are not daily management as this thesis understands it. For example Hoshin Kanri is explained shortly in the theory part. It is excluded from results but revisited in further research and conclusions.

1.2.1 Sources, data gathering and methodology

Preliminary data gathering was done using several databases including, but not exclusively, Emerald (Science Direct), Elsevier (Elsevier), EBSCO and Springer Journals. Searches were done using many general terms such as "lean manufacturing", "lean production", "lean visual management", lean daily management", "kaizen" etc. As the subject and the objective of the thesis became clearer and more familiar, more refined searches were done using more exact terms. Some articles were found from the reference lists of previously found articles and most influential articles were searched using ISI Web of Knowledge.

In order to find examples of best practices already in used in manufacturing industry, benchmarking visits to two Finnish factories were made. First visited factory manufactures heavy moving equipment and the second factory manufactures electrical systems and supplies. Both benchmarked companies have started their lean implementation journeys several years ago. Nothing has been directly copied from the benchmarked companies but they did inspire some elements of the tools presented in this thesis.

In order to have some information about current situation and current management habits in the factory, interviews with managers in the factory were conducted. Interviews focused on finding out what are the current managements standard work elements, if there are any. Employees ideas were heard in a lean training session carried out by the consultant firm Lean5 Europe Oy. Several visits to factory floor alone and together with different people (outsiders and current management) were done and several discussions have been had with employees and managers from different levels.

1.2.2 Terminology

Due to its historic background lean manufacturing is tightly linked to Toyota Motor Company and Toyota Production System (TPS). This thesis will often refer to the way in which Toyota operates and often uses Toyota related terms such as "*Toyota Way*" or "*Toyota Kata*". These two terms rise from the books by Liker (2004) and Rother (2010), both of whom are generally acknowledged to be one of the leading lean experts outside Japan. When this thesis uses the Toyota based terms it is talking about lean in general. Because of the link to Toyota, lean literature uses several Japanese terms (such as Kaizen) commonly. Because the Japanese terms often fit the situation best, this thesis will often use the Japanese terms. A short explanation to these terms is provided in the "Terms and Abbreviations" section as well as midst the text.

Some authors debate over lean terminology and try to find distinctions for example between terms like lean production, lean manufacturing. This thesis does not take part in that discussion. For the purposes of this thesis, lean is a complete system which includes both philosophical background and the generally accepted tools. This thesis acknowledges that it is impossible to accurately define lean because at its heart it is continuously improving and ever changing and every successful adaptation of lean can and should be different.

1.2.3 Structure

The introduction part (Chapter 1) of this thesis consists of an introduction to Outotec, its history, mission, values and strategy. Chapter 1 also introduces this thesis to the reader. The **second chapter** will introduce the reader to lean manufacturing ideology and to the main ideas behind it. The **third chapter** contains basic information of lean processes, tools and practices. The ideas from the benchmarking visits as well as from literature are presented together with the current state observations in the **fourth chapter**. The results of this thesis are presented in the **fifth chapter**. **Chapter six** proposes development and research subjects and the seventh chapter is the conclusion of this thesis.

2 LEAN MANUFACTURING PHILOSOPHY

Lean manufacturing philosophy (lean) is based on Toyota Production System (TPS) which was developed in Toyotas Motor Company's factories during several decades by its engineers and leaders such as Ohno and Shingo. Lean was Toyotas solution to the scarce resources and difficult economic situation, which Japanese manufacturers had to face after the Second World War. The first written description of the system was published in year 1978 (in Japanese) by Ohno. In it, Ohno described the fundamentals of TPS which included for example the concepts of jidoka, just-in-time production using kanban and supermarkets, small-lot production and fast machine changeovers. In addition to Toyotas own research and insights Toyota Production System was and still is influenced by for example German and American manufacturing methods, which Toyota modified to fit their own needs and processes. Fujimoto (1999) described the TPS by saying: "*The Toyota-style system has been neither purely original nor totally imitative. It is essentially a hybrid*". The word "lean" (to describe Toyotas production system) was first used in 1996 by Womack, Jones and Roos in their book *The Machine that Changed the World.* They used the word meaning that the system was "low-fat" or "stripped from any excess". (Holweg 2007, 420-422.)

Lean philosophy and its components have been developing through several decades in several companies. It could be said that whatever lean is today for some company may be something totally different for a different company today or for the same company tomorrow.

Many authors have tried to define what lean is (for example Pettersen (2009), Shah and Ward (2007 and 2003)) and most have come to the conclusion that lean is not clearly defined. Some authors (for example Pettersen (2009)) have focused on the tools and tried to define lean by studying which specific tools are being used in lean companies. Others (for example Bashin (2011) and Bashin & Burcher (2006)) have focused on the philosophical side. Most authors however agree that lean is to be understood as a combination of both. Lean is essentially a set of ideas and tools that make up a complex interdependent system which has both visible and invisible parts (Figure 3).

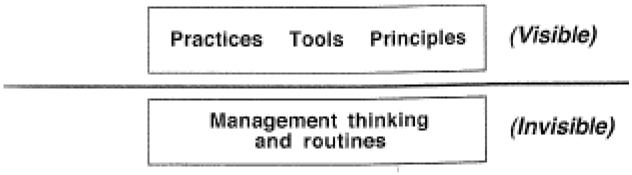


Figure 3. The two layers of lean (Rother, 2010, 5).

Lean manufacturing has been implemented, or tried to be implemented, in countless companies over the years. Most lean implementations have however failed. The success rate in the United Kingdom is around ten percent and less than 4 percent in United States of America (Bashin, 2011, 403). In *Toyota Kata* Rother explains that the reason behind so many fail is that the companies have failed to see the invisible ideas behind lean (Figure 3). Rother makes a clear distinction between adapting lean and implementing lean. When companies just focus on the visible tools and principles they see in use in other lean companies, they are trying to reverse-engineer the "Toyota Way" or TPS. Instead, Rother says, companies should realize the invisible ideas behind the tools and apply them to their own specific needs and processes. (Rother, 2010, 4-5.)

At the heart of lean are quite simply the idea of customer value and the idea of waste (Japanese: Muda). The more waste there is in the process, the less efficient it is, and the more the product will in the end cost to the customer (Hines, Holweg & Rich, 2004, 996-997). Figure 4 represents the total costs of a production process.

- Green area represents the value adding activities (VA). The actual manufacturing activities that add value to the product, such as welding or machining, are VA activities.
- Yellow represents the necessary but not-value-adding activities (NNVA). These are activities like quality checks or absolutely necessary transports. They do not directly add value, but are necessary in the current situation.
- Red represents the not-value-adding (NV) activities or waste (Japanese: Muda). These are wasteful activities like re-work, unnecessary inventory and so forth.

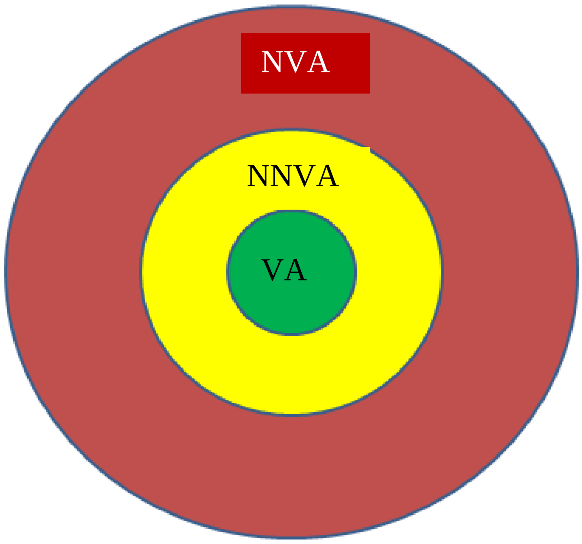


Figure 4. The layers of manufacturing process (adapted from Torkkeli, 2013).

Most western improvement efforts only focus on how a factory can run their processes faster, and focus on the green area of the process. This means that they try to fine-tune their welders to weld faster, lathes to turn faster and so forth. The result often is that they try to run faster and faster all the time, which in the end only results to catastrophe. When a company starts to see things in a lean way, they start to see waste (Muda) everywhere in their processes and around them. When companies study their processes carefully, most realize that the share of waste in for example their through-put time can be up to 90 % (warehousing, WIP, unnecessary transport etc.). When this is realized, companies can start to systematically reduce the waste (the 90 %) instead of fine-tuning the part they already are doing well (the 10 %). The idea of a lean process is not to run faster, but to travel a shorter distance. (Torkkeli, 2013.)

As mentioned before, lean philosophy was described in English for the first time in a book by Womack et al. in 1996. In their book, they describe how waste can be attacked by “lean thinking” and identify five core principles that guide a lean manufacturing system (Figure 5).

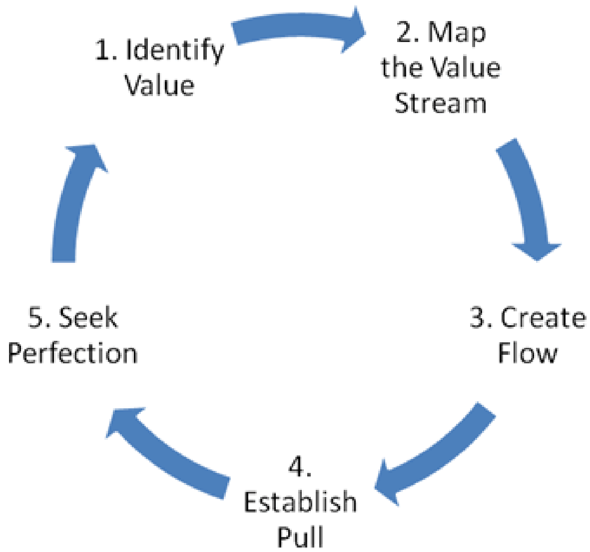


Figure 5. Principles of Lean (Lean Enterprise Institute, 2009a).

The process starts with identifying the customer value. Then the value stream is mapped and process is made to flow and pull control is introduced. After that the process is continuously made better by seeking perfection. These principles will be described on a more detailed level in the next chapters.

2.1 Identify Customer Value

Identifying customer value is the starting point of lean. Value for customer can be defined as any activities that the customer is willing to pay for. When a customer pays for a product it expects to get the correct products at the correct time at correct costs, but in principle only wants to pay for activities that actually add value to the product. (Womack & Jones, 1996, 27-36.)

In his book *Gemba kaizen: a commonsense low-cost approach to management* Imai noted that all work is usually a series of processes and the next process should also always be regarded as a customer. Understanding this, according to Imai, should lead to a commitment never to let a faulty piece to be delivered to the next process thus leading to a better quality. (Imai, 1997, 7.)

In their 2004 article Hines, Holweg and Rich broaden the ”traditional lean” by noticing that value can be created for the customer by two ways:

1) Removing internal waste from the process by “traditional lean”.
2) Developing the customers perceived value.

Traditional lean has mostly been focusing on removing internal waste. As Hines et al. (2004, 1006) note, this can lead to only focusing on the cost axis and to “island optimization”. Hines et al. also explain that lean has evolved during the centuries from a simpler set of tools to “lean value system” where organizations can look past the traditional lean waste (cost) removing ideology and start to see customer value as something that can also be increased by better packing, shorter delivery time, smaller delivery batches and so forth. The two different ways of creating value for the customer is shown in Figure 6.

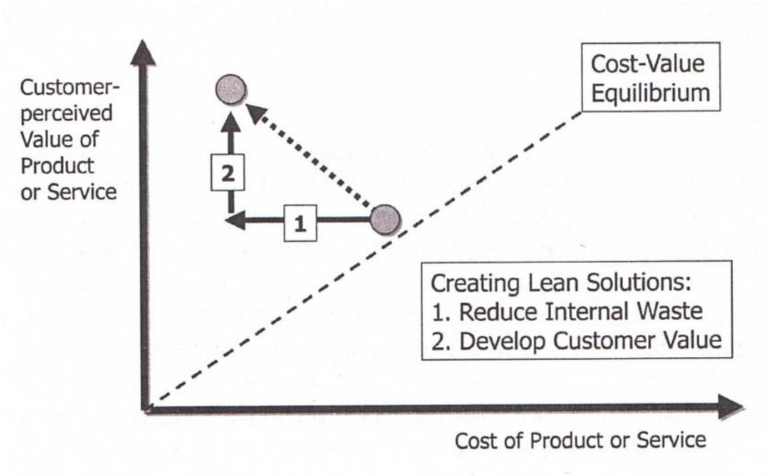


Figure 6. The two ways of adding customer value (Hines, 2004, 997).

2.1.1 The Seven Wastes, Unevenness and Overburden

From the customers point of view all actions that do not add value to the product are considered to be waste (Japanese term: Muda). Removing waste from and around the processes is the essence of lean. The seven classic wastes of TPS are:

Overproduction is often mentioned as the most serious of all the wastes, because it may cause many other problems in the process. Overproduction makes it impossible to make the goods flow smoothly through the process. It causes extra inventory, which again causes new problems: for example extra inventory makes it difficult to trace process backwards and defects often go unnoticed. Even if defects are noticed in a later stage it is often impossible to track the root cause of the problem. (Hines & Rich, 1997, 47-49.)

The waste of **waiting** occur whenever goods are not moving or being worked on. (Hines & Rich, 1997, 47-49.)

All moving of goods is **transport.** Some transport is always needed in any factory but all extra handlings and long transports should be viewed critically and be reduced to minimum whenever and wherever it makes sense. Transporting is also a safety issue because of extra lifts and movements. (Hines & Rich, 1997, 47-49.)

Inappropriate processing happens for example when a factory uses a big and expensive machine when it could get the same result with a smaller one (Hines & Rich, 1997, 47-49). If there is a "too productive" machine available, it can lead to workers (and managers) to think that it is necessary to keep the machine at work as much as possible, thus leading to overproduction.

Unnecessary inventory causes a lot of different problems, for example binds capital, uses extra warehouse space, increases lead time when items need to be moved more often and prevents other problems to be noticed. (Hines & Rich, 1997, 47-49.)

Unnecessary movements are the movements of the worker. They can include things like walking to get tools, walking to get the raw materials etc. Unnecessary movements can be tiring for the employees and can lead to poorer productivity and for example quality problems. (Hines & Rich, 1997, 47-49.)

Defects always cause direct extra costs. The philosophical mindset about defects in lean philosophy is that they are considered as opportunities to improve something in the process rather than mistakes as such. (Hines & Rich, 1997, 47-49.)

An 8th waste added by for example Liker (2004, 29) is ignoring or **not using employees ideas and skills**. Matti Torkkeli from the company Lean5 Europe Oy highlighted this in a training session when he started a training session by asking everyone to introduce them and telling how long they had been in the company. The result just in one small room was easily more than 250 years of work experience. In the whole manufacturing department the result added up to more than 1500 years of experience.

Some authors are starting to introduce a ninth waste (for example Vindoh, Arvind & Somanaathan (2011, 469)) of **environmental waste** which includes the excessive use of earth's natural resources or release of harmful substances to air, water or earth.

Most lean literature seems to focus mostly on waste (Muda). Waste in the processes is often easy to spot and can be eliminated using different lean methods. Just focusing on removing waste in the processes can however result on other problems, such as overburdening the people and equipment (Muri) and unevenness of the process (Mura). Muri can be seen as being in the opposite end of the spectrum as Muda. Removing waste from the process can therefore lead to more pressure on the workers thus creating Muri. (Liker, 2004, 114-115.)

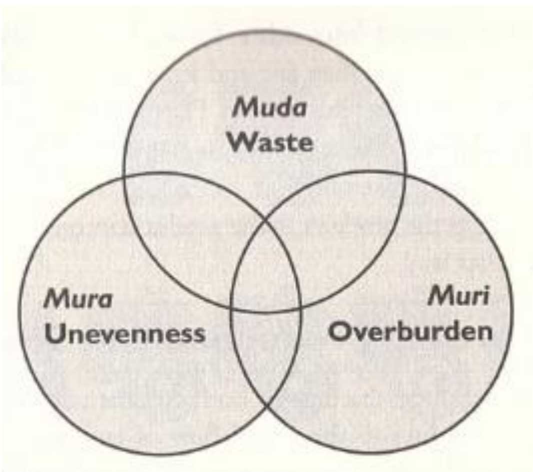


Figure 7. The three Ms (Liker, 2004, 115)

All of the three Ms are overlapping and somewhat causal, but equally important for Toyota (Figure 7). As Liker (2004, 115) points out, when most companies try to implement lean, they often only focus on reducing the Muda and as a result they often get a process which is moving wildly out of control and stresses their workers and machines to a point where it starts to cause i.e. quality problems. When companies notice their wildly fluctuating processes and stressed out workers they often reject lean as whole. Lean failures often are caused by missing the ideas behind the tools and ignoring the other two Ms. (Liker, 2004, 115.)

2.2 Map the Value Stream

The second step in lean, after identifying customer value, is mapping the value stream. Identifying customer value can be thought of being a philosophical idea that is "out of the process itself". Value stream mapping (VSM) scrutinizes the process itself to whatever level of detail it is seen necessary at that moment. There are several simple and more complex mapping tools but the analysis always follows pretty much the same path as described by Rother (2010, 271-272):

1) Select the value stream or product family to be analyzed
2) Identify process steps, what exactly is being done? Why? And what is the processing time in each of the steps. Including all VA, NNVA and NVA activities.
3) Is the process step dedicated or share with another product family
4) At which points along the value stream inventory is kept and how much?
5) How does each process know what to produce (information flow)?
6) At what process are changeovers needed?
7) Identify which processes need to be controlled the best if customer demand is to be met correctly (pacemaker loop)?

After the process is mapped, the NVA activities are removed from the process whenever possible. The means vary, because the activities to be removed vary.

Several value stream mapping tools and aids exist in the literature (as described by for example Hines & Rich (1997)), but as VSM was excluded from the scope of this thesis they will not be presented in detail here.

2.3 Make the process flow

After the value stream is mapped and the process understood it is time to make the process flow. In *Toyota Way* Rother (2010, 45) describes one piece flow as an ideal where a piece moves straight from one processing step to the next value adding process. In a sense the ideal situation would be that every part in the process is getting value added at all times and move to the next process without any interruptions or batch inventory.

2.4 Introduce Pull

In *The Toyota Way* Liker (2004, 37) describes Toyotas principle of pull to be a method by which they can avoid overproduction. In a pull system downstream internal customers are provided the parts they need, at the time and in the quantity they need so it as quite basic just-in-time principle. Material replenishments are being done based on an actual need rather than a production schedule. Kanban method to achieve pull will be described later.

2.5 Strive for perfection

The last core principle of lean is striving for perfection. Lean Enterprise Institute describes seeking perfection as the last step of lean by saying: “As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste”. (Lean Enterprise Institute, 2009a.)

3 LEAN PROCESS, TOOLS AND PRACTICES

Lean philosophy is the building block upon which lean is built. Different tools and techniques are used in order to execute the ideas. When applying any lean technique it is important to realize the idea and intention behind it, not simply blindly copy the tool.

In *The Toyota Way* Liker (2004) represents the TPS house (Figure 8). The house diagram was developed at Toyota when it was noticed that the supplier base also needs to be trained in TPS and they needed a clear depiction of the system. The house diagram represents the idea that the complete system only works if all of its parts are strong and in place. At the roof are the goals including best quality, short lead time etc. The foundations of the Toyota House are made from four elements: the Philosophy, Visual Management, Stable and Standardized Processes and Leveled Production. The pillars of TPS are formed by just-in-time -practices (JIT) and Jidoka (which is a quality control idea of never letting a defect go past one station to a downstream process). At the center of the house are the people, continuous improvement and waste reduction. All parts of lean need to work together, in order for the system to work.

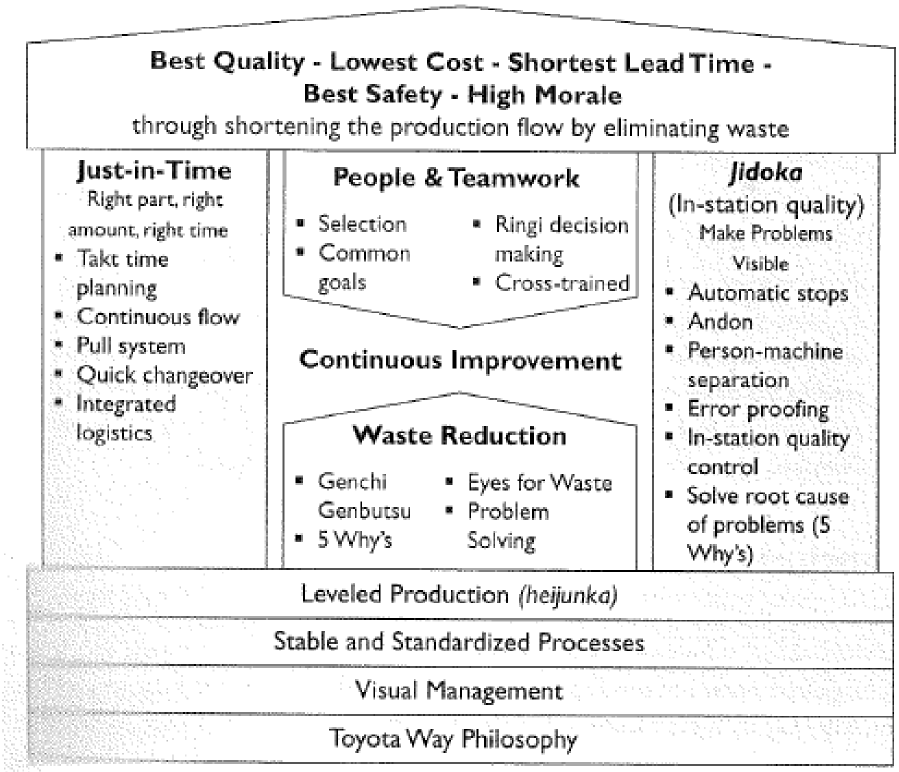


Figure 8. The Lean (or TPS) house (Liker, 2004, 33).

3.1 Lean management

Lean management is different from traditional management in a lot of ways. In lean philosophy, the focus is almost entirely in the process instead of the results. This does not mean that results are not important but Toyota believes that by focusing on and controlling the process and making it continuously better they will, in the end, achieve the good results. In *Toyota Kata* Rother (2010, 141) explains that Toyota focuses on the process instead of blaming people. It assumes that people are doing their best and the problem is in the system; the problem would arise no matter who is working on that exact part of the process.

Traditional leaders in traditional western are often in “fire-fighting” mode. In this kind of an environment people are rewarded when they “get things done” regardless of what it takes. The focus is on the short term wins and not in continuously improving the process. (Liker & Franz, 2011.)

In his book “*Creating a Lean Culture: tools to sustain lean conversions”* Mann has broken down lean management into four pieces: leader standard work, visual controls, daily accountability process and leadership discipline. These elements match well with the Lean House and form the basis upon which lean is built. Standard work can help leaders to shift their focus from firefighting to continuous improvement. Visual controls are implemented to help leaders easily see if processes are in control or not. Accountability process is there to continuously keep track of what is going on in the process and keep track of the different tasks each member of the team might have at a specific time. Without discipline the lean system will not work. Metrics have to be updated regularly and if the process is not working as it is supposed to, it should show in the metrics regardless of the reasons. (Mann, 2010, 24-36.)

3.1.1 Attributes of lean leader

In Toyotas internal document *The Toyota Way 2001* (Figure 9) it listed five core values for leadership. **Spirit of Challenge** is way philosophical idea of challenging oneself not just to excel in every current role that a leader/worker might have but to take on bold challenges along the way. **Kaizen Mind** is a mandate to constantly improve the performance. All leaders at Toyota are taught that processes will always contain loads of waste and can always be improved. Even if the process for some miraculous reason would be perfect today the environment would change tomorrow and improvements could be done. **Genchi Genbutsu,** or "Go-and-See", as a value is the idea that decision makers should understand the situation and handle problems at Gemba (Japanese for "the place where the work actually happens) as if it was their own daily problem they are trying to solve. Fourth leadership value of Toyota is **Teamwork**. Teamwork is promoted for example by different promotion processes and incentives which at Toyota focus heavily on team based performance. The last core principle of **Respect** can be seen as the most fundamental core value, and even as the purpose of Toyotas existence. Respect shows in the whole way the company operates; for example during the recession no regular employees were laid off. (Liker, 2012, 35-39.)

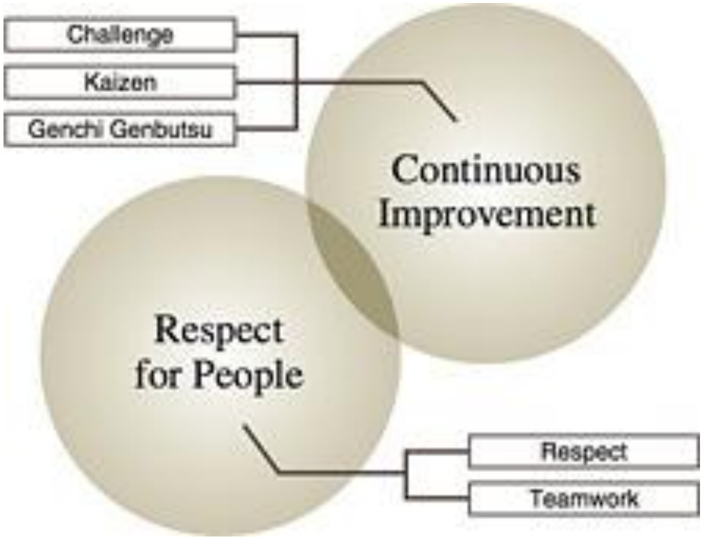


Figure 9. Toyota leadership **(**Toyota Motor Corporation, 2012, 2-3).

In his book Mann also listed nine attributes that a lean leader should have. **Passion for lean** is more than just some behavior that you can do. A leader who wants to lead a lean process should be passionate about lean and really want to change for good. Passion for lean means willingness to change one's own personal way of acting by for example adopting standard work and actually doing standard work before demanding it from anyone else. (Mann, 2010, 140-142.)

Disciplined adherence to the process and accountability means setting clear expectations for the process and implementing a systematical follow up. Multiple layers of checkup make sure that processes are both done as they are planned and misses in the process are followed up on. (Mann, 2010, 143-144.)

Project management orientation is important especially in the implementation stage of the lean journey. There should be a defined and visual tracking of the ongoing (and overdue) tasks. (Mann, 2010, 144-145.)

Lean thinking as a management principle means that a leader should think that there is always room for improvement in the process even if is not obvious. Often in these situations support from workers and leaders closest to the process is needed. A good leader should by his/her own example seek improvements and especially try to reveal and solve the root causes of the problems (Mann, 2010, 146.)

Lean leader should have the ability to have **ownership** of the lean improvement process without dictating what others should do. The leader should be able to create an environment where improvement ideas are brought to the surface and the best ones are acted upon. A lean leader has a direction giving and a guiding role who creates an environment for lean progress. (Mann, 2010, 146-147.)

It is important that lean leaders understand the **tension between the applied and the technical details**. A lean leader who does not understand the process deeply enough can for example order that inventories are to be cut by 25 % without understanding the other changes that need to be done in the process to support this (i.e. reducing set-up times). A lean leader should always listen and understand the technical experts' advice when considering drastic changes in the process. (Mann, 2010, 146-153.)

In the implementation stage leaders often pay more attention to the technical details of the lean process than to how they will be managed when the system is up and running. The **balance between production and management systems** should be taken into account early on. (Mann, 2010, 146-153.)

A lean leader should understand the **meaning of the support groups** such as engineering, maintenance and even accounting. Support groups should also understand that the production is where the money comes from, and support groups are there to support that. Lean (value stream) leader should incorporate support groups closer to the production and expect them to provide solutions to the problems experienced in the shop floor. (Mann, 2010, 152-153.)

An important part of lean leading and the ninth attribute of Mann´s list is **not confusing measures of the process between measures of the results.** A lean system is designed to show problems visually as soon as they arise. Problems and misses should not be hidden for any reason. A traditional leader wants to see green measures everywhere so he/she can assume that everything is going well but this often leads into tweaking the numbers to show green even though there are problems in the process, which need to be solved. (Mann, 2010, 146-153.)

3.1.2 Hoshin Kanri

Hoshin Kanri (policy deployment or direction management) is a management tool used in lean that is used to give a company a direction as a whole. Mothersell, Moore & Reinerth (2008) describe how it is used enable organization to move together in one direction according to the company´s strategy. If Hoshin Kanri is applied correctly all functions of the company should move towards the same direction and share the same strategic goals. Hoshin Kanri is also used in a vertical direction so all levels of organization have defined responsibilities towards the common goal. Built in the Hoshin Kanri are also Plan-Do-Check-Act -cycles and it incorporates continuous learning and employee development through all levels of the organization.

3.1.3 Organization structure

Organization at Toyota is based on work groups. Work groups are found in every department from marketing and logistics to manufacturing. An ideal Toyota style work group is shown in Figure 10. It consists from roughly 20 production workers, one team leader for each team and a group leader. (Liker & Convis, 2012, 134.)

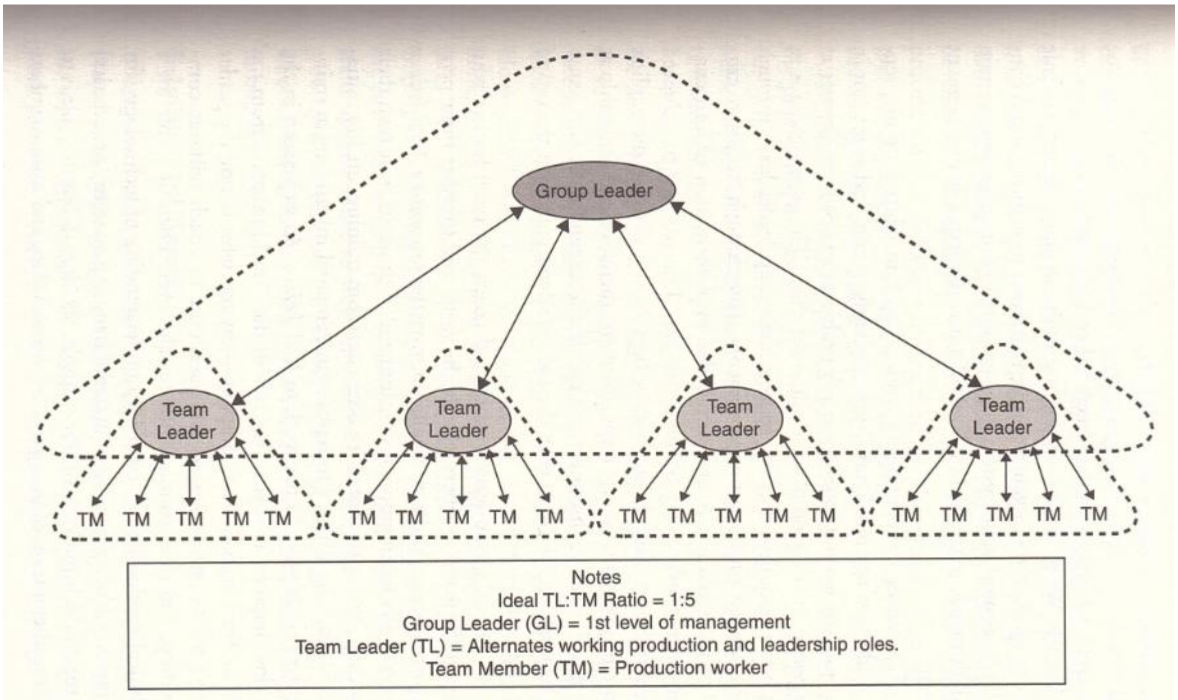


Figure 10. Organization structure (Liker & Convis, 2012, 135).

Team leaders are alternating between production work and other activities such as doing continuous improvement, answering andon calls or solving any production problems that may rise during the day. (Liker & Convis, 2012, 134.)

3.2 Visual management

After the long term philosophy the next element of the lean house (Figure 8) providing stability to the lean system is visual management. According to Mann (2010, 53) virtually any process in lean environment should be visibly controlled; in the office as well as in the production area. A good visual control tells the workers and leaders immediately if the process is running as planned or if process is for some reason deviating from the standard. Galsworth (2004, 44) defined a visual workplace as being "*Self ordering, self-explaining, self- regulating, and is self-improving work environment where what is supposed to happen happens on time, every time, because of visual devices*".

A good visual control should give anyone who glances at a chart or a graph an idea how process is currently running compared to the standard. A glance should also be enough to determine the current workload, orders that need to be started as well as orders that have been delayed. (Grief, 1991, 109.)

Grief (1991, 67) explains how the “traditional” personal or centralized information differs from the public knowledge of a visual workplace. There is no good reason why information should not be shared instead of kept hidden as a sign of authority. Grief´s idea is visualized in Figure 11.

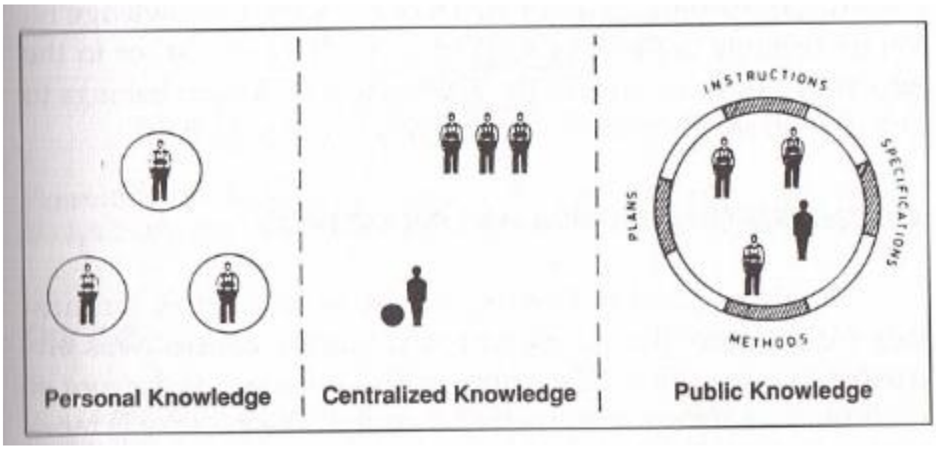


Figure 11. The role of visual documentation in creating public knowledge (Grief, 1991, 67).

A visual workplace according to Grief (1991, 20-21) can include for example the following areas:

- Identification of the territory, activities, resources and products; markings on the floor, tools and racks and information and instructions.
- Visual manufacturing instructions and technical procedures.
- Visual production control with computer, production schedule, maintenance schedule and identification of inventories and WIP.
- Visual quality control with monitoring of machines, statistical process control and record of problems.
- Displaying indicators such as objectives, results and differences.
- Improvement projects and company communication.

In their 2012 paper Kattman, Corbin, Moore and Walsh benchmarked visual tools used in different manufacturing environments. Different tools they gathered are presented in Figure 12.

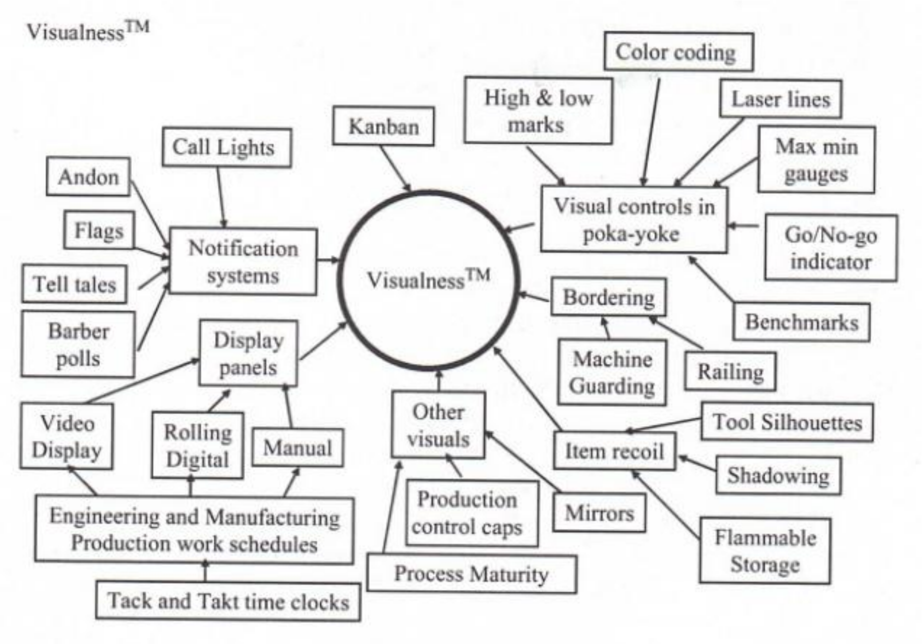


Figure 12. Visual elements used in manufacturing environments (Kattman et al., 2012, 425).

Kattman et al. also concluded in their study that a good visual workplace must answer six questions (Kattman et al., 2013, 427):

1) What is one working on?
2) Why is one working on something?
3) When is something being worked on due?
4) What issues exist?
5) Is the customer satisfied?
6) What is the process maturity?

According to *Toyota Way* (Liker, 2004, 38) simple visual systems should be designed, updated and kept at the Gemba. This is supported by Mann (2010, 81-83) who explains that leaders often forget that workers at the Gemba are often not trained to read spreadsheets and reports in the same way that managers are. Kattman et al. (2012, 416) also point out that 75 percent of learning is done by sight which also supports using more visual guiding than numbers in spreadsheets. Mann (2010, 83) goes on saying that if the workers are creating data entries by hand it creates a more personal connection to the data and its source than any computer generated graph that might look nice to the managers' eyes. Grief (1991, 211) also states that it is necessary that the team updates any charts to build commitment to them.

The visual controls are only limited by the imagination of the company that is creating them. The methods used are determined by the needs of the process: both the stable needs and more urgent needs emerge as interruptions in the process. (Mann, 2010, 84.)

3.2.1 5S

In *Toyota Way* Liker (2004, 150) describes how American leaders visiting Toyota in the 1970s and 1980s were amazed by the cleanliness on order of the factories. Liker goes on to describe that the reason for this was Toyotas 5S method. 5S is a method for maintaining the workplace in order and clean. The 5S' come from Japanese terms Seiri, Seiton, Seiko, Seiketsu and Shitsuke and are usually roughly translated to (Takeda, 2006, 35-44 & Torkkeli, 2013):

Seiri (sort) – go through all items in the workplace and keep only the ones that are needed. This can be done for example by letting the workers go through the workplace and attach a green label to all items that are needed and a red label to the ones that should be taken away. If it is decided that the items are not needed at the workplace they are taken to a quarantine area where it is kept for a certain amount of time so that it can be taken back to the workplace if a need is noticed. Tools that are used only seldom can be stored somewhere where they don't disrupt daily work but can be accessed then they are needed.

Seiton (straighten) – assign a place for each item that is kept in the workplace and mark the places properly. This can be done by labeling or any method that works for the specific item and workplace.

Seiso (shine) – cleaning the workplace both keeps the environment clean and acts an inspection that can show for example tool defects that can cause any number of problems.

Seiketsu (standardize) – create rules/system to maintain the first three S'.

Shitsuke (sustain) – sustaining the system needs self-discipline from workers and regular audits to make sure that the system is working.

In their paper Kattman et al. (2012, 418) listed elements of visualness in a workplace (Figure 12), among which are bordering and recoil. Both of these are simple ideas that should be used in 5S environment. Bordering makes it clear that an item is missing from its correct place. This can be done for example by silhouettes of tools on in the place where they are kept or for example differentiating raw material and finished goods areas by different colors. Recoil is a feature that allows items to find their way back to their correct location. In practice this could be for example color coding tools from different racks so that a lost tool can be returned to its correct location.

3.2.2 A3 Reports

According to Liker (2004, 244-249) one of the ways in which Toyota incorporates visual elements in everything it does are A3 reports. A3 reports are exactly what the name suggests: reports that fit into one A3 size sheet of paper. Liker explains that a Toyota style A3 report follows the PDCA structure so that it displays enough data about the background of the problem and explains the current situation deeply enough for the situation. It then makes a recommendation (plan), introduces the details of implementation (do) and information about the expected results as well as info about when and how the results will be checked.

In *Toyota Kata* Rother (2010, 221-224) explains the A3 format (Figure 13) form a slightly different angle. The purpose of A3 format is to force the reporter to carefully think of something and understand it deeply enough so that it can be distilled in one paper. Rother explains that A3 sheets are used as part of “improvement kata”, a kind of a mentoring method. A3 sheets according to *the kata* is also a dialogue tool between the mentor and the mentee, it makes dialogue of the problem focused, helps to analyze the problem thoroughly and acts also as a tool to check the progress.

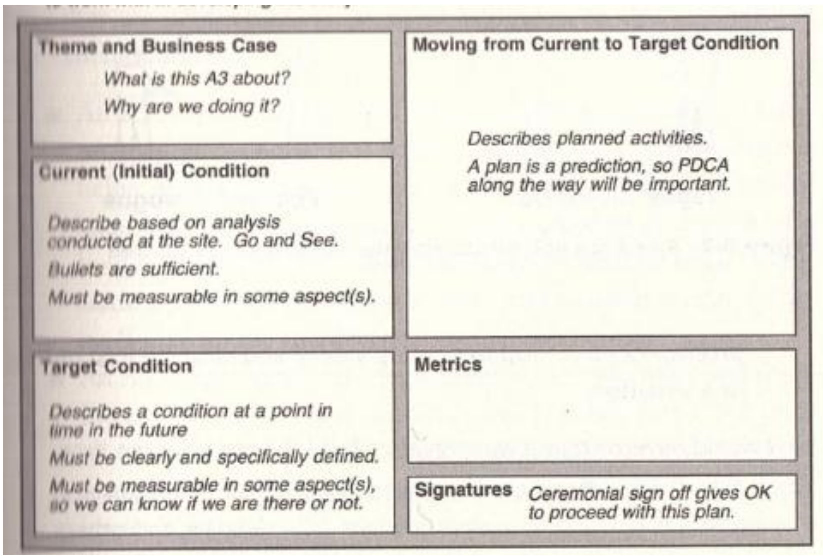


Figure 13. Example of A3 format (Rother, 2010, 221).

3.2.3 Skill matrices

Skill matrices can be used in on order to have more flexibility in the organization and to respond quickly to any changes in the production. A skill matrix is easy to read and helps when there is a need for example to cover some other work station due to absence. (Grief, 1991.)

3.2.4 Process indicators

Many western companies are keen on measuring results instead of the process. According to *Kaizen* by Masaaki Imai this is due to that most western companies put more focus on short term benefits but do not really care how to achieve them. Japanese companies focus on the process and believe that if the process is in good shape the results will also be good. This does not mean that results should not be measured or ignored but that there should be more focus put on the process. (Grief, 1991, 175-176.)

Grief (1991, 186-188) has listed several indicators that are in use in certain companies around the world but selecting which process indicator to be used depends on several things such as companies' manufacturing policies, production process and type of parts produced. Some of the indicators in the list are presented below:

Flows: average production lead time and variance, productivity, fulfillment of commitments (deadlines and quantities), volume of semi-finished items, throughput time.

Materials and inventories: Monitoring of unavailable items in the warehouse, quantity of material needed to produce on unit, inventory volume and turnover, warehouse management performance.

Technical resources: Availability of machinery, yield level, breakdown rates/production time without problems, time needed for changing production runs, maintenance costs, number and duration of technical assistance calls, average length of repair periods.

Quality: percentage of unacceptable items, rejection and retouching rates, results of quality audits, total cost of not meeting the standards

- Clients and suppliers
  - sales volume, delivery time, customer satisfaction indicators
- Employees
  - labor supply, number of suggestions, hours of training, level of skill diversity, absenteeism
- Work environment
  - housekeeping indicator, safety audits, work audits,
- Overhead
  - monitoring of teams costs, power, oil, small tools etc.
- Miscellaneous

Design of charts displayed in the work area should be simple and clear. Grief (1991, 192) suggests organizing information to two levels: one for quick glances for overall perception and another level of information on a document rack or on smaller print on the same document.

3.3 Stable and standardized processes

Stable and standardized processes are one of the elements which form the basis of the lean house depicted previously in Figure 8 (page 20). Unevenness was also mentioned as one of the Ms (Mura) of lean.

Standardization and standard operating procedures are the basis of continuous improvement. This means that it is management´s responsibility to establish policies, rules, directives and procedures for all major operations and then see to it that everyone follows the procedure. If someone is not following the standard procedure management must either provide training for the workers or change the procedures. (Imai, 1986, 6.)

Several writers (for example Imai ((1997, 176 & 130-140) mention that checklists are used for example by Nissan to guide leaders in their standard work and to direct kaizen events.

In *Toyota Way* Liker (2004, 140-148) also lists standardization as the basis of continuous improvement. Liker explains that if the process is moving a lot, any improvement will just be one variation of the process and any changes in the process will occasionally result in both good and bad results. Standardization should however not be taken too far. Too rigid instructions and limitations will only lead to trouble. Critical task in standardization process is to find a correct balance so that the standards are specific enough to be useful guides but yet provide enough freedom to let workers use their creativity.

3.3.1 Meetings

Mann (2010, 86-87) proposes a three-tier structure for standardized meetings. Meetings should be brief (no more than 15 minutes), be held standing up and at the workplace or in its immediate proximity. The agenda and content of the meeting should be guided by the visual controls.

At the first tier team leader meets with the team and goes briefly through the days agenda. Team leader updates the performance, and covers any issues that have happened the previous day and lets the team know if there are any things to note that day and team members check their daily agenda from the work scheduling board. There is also a second team board which might hold information for example about improvement projects which concern the process area. Some things on the board such as 5S results, work safety figures and improvement ideas from team members can each be handled for example once a week. (Mann, 2010, 89-90.)

The second-tier of daily meetings suggested by Mann (2010, 86-87) is the meeting between supervisors and team leaders. If support from any external people is needed (from for example engineering or procurement), they can be invited to this meeting. The purpose of this meeting is both running the process and improving it. Meeting is held at the departmental board where the status of key processes as well as performance data on safety, quality cost etc. and the production tracking data brought by the team leaders is kept. The meeting's agenda is quite similar to the first tier meeting. First the meeting goes through the noteworthy things that have happened yesterday and things that are expected to happen in near future. The focus is then moved to the production tracking charts and the reasons for misses. In the next tier meeting the supervisor needs to explain the main reasons for misses and if there are any improvement projects going on to fix these issues. (Mann, 2010, 90-91.)

The second topic in this second tier meeting is the visual task assignment board, in which the supervisor can assign tasks based on the production-tracking-charts or on any other identified need. The board is a matrix that shows all persons, their tasks and their deadline. In each meeting the tasks that are past their due are revised. According to Mann it is important that past due tasks are never for any reason moved in order to make them seem as they are in-time. The reason is that the purpose of the board is not to blame anyone but to identify if for example supervisor is assigning too many tasks or if the resources are overestimated or the capacity is too low. (Mann, 2010, 90-93.)

The third tier of meetings proposed by Mann (2010, 86) is between the value-stream manager (or some equivalent) and the supervisors. In this meeting again issues like daily staffing, yesterday's performance figures and other items worth noting are gone though. Next the reasons for the previous days misses are gone through and assessed by value stream manager. Value stream manager can then (based on the date) assign tasks for the supervisors. In this meeting representatives of support groups are regular attendees and can be assigned tasks as if they were responsible for value stream manager regardless of the organizational structure. (Mann, 2010, 96.)

3.3.2 Waste walks

The lean philosophy starts from the idea, that to fix any problem you must first understand the problem thoroughly. Once one have worked in a system for long enough it can become hard to see the wastes anymore. One way to try to see new wastes in the process are "waste walks". Lean Enterprise Institute (LEI) (Lean Enterprise Institute, 2009b) describes them as "*simply a planned visit to where work is being performed to observe what's happening* *and to note the waste*". Common waste walk objectives can be for example validating the problems pointed out in the current-state map (mapped in VSM) or providing opportunity for the staff to gather ideas about current state problems. Waste walk consists of walking the whole value steam, observing what is happening and taking notes.

3.4 Just-in-time practices

The idea of Just-In-Time (JIT) and methods of producing it is the first pillar of the lean house presented previously in Figure 8. JIT is a set of tools, principles and techniques that allow company to produce small batches (preferably 1 by 1) with short lead times meeting customers specific demands. It is a method to produce the right items at the right time in right quantity. When there are several processes the idea of customer is broadened to include both internal and external customers. (Liker, 2004, 23.)

3.4.1 One-piece flow

One-piece flow, one-by-one production or continuous flow: the three are all names for basically the same idea that parts should move from one value-adding process quickly or even directly to the next one. As so many lean elements, the idea has not been invented by Toyota but similar ideas have been used for centuries in Europe and elsewhere (Rother, 2010, 45-46.)

According to Liker (2004, 88) creating flow where it is applicable in the core processes is a good way to start a lean journey as it delivers the core messages of lean; shortening the delivery time from raw-materials to finished goods with required quality. Creating flow also forces other lean ideas to be implemented; such as Jidoka and preventive maintenance. Better flow in the process lowers the inventory levels and reveals problems that otherwise would be hidden by inventory. Other benefits of one-piece flow listed by Liker are flexibility to change the production line faster, higher productivity when items are no longer over-produced, freed up space when inventory levels are taken down and improved safety and increased morale when more value-adding work is done. (Liker, 2004, 88-97.)

In order to achieve efficient one piece flow in a factory it is vital to know how fast each manufacturing stage should be performed. A simple answer to this question is **takt time**. Takt time is the rate at which customer is buying the product in relation to the effective processing time available. Effective processing time means that it should take into account all planned breaks for maintenance, meetings etc.

The simple equation for calculating takt time is shown in Formula 1. (Rother 2010, 79-80 & Liker 2004, 94.)

$$Takt\ time = \frac{Effective\ processing\ per\ time\ per\ time\ unit\ [time]}{Customer\ demand\ per\ time\ unit\ [units]} \qquad [1]$$

Planned production cycle time is not to be mistaken to be the same as takt time. Planned cycle time is usually faster than the takt in order to compensate for example changeovers. Takt time is an ideal rate in which a factory sells one piece and produces any piece at the same exact rate. Literature (i.e. Liker, 2004, 94-95) acknowledges that takt time concept works best in high volume repetitive environments. When explaining the intention behind takt time Rother (2010) also explains that if takt time is something that the factory strives to achieve in average the fluctuation in the actual process may be huge.

3.4.2 Pull

Pull production control allows jobs to be processed only if there is a need for it. In push system work order is released according to predefined target level or schedule, whereas in pull system work orders are released based on the system status. It is characteristic to a pull system that information and material flows go to the opposite directions (Figure 14). The goal of pull system is to find a balance between desired throughput and the lowest WIP level. (Gonzáles-R & P. L., Framinan, J. M. & 2012, 5.)

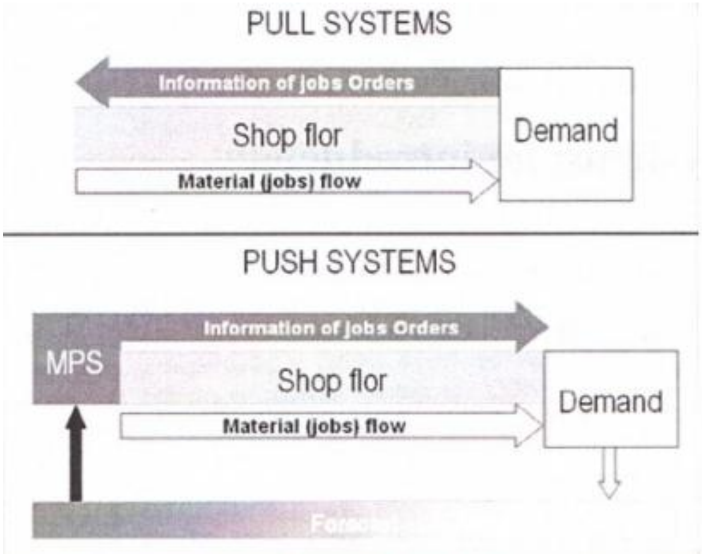


Figure 14. Pull vs. push manufacturing (Gonzáles-R et al., 2012, 6).

The principle of pull was borrowed by Toyota from American supermarkets, where items were replenished to the shelves only when they were needed. Toyota developed a kanban method by which it could signal to the previous step when parts were needed. (Liker, 2004, 23.)

There are numerous variations to kanban (Gonzáles-R et al., 2012) but the basics of it are always similar. When there is a production instruction from customer or from customer process material is pulled either straight from the previous process or from a supermarket built between the processes. The previous process is only allowed to produce when it has received a production kanban either from the next process or there is room in the supermarket. A simple example of a pull production system using kanban cards is shown in Figure 15. (Rother, 2010, 94.)

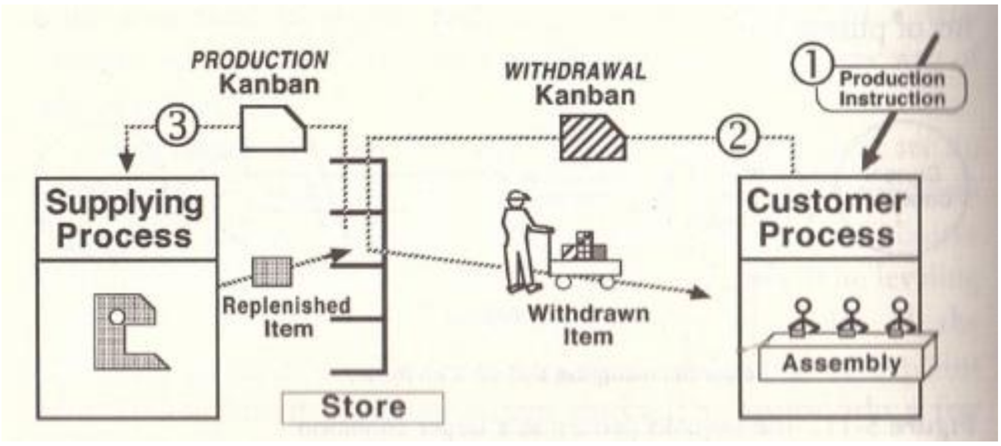


Figure 15. Basics of pull production system using kanban cards (Rother, 2010, 94).

Kanban systems are proven to be able to dramatically decrease throughput times and WIP inventory as demonstrated by for example Lee-Mortimer (2008).

3.5 Quality and Jidoka

Forming the second pillar of the TPS house along with JIT practices are the principles of Jidoka and quality. Jidoka is a Japanese term that can be translated to autonomation. Historically the concept was developed in an era when Toyota produced looms and Sakichi Toyoda built a feature that stops the loom when thread breaks which enabled the user to prevent defected fabric being sent to the customer/next process and what is more important solve the problems that resulted in the thread breaking thus solving the problem. (Liker, 2004, 128.)

In a modern (car) manufacturing line Jidoka can mean that each time a problem is noticed at any station the worker has a device (called Andon) by which he/she can stop a certain segment of the line and at the same time call team leader to check the situation. According to Liker the team leader at a car factory can have roughly 15-30 seconds to either fix the problems then and there or decide that the problem can be fixed while the car is moving. Liker also notes that team leaders have been trained in standard procedures on how to handle line stoppages. (Liker, 2004, 128-132.)

Stopping the line with low inventories forces the processes to produce the correct quality at the first time. Low inventories also reveal any problems sooner than working with bigger inventories. Working with bigger inventories would enable workers to hide the problems because every station would be able to continuously keep working even if there are faulty pieces in circulation. (Liker, 2004, 130.)

One of the tools, by which Toyota battles against quality problems, are **Poka-Yoke** devices. Poka-Yoke is simply something that makes it almost impossible to perform a job incorrectly. (Liker, 2004, 133) Examples of Poka-Yoke devices could be for example power plugs of electronic devices which can only be plugged in the correct way.

Another useful tool is **andon** devices. Andon is a device by which workers can stop the line in case of a problem and inform the team leader about the problem (Liker, 2004, 130). The device itself is trivial; it can include for example visuals like call lights and sounds.

3.6 Continuous improvement

As mentioned in a previous chapter continuous improvement is based on establishing standards and then improving them.

Problem solving in lean philosophy is based on understanding the situation deeply and firsthand. The idea is that it is impossible to solve any problems in the manufacturing line just by looking at the figures in the office. The lean problem solving method descriptions vary a little but at their core is the same idea: to make the correct countermeasures it is essential to identify the root causes for the problem.

In *Toyota Kata* Rother (2010, 75) describes continuous improvement as a journey towards a vision. According to Rother the journey starts with an idea or vision of the future. Vision does not necessarily have to be achievable. It is an ideal situation that can be vague and very far away. It serves as a direction towards with improvement actions should take the company. At Toyota the vision is called “True North” and it consists of zero defects, 100 % value added work, one piece flow and security for the people. The road to the vision is by definition not clear: if the road to vision would be clear, any company and their competitors could already have just implemented it. In reality the road is long and clouded. Company moves towards a vision by accomplishing target conditions on the way and solving unforeseen problems. The obstacles that rise cannot be defined in advance because they rise from observing the process and comparing it to the target condition. A road towards a vision through two target conditions is depicted in Figure 16. In reality the journey probably never ends if the vision is ambitious enough. (Rother, 2010, 44-48.)

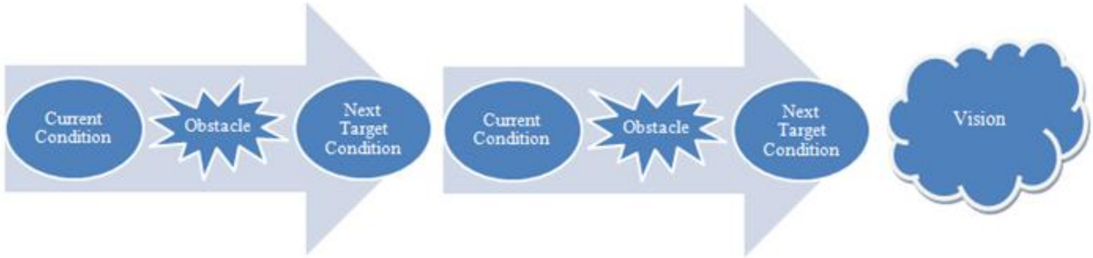


Figure 16. “Toyota Kata” (Adapted from Rother, 2010, 75).

3.6.1 Plan-Do-Check-Act

PDCA (Plan-Do-Check-Act) method was developed by Walter Stewhart at Bell Laboratories in the 1920's. Mr. Stewhart taught it to Dr. W. Edwards Deming, who then introduced it to Toyota in 1950's. The purpose of the circle is to systematically and in a planned manner improve the process. PDCA -method recognizes that processes are dynamic and uncertain and there are no absolutely right answers, there are only best estimates that we currently have. PDCA guides people to identify, define and solve problems as soon as they arise. (Liker & Franz, 2011, 23-30.)

A PDCA -circle (Figure 17) starts with planning. In **Plan** -stage a gap to the target is identified. And its root cause analyzed using any working method. Then a countermeasure is planned so that it targets this specific cause. In **Do** -stage a implementation plan of the countermeasure is developed and communicated to all parties necessary. Countermeasure can then be executed. In **Check** -stage the progress of the implementation plan is monitored and the plan is modified if it is seen necessary. In **Act (Adjust)** -stage the results are evaluated and if the countermeasure has proven to be effective it is standardized and spread forward to other departments that might have the same problem. Any further development possibilities are identified and PDCA -circle started again. (Liker & Franz, 2011, 27.)

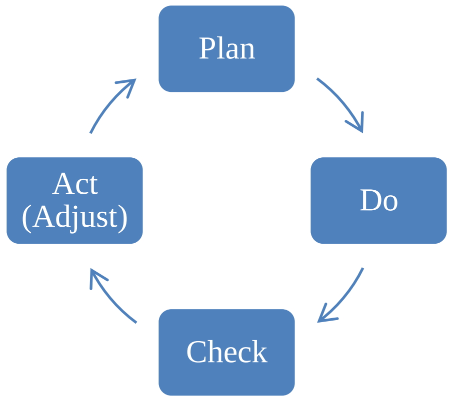


Figure 17. Simple PDCA -circle. (Adapted from Liker & Franz, 2011, 27).

As mentioned, PDCA comes from the words Plan-Do-Check-Act. Sometimes the word "act" is placed with "adjust" to better represent the continuous change in unpredictable environment as well as the continuous circles of improvement. (Liker & Franz, 2011, 28.)

3.6.2 Root-cause analysis (*5-Why?*)

A simple but effective root cause analysis tool used in lean is a method called "*5-Why*". It is quite simply a method in which one identifies a problem and asks "why?" five times going deeper and closer to the true root cause of the problem with each question. (Liker, 2004, 252-253.)

As effective as "*5-Why*" is, it can be difficult to use at first. Liker (2004, 255) explains that Toyota uses it as an important part of its practical problem solving process. A classic example of the "*5-Why*" from Peter R. Scholtes´s *The Leader´s Handbook* is shown in Table 1. (Liker, 2004, 252-254.)

Table 1. “5-Why” problem solving (adapted from Like,r 2004, 253).

Level of problem	Corresponding level of countermeasure
There is oil on the floor	Clean up the oil
Because the machine is leaking oil	Fix the machine
Because the gasket has deteriorated	Replace the gasket
Because we bought gaskets of inferior material	Change material specifications
Because we got a good price on these gaskets	Change purchasing policies
Because the purchasing agent gets evaluated by short-term cost savings	Change the evaluation policy for purchasing agents

Liker (2004, 255-256) also describes the problem solving at Toyota with a funnel that starts with a problem (Figure 18). Problem can be vague and complicated and not distinct. To identify what is the most serious problem Toyota uses pareto diagrams, which sort problems by their frequency and severity or nature. According to Liker pareto diagrams are the most used statistical tool at Toyota.

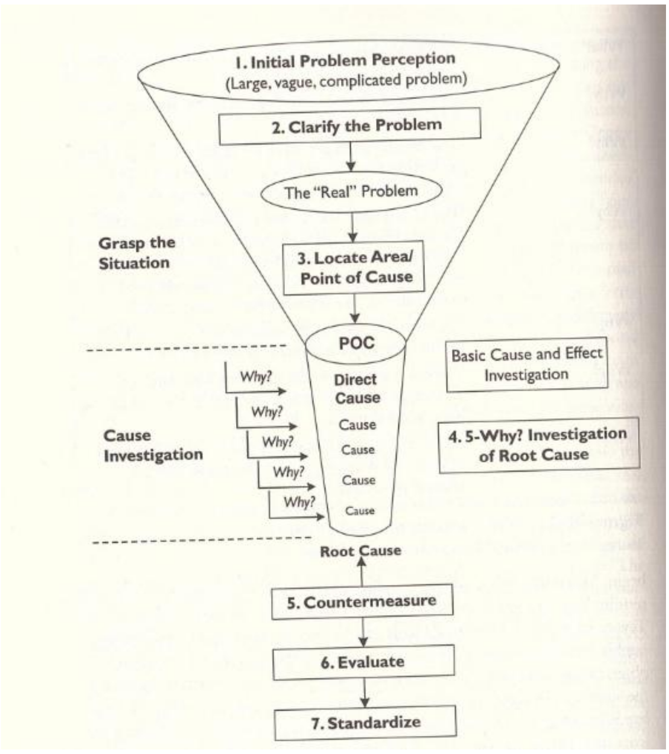


Figure 18. Problem solving funnel (Liker, 2004, 256).

The problem solving starts by grasping the real situation. According to Toyotas principles this starts by observing the real situation with an open mind and comparing what is happening to the standards or what should be happening. When a problem to be solved is identified it is time to try to find its point of cause (POC) and to find the root cause of the problem. A simple but effective tool to finding the root causes is "5-why?". (Liker, 2004, 255.)

The goal of the process is to generate a countermeasure to eliminate the root cause and to evaluate its success. If countermeasure is found to be effective it is added to the standard procedure and spread to other departments if applicable. Liker reminds that problem solving is 80 % of thinking and 20 % of tools, which some companies seem to forget. (Liker, 2004, 255.)

3.7 Leveling production (heijunka)

The last element in the lean house (Figure 8) is leveled production (japanese heijunka). It is a method of leveling production in plants that produce larger quantities of any product mix and not really applicable in this working environment nor inside the scope of the thesis.

3.8 Lean and environmental sustainability

Environmental technologies and management practices can be divided into two categories. The first are different pollution prevention techniques which can involve for example changes in the basic product or in the processes in a way that they reduce emissions. The second category is “end-of-pipe” solutions, which treat the dispose of harmful substances. The latter is often used for example to meet any current or future regulations or because of community pressure. Because of its nature the end-of-pipe solutions can be associated with worse process performance and do not in themselves add value to the company/product. The first category can decrease for example the amount of raw-material that is used and can thus lead into both better environmental performance and add value to the company (Rothenberg & Pil & Maxwell, 2001, 230.)

Some of the lean and green principles can have trade-offs. For example painting cars in batches of same color does reduce the amount of emissions but conflicts with lean principles (JIT and heijunka). When using lean principle of “getting it right the first time”, companies may rely on using spray paints which get better result but also produce more emissions. Conclusion is, that not all lean practices produce environmentally friendlier production and just using lean is not enough to address all environmental issues. (Dües & Tan & Lim, 2013, 94-95.)

Rothenberg et al. conclude in their study that the relationship between lean practices and environmental performance is complex. They did however find some correlation that supports their hypothesis that different lean aspects have positive effect to lean companies environmental efficiency. They for example found that workers in lean companies are more trained and willing to track environmental metrics and provide creative solutions to increase environmental efficiency. (Rothenberg et al., 2001, 240-241.)

Rothenberg et al. also found data to support their other hypothesis that lean principles can preclude solutions that seemingly increase costs namely the end-of-pipe type solutions. This is because some lean companies see it as conflicting with lean philosophy. (Rothenberg et al., 2001, 240.)

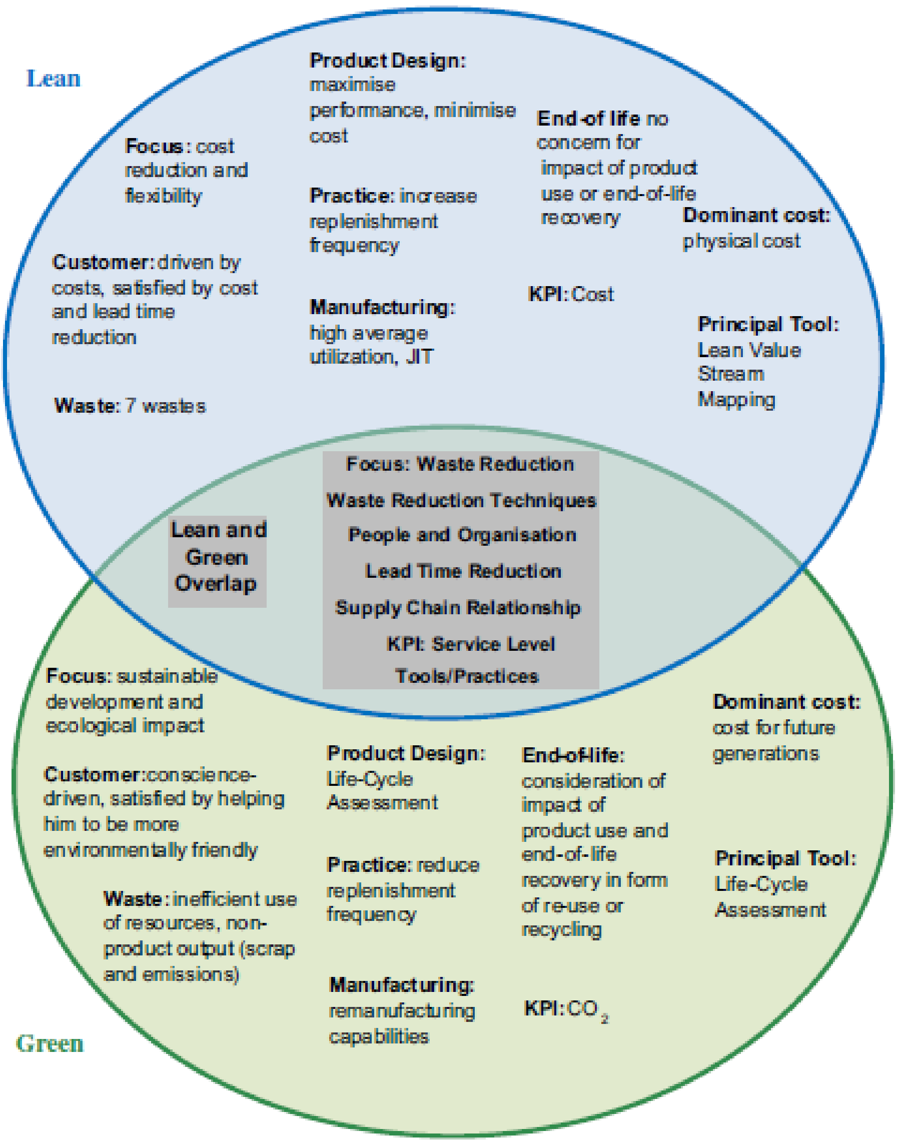


Figure 19. The overlapping of Lean and Green paradigms (Dües et al., 2013, 97).

In their recent study comparing existing lean and green literature Dües et al. (2013) have compiled features of both and created diagram (Figure 19) which shows how green and lean paradigms overlap. Even though the observation angle is slightly different, the main similarity between the two is reducing waste. Lean targets the “traditional“ seven wastes whereas green targets environmental wastes in form of inefficient use of resources or production of scrap. Both green and lean paradigms rely on having strong employee involvement and commitment. (Dües et al., 2013, 95.)

Dües et al. argue that green wastes can be incorporated into lean metrics and be simultaneously reduced. (Dües et al., 2013, 98.)

Lean and green paradigms target slightly different customer benefits. Lean paradigms target customer is driven and satisfied by achieving cost and lead time reduction. Green customers on the other hand are satisfied when products are produced in an environmentally friendly way and help them become more environmentally friendly. Cost focused customer will not criticize if products are manufactured with environmentally sound principles and green customers will not mind paying less for their products. (Dües et al., 2013, 98.)

From the viewpoint of product design lean focuses on both performance maximization and cost minimization. Green focuses more on life cycle assessment (LCA). According to Dües et al. (2013, 98) adopting LCA enable building of products with less manufacturing steps and by-products, requires less packing and storage space in transportation and delivers less scrap.

One of the main points of conflict between lean and green seems to be replenishment point of raw materials. Since lean works according to JIT principles it requires replenishments often. This however produces lots of CO_2 emissions which contradict with green thinking. In order to find a balance with these two companies can for example look into finding more local suppliers so stock can be replenished more often with minimal environmental impact. (Dües et al., 2013, 98.)

Even though environmental wastes are not part of the classic wastes, it does not mean that they are unrelated to them. In their *Lean and Environment Tookit* the U.S. Environmental Protection Agency (EPA) explains how several environmental gains raise straight from the seven classic wastes. For example:

Overproduction requires more material and energy that is needed. The items that have been produced too early or are unnecessary may spoil or become obsolete and require scrapping. **Inventory** takes up space, which needs heat and light. **Transporting and moving** needs energy and causes emissions. Transporting is always risky to the items being moved and to everyone working around moving machines. **Defects** consume extra raw material when new items need to be manufactured. Defected items need to be disposed of or recycled. More energy is needed for rework and repair, increased use of for example energy, air and heating. **Waiting** can potentially damage the goods causing waste and wastes energy, space etc. during the downtime. (United States Environmental Protection Agency, 2007, 13-14.)

The inbuilt green effects of lean efforts have been identified by King and Lenox (2001) when they concluded that lean activities reduce waste generation and waste emissions. Carvalho and Cruz-Machado (2009) went a step further and found that lean and green have synergic benefits. Bergmiller and McCright (2009) also found a strong correlation between green operations and lean results. Bergmiller et al. (2009) found that lean companies that have green practices achieve better lean results than those companies which do not. (Dües et al. 2013, 93.)

United States Environmental Protection Agency (2007, 15-16) suggest including environmental metrics to the key performance metrics being recorded such as scrap/non-product output, materials use, hazardous material use, energy/water use, air emissions, solid waste, hazardous waste and water pollution.

As in all lean efforts, environmental goals also need targets, accountability and management support. Personnel and management should be trained to consider environmental wastes as just as bad as any other lean waste in trainings and other materials. Environmental waste should be added to waste/Gemba walk checklists to develop eyes for it. As part of 5S the workplace it should be clear where each type of waste is by using color/images or any other visual guiding method. If possible, fool-proofing is always a good solution. Lean environmental targets should be displayed along with other lean metrics to show how each department is doing relative to the targets. (United States Environmental Protection Agency, 2007, 16-17.)

3.9 Environmental waste in the value stream

In their toolkit United States Environmental Protection Agency suggest adding environmental issues in the value stream maps that are usually created in lean conversions (Figure 20). United States Environmental Protection Agency uses a text “EHS” to show that there is risk or potential identified in this process. The amount of raw material is also weighted and especially the amount of wasted material is recorded. In EPAs diagram the materials line is analogous to the normally used time line. In addition to (or in place of) raw material usage there could be an analysis of for example water or energy usage or air/water emissions per process. (United States Environmental Protection Agency, 2007, 25-39.)

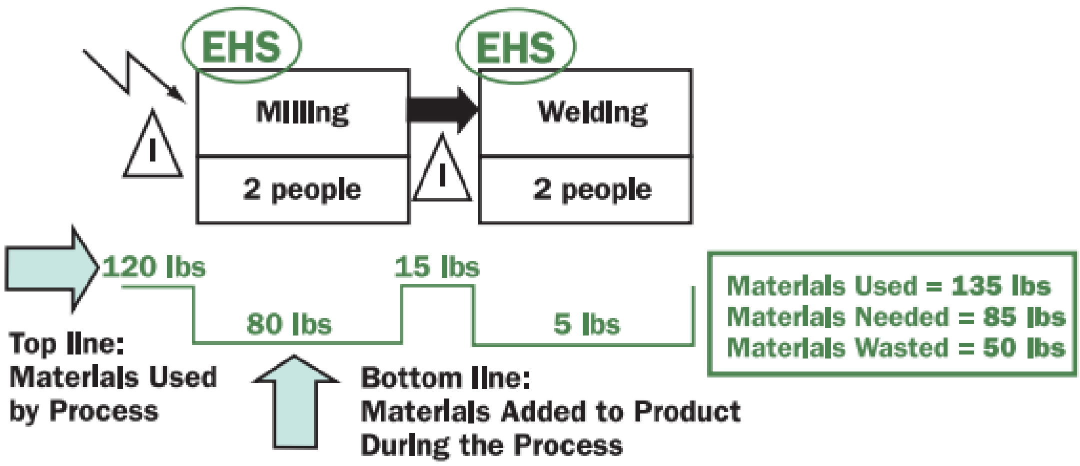


Figure 20. Environmental data added to VSM graph (United States Environmental Protection Agency, 2007, 26).

In places where environmental waste has not been recorded before, getting good metrics may require some extra work and/or investments for example if there is a need to weight solid wastes. (United States Environmental Protection Agency, 2007, 24.)

4 CURRENT STATE OBSERVATIONS AND BENCHMARKING

As explained in the first chapter, the purpose of this thesis was to give Outotec an outsider´s perspective on what kind of lean tools and methods they could use. So, even though several visits to factory floor were made, for the purposes of this thesis the processes were not thoroughly studied. However, it would have been impossible to create any tools without some superficial observation of the processes, goods flows and habits of workers on the work shop floor. The results of the superficial and shallow observations are presented below.

4.1 Current state of visual management

Most lean adaptation projects start with implementing 5S, which can be seen as part of visual management. Outotec too has started their lean journey with implementing 5S, and the implementation is still going on. Changes are made on it on almost daily basis, so it is impossible to give accurate description of what has been done, is currently being done or will be done in the future. 5S as such was also outside of the scope of this thesis.

At the same time with 5S, Outotec has started to implement visual management and process measurement tools, which can be seen as part of the scope of this thesis. A good example of simple visual guiding is pictures of the desired state at each 5S area. Each 5S area is audited regularly using a standardized sheet and the 5S audit sheet is placed in view near the audited area. The audit sheet also has action points, the name of the responsible person and the deadline. In addition to the audit sheet each area is given a score based on its performance. The score is also shown near the area in question. The idea of the score is to make different areas comparable to each other.

Visual process controls are also being experimented for example in the receiving area, where the number of pallets on the area, that are not yet booked in is counted at the end of each shift. The idea of this is good, but the result has been “0 pallets” almost every time. This seems to indicate that problems are being hidden, each shift “fights” the area clean or the interval of measurements should be tightened. The result seems to be seen as being more important than how it was achieved. The lean management mindset seems not yet to be achieved at least in this process measurement tool.

4.1.1 Visual management of the processes

At the moment it would seem that the management of processes in the manufacturing is being done mostly hidden in the computer files. No visual management (of processes) was found in the workshop floor. Parts do have an identification tag, but there seems to be no way to know of knowing if process is going as planned or if it is running behind schedule.

At the moment the schedule of each assembly is shown near the assembly site. The schedule is printed out from Excel (Figure 21) and has the target hours and schedule which is planned before assembly is started.

60 series					Week13						week 14							week 15				
	Target	Done	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13
	Hours	Hours	mon	tue	wed	thu	fri	sat	sun	mon	tue	wed	thu	fri	sat	sun	mon	tue	wed	thu	fri	sat
	320	0																				
	5	0																				
	90	0																				
	24	0																				
	3	0																				
	23	0																				
	17	0																				
	22	0																				
	24	0																				
	24	0																				
Sub-assemblys	112	0																				
	15	0																				
	24	0																				
	0	0																				
	40	0																				
	8	0																				
	80	0																				
	10	0																				
	0	0																				
	0	0																				
	4	0																				
	0	0																				
	350	0																				
	40	0																				
Total	1 235	0																				

Figure 21. Assembly schedule

The assembly schedule is quite visible and it does have indication of “Target Hours” and “Done Hours” but to an outsider it does not give a good overview of what is actually the current schedule situation. There is no indication of if subassemblies are on time or not, or even if they are started or not. Updating of the sheet seems to lag and is at the responsibility of the managers who do not necessarily update the sheets even once in two weeks.

Both manufacturing and assembly department visual management styles seem to fail in most if not all questions of visual workplace (Kattman et al., 2012, 427):

- Identification tag on each item does identify the individual product being worked on but it should be made more visual. On the assembly department the schedule does show what should be happening each day, but it does not show if it actually is.
- There seems to be no visual presentation of the schedules in the manufacturing department and no way of knowing if each product is on schedule or not. On the assembly department the schedule is visible, but there is no way of knowing if the assembly is actually on that schedule.
- There are red labels placed on faulty items, but there seems to be no process on tracking and fixing the root causes that cause faulty items.
- There seems to be no way of knowing if customer is satisfied.

4.2 Current state of standard work

In the interviews with the managers and discussions with both managers and workers it has become quite clear that most work stages are not standardized or at least not documented as such. At the same time with this thesis and 5S implementation project Outotec has started describing the work stages and started to prepare work instructions.

According to the interviews work for the leaders seems not to be standardized at all. Leaders do have tasks they have to perform on regular basis but the tasks are not documented and there seems to be no instructions or documentation.

4.3 Current state of continuous improvement

The current process for continuous improvement seems slow and difficult. In the lean training session many workers raised a question of how engineering is going to be involved in the lean processes. According to the workers’ comments, there have been many cases where drawings have been wrong, old versions or have other mistakes that should have been fixed by engineering department but changes have been slow or non-existing.

Currently the formal way of making a change suggestion is to fill in a sheet in company’s intranet. The suggestion is then picked up by a suggestions group which handles them. The process seems invisible to the reporter and slow, especially on the shop floor where workers do not necessarily work at the computer every day. Since engineering is physically located near manufacturing, workers have often reported mistakes in the drawings to engineering but the general feeling is that little improvement has happened.

Successfully adapting lean manufacturing philosophy requires a quite complete change of mind in the way that things are done and managed. The focus needs to be put in the process and problem solving needs to be taken from “firefighting” -mode to a more controlled process, where if and when problems are noticed, the root cause is found out and eliminated. Currently problems seem to be thought of as being “part of the normal process”. If a faulty item is found somewhere in the processes, the item seems to just be fixed then and there without trying to locate the root cause of the problem. For example sheet metal parts arriving from suppliers were fixed to fit the tolerances the first thing they arrived to the factory, when more efficient would be to get proper parts from the supplier in the first place. Also for example straightening metal parts after welding due to heat seems to be considered normal work and only little was done to prevent the heat input in the welding process itself, which would eliminate the need for straightening the parts.

4.4 Benchmarking: Production control at Rolls Royce

A visual control board (Figure 22) for production designed in Rolls Royce Civil Aerospace takes the anticipated production from ERP and makes it visual at the shop floor. Each tag represents product. The tag has the product code and the anticipated finish date. Each day as production advances the item tag is moved on hooks representing each production step. On the top of the board is a date slider, which advances each day. If there is a misalignment with the date on the tag and the date running above it is clear to see that production is either in late or too soon. The board was designed by the process operators and has numerous benefits such as process transparency, FIFO of products to individual operators, transparency of bottlenecks and possible arising problems, a mechanism upon which to base process reviews and focus on continuous improvement efforts. (Parry & Turner, 2006, 80-81.)

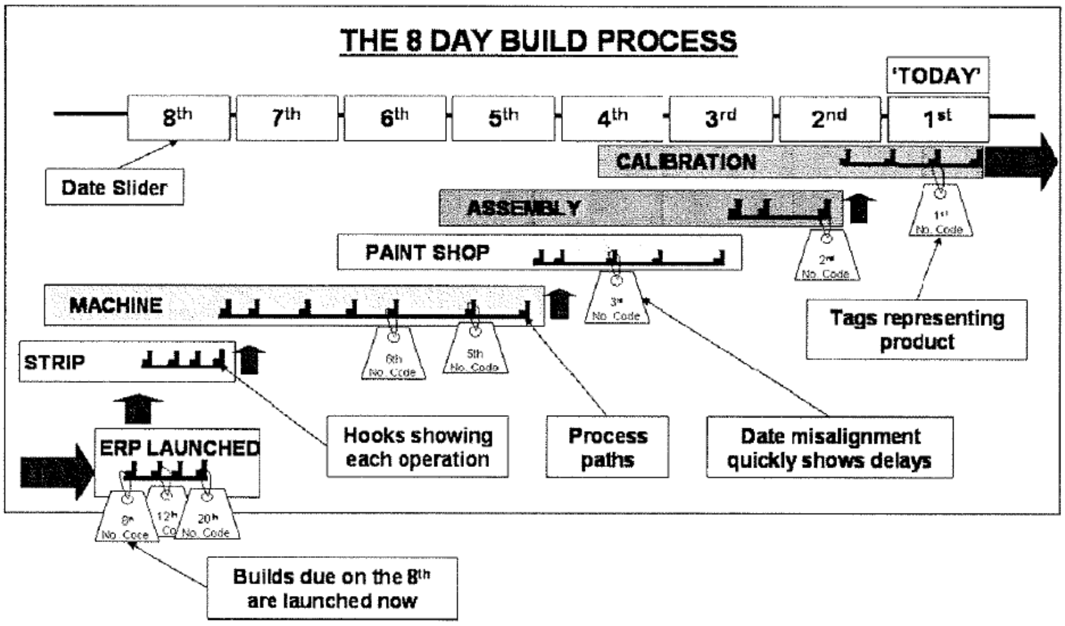


Figure 22. Visual Control Board at Rolls Royce (Parry & Turner, 2006, 80).

4.5 Benchmarking: Process control board at Airbus

To control their complex knowledge-based process at their Long Range Aircraft Maintenance Manuals division airbus has developed the simple process control board schematics of which shown in Figure 23. New jobs enter the board from left. Each card represents a separate department. Each worker is identified by a marker they leave on the card representing that they are working on this issue. Issues rising from the tasks that need external support are written on the issue sheet and owners are assigned for them. Also on the board is a small number of KPIs that the team directly can influence. The board gives visibility of progress of each task and identifies the resources that are working on each task. The board area is the center of daily activities and meetings are held around it. (Parry & Turner, 2006, 81-82.)

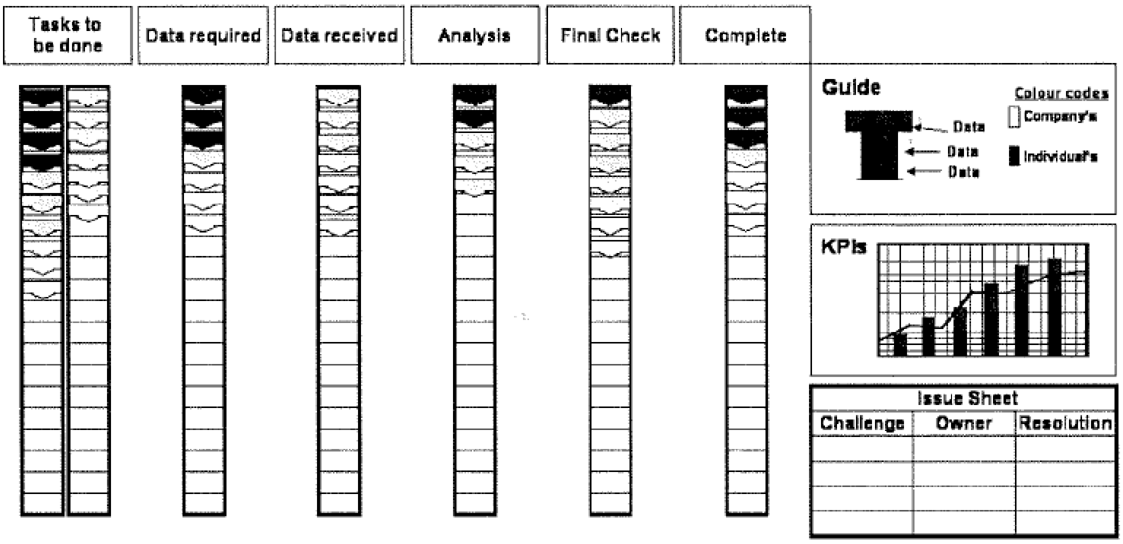


Figure 23. Schematic process control board. (Parry & Turner, 2006, 82).

A similar idea was used to control the continuous activities at one of the benchmarked companies. In their board, each resource had their own row and each column represented the stages of Plan-Do-Check-Act. Each resource worked on their issues and the results were reviewed in a meeting held each week or once every two weeks. The board was kept in a "war-room" where they were visible to everyone. Accountability for each project was clear and the status of each project was reviewed regularly.

4.6 Benchmarking: Defects at NUMMI

Defects are one of the most serious wastes in lean philosophy. In Figure 24 is shown a defect information board located in NUMMI plant (Grief, 1991, 164). In one of the benchmarked companies a similar board displaying the most frequent defects, how they are caused and how they can be avoided was displayed on each workstation.

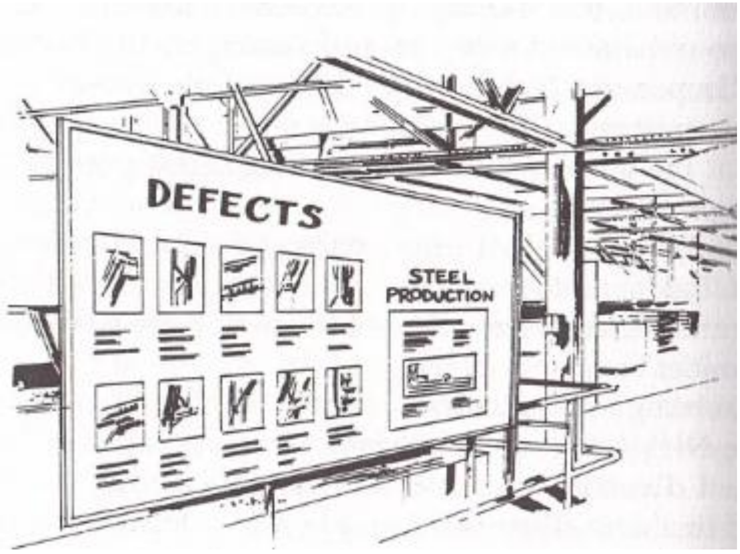


Figure 24. A defects communication board. (Grief, 1991, 164).

According to the quality manager in benchmarked company just displaying the most common defects had an effect on their frequency. The information about common defects helps most in situations where there are new people working in that specific workstation.

4.7 Benchmarking: Continuous improvement

In one of the benchmarked companies continuous improvement was done by monitoring their machining shops unscheduled downtime. Monitoring was done automatically and each time a stoppage of certain length was observed it was documented. The root causes of stoppages were collected, analyzed and root caused made into pareto -sheets. Paretos from different machines were combined in order to find the most prominent root causes.

Benchmarked company had a regular meeting where paretos were analyzed and root causes to be worked on were chosen. Each root cause that the groups decided to work on was then assigned to some individual. A countermeasure was developed and tested through PDCA method. The progress of each kaizen effort was monitored on a simple pigeon hole wall where each responsible department had their own boxes for all the stages of PDCA.

5 RESULTS

The lean adaptation project is still going on, and as stated before, changes are made on it on almost daily basis. Lean ideology by its nature is always changing and evolving. Therefore, it is impossible to have a perfectly up to date list of things that have been done, are currently done or will be done in the future. The objective of this thesis was "*to create and propose methods and tools for daily management in production, visual management and continuous improvement based on lean philosophy presented in such a general way, that they could be adapted in any Outotec manufacturing facility around the world*". During the writing of the thesis, the scope was narrowed to focus mostly on the visual guiding of the assembly process and manufacturing process, but tools were also developed for continuous improvement, daily task accountability process and standard work for the leaders. As results of this thesis:

- Two different *Daily Work Management* -boards were designed. First one is for parallel processes and suited more for the assembly department. The second board is for processes, which need to happen in a certain sequence and it is suited better for the manufacturing department.
- Method for doing continuous improvement in a controlled and planned manner was outlined.
- Simple tool for accountability was proposed.
- Simple proposition for managing leaders' standard work was created.

The tools presented in this chapter are generalized. Any processing times or other details they might include are only rough estimates. The tools presented in this thesis should be thought of as "sketches" or "frames" which need to be developed further. In other words they cannot be implemented without heavy modifying to fit them to the actual situations. It would be against lean principles to blindly implement anything that has been developed outside of the factory floor. For this reason, the tools were not polished further, but development was handed over to the people in Gemba, where the final tools should be created, tried out, modified, implemented and changed again to fit any new need that is noticed.

5.1 Standardization of work

Standardization is one of the bedrocks upon which a lean manufacturing system is built. Work descriptions for manufacturing and assembly are currently being described and instructions on different work stages are being prepared separate from this thesis. When the descriptions and instructions are ready, they should be taken into the factory floor and access to them should be made as easy as possible. All critical instructions such as tolerances, quality demands and examples of the most common mistakes should be displayed close to the workstation visually so that the possibilities of making mistakes due to lack of information is minimal. The validity of work instructions should be checked regularly and they should be compared to how workers actually are doing their tasks. If there is a discrepancy between the instructions and what is actually happening, one of the following should happen:

1) Instructions should be updated to match the best know practice and the best know practice spread to other departments doing same or similar work.
2) Workers should be guided to work according to the instructions and the reasons behind the current instructions should be explained to the workers and if possible updated to the instructions.

5.1.1 Leaders’ standard work

In the interviews with the managers it became clear, that there is no clearly defined standard work for team leaders and other foremen. At least if there are standard procedure descriptions, they do not provide much structure for foremen´s daily work. To provide the first step in standardizing foremen´s work a simple to-do/check list should work. One example of what a standard *Leader´ Folder* might look like is shown in Figure 25.

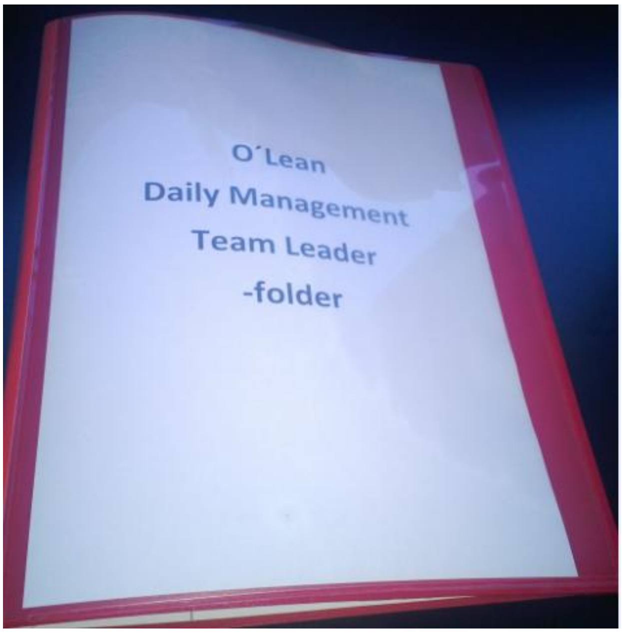


Figure 25. Leader´s folder (an example).

Leader´s Folder could include all the necessary documents that leaders need when they are on the shop floor. This would remove the necessity of remembering each individual task especially from new leaders. Also because older leaders are so set in their old habits, the *Leader´s Folder* could act as a reminder to update all the new lean metrics and other new responsibilities due to lean adaptation. The items that could be included in the *Leader´s Folder* in the first implementation round are for example:

- A To-Do –list
- *Morning Meeting Minutes* -blanket
- *Process Discrepancy -reports*
- Any other documents that leaders might need such as material order sheets, near miss -reports and so forth.

The most important item in the folder is a simple To-Do -list. The list is not supposed to make up for the whole day, but have the essential things needed to support production in a lean environment. The tasks included in the list may be anything from “Update metrics” to doing a “Gemba Walk” together with a superior or other worker. Leaders should take an active role in developing their standard tasks and add or remove things from it if it is seen necessary. Checklists are simple low-cost and low-tech method, which are in use in many lean companies, for example Nissan (Imai, 1997.)

Any item on the list should be a reminder to keep a continuous improvement mindset and eyes on the process. Using such a list is bound to be difficult in the beginning, but with correct attitude and continuous improvement mindset, creating a working to-do -list should be possible. An example of an early version of daily tasks is shown in Figure 26.

DATE:

TASK	DEADLINE	FINNISHED
Morning meeting with team		
Update metric 1		
Gemba Walk		
Quick check of own 5S area		
Update metric 1		
Check the production progress		
Check missing materials		
Return of daily tasks sheet		

Figure 26. Team Leader´s To-Do -list (example).

The To-Do -list in Figure 26 shows some ideas that which could be included in the daily task list:

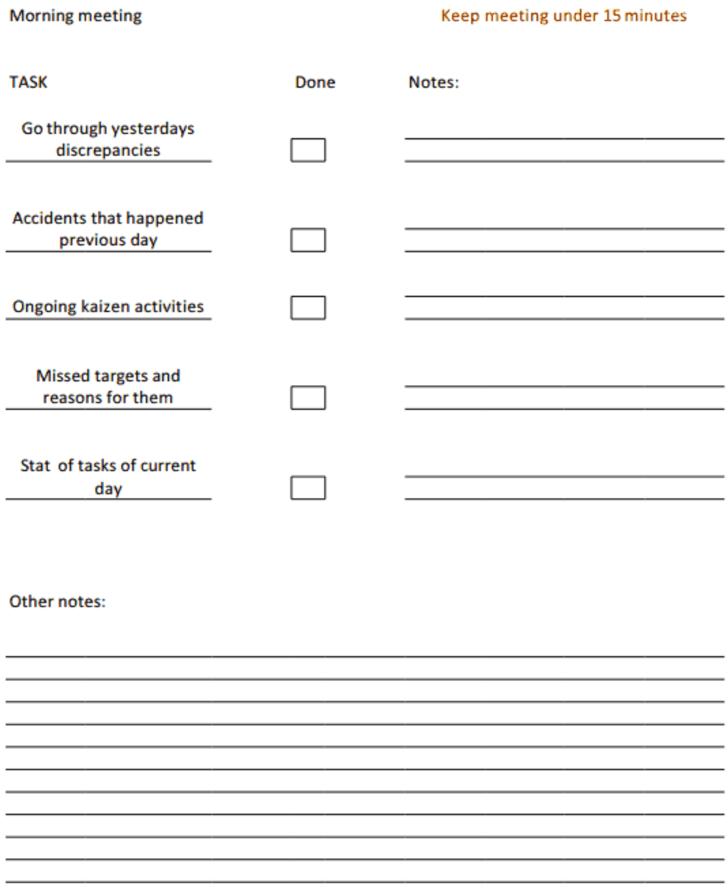
- Morning meeting practice should be started in order to realize the other tools presented in this thesis. Morning meetings will be explained on a more detailed level in the next chapter.
- Updating metrics should be added as standard tasks. The more often process is measured, the more accurate the information is. The manufacturing schedule tool presented in this thesis also requires hourly maintenance to keep it accurate.
- 5S audits should not only be held once a week, but a quick but organized glance each day can give a lot of information and ideas for improvement

- Gemba/waste walks should be made a regular habit for leaders. If possible walks should be done with a mentor to get more discussion and ideas flowing.

Because this thesis studied the processes only from the surface it would be impossible, and against lean principles, to give any final task lists. Leaders have to create the list themselves together with the managers.

5.1.2 Daily meetings

Of the three meeting tiers proposed by (Mann, 2010, 86-87) it would be best to start with morning meeting between the team leader and the team. A morning meeting should be kept short, maximum of around fifteen minutes. An example of what the minutes of the meeting might look like is presented in Figure 27.


Morning meeting
Keep meeting under 15 minutes

TASK	Done	Notes:
Go through yesterdays discrepancies	☐	
Accidents that happened previous day	☐	
Ongoing kaizen activities	☐	
Missed targets and reasons for them	☐	
Stat of tasks of current day	☐	

Other notes:

Figure 27. Morning Meeting Minutes -blanket (an example).

In this version of the meeting there are only a few things to be gone through:

1) **Discrepancies in the process that were reported in the previous day.** The discrepancies that occur during the work day should be shortly reviewed with the manager as soon as they appear. The best situation would be that worker could call foreman with an Andon device to let the manager see firsthand what is happening. This way the foreman has the most accurate information and discrepancy report card can be written immediately and the process to find the root cause started.
2) **Accidents/near-misses that happened the previous day.** Any near-misses that happened the previous day should be brought to the attention as soon as possible and countermeasures to prevent them initiated immediately.
3) **Review and update the teams *Daily Work Management –board*** as described later. Start of the current days' work. Assigning tasks for the team members using the Daily Work Management –board or some other similar tool.
4) **The statuses of any ongoing Kaizen projects**. If there are any projects, Kaizen or another, on the teams *Accountability- board*. The status of them should be reviewed in the morning meetings.

Any additional things can be added or things removed from the morning meeting agenda if it is noticed that there is a need/is no need for them. Things that need to be discussed, but not necessarily every day (such as environment, predicted workload for the coming month, holidays etc.) can be discussed for example once a week.

Leader´s Folder as well as everything inside the folder is just a frame for the tool and the actual items should be developed in Gemba. Since no detailed knowledge of the current situation was acquired it would be impossible and it would be against lean principles to dictate the content on a detailed level.

5.2 Daily Work Management -boards

Lean daily work management should be visual, focus on the process, have built-in focus on continuous improvement and support pull production. At each workstation it should be visually shown what is being done and why. There should also be some way of knowing if process is running as planned or not. The proposed solution to this problem is Daily Work

Management –board. The designed boards are based on the ideas derived from the board used at Rolls Royce and existing system using Excel sheets.

The manufacturing process as a whole consists of two different sets of processes. The workshop manufactures metal parts and naturally the process steps need to be done in a certain order. On the other hand, in the assembly department several subassemblies (processes) can be worked on at the same time. Because the manufacturing and assembly departments are so different, quite early on it was noticed that the same *Daily Work Management -board* would not work for both parallel (assembly) processes and sequential (manufacturing) processes. So, two different boards were created.

5.2.1 Parallel Processes Daily Work Management -board

Each product in Lappeenranta factory is designed and produced MTO. When production is started the assembly for each product is divided into sub-assemblies and scheduled. The work hours needed for each sub-assembly are quite well known based on past experience. Because the assembly schedule is planned in the beginning of the project, the assembly can be used as pacemaker for other processes in warehouse and manufacturing.

In order to visualize the assembly process *Parallel Processes Daily Work Management -board* was designed. The board went through several improvement circles and several modifications were made after each circle. The latest version of the board is shown in Figure 28. Each product being assembled should have its own schedule and therefore its own board. The board can be modified to be used in other departments where processes are parallel or where different processes are not connected to each other. For example the picking process in the warehouse could use a similar board with small modifications.

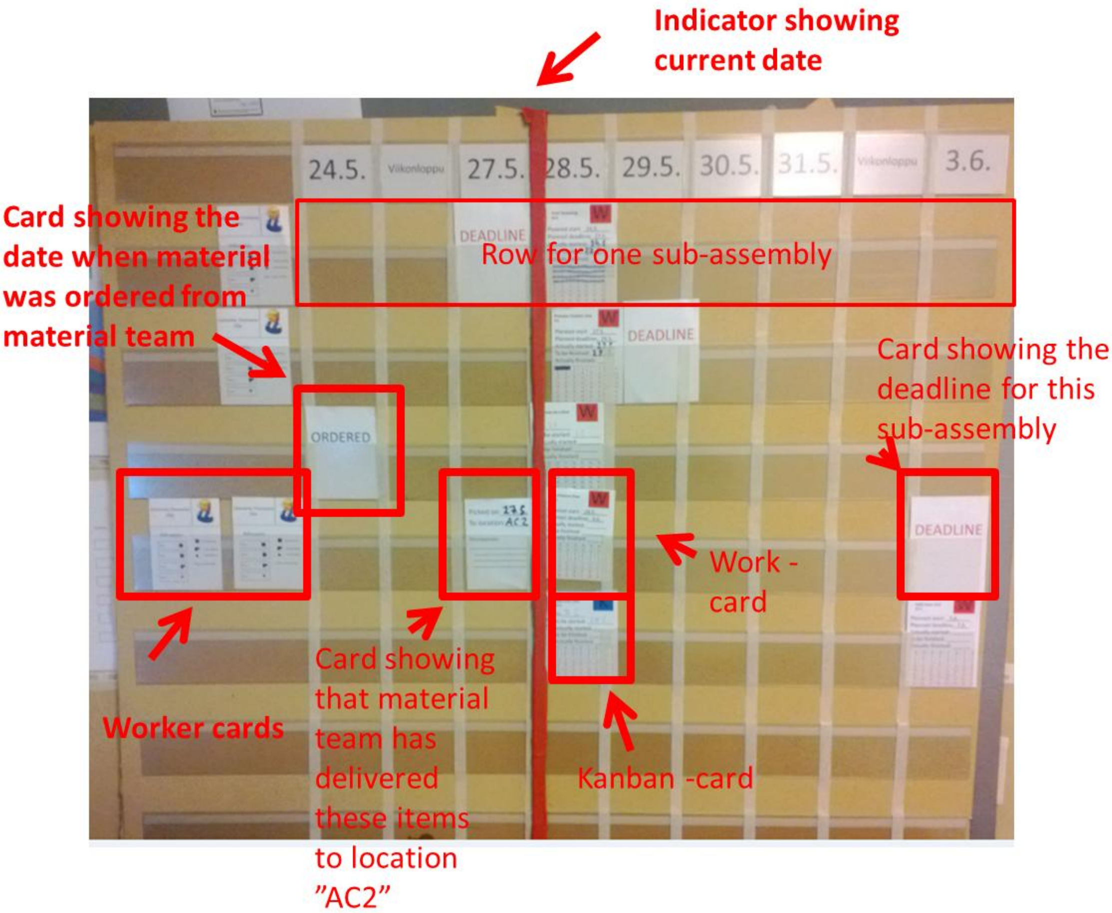


Figure 28. Parallel Processes Daily Work Management –board.

The layout of the board consists of time in columns (each column represents for example one week) and different subassemblies on the rows (each row represents one subassembly). The red indicator shows the current time, everything on the left side is in the past and everything on the right side is in the future. The column in far-left is reserved for the *Worker -cards*, which indicate who is currently working on which sub-assembly. There are five slightly different cards used in this design: *Work -cards*, *Kanban –cards*, *Worker -card*", *Deadline -card*" and *Ordered -cards*.

Each sub-assembly has its own ***Work -card***. When the assembly is planned in the beginning of the project a *Work -card* of that sub-assembly is placed on the boards matrix on the slot when work on that subassembly is planned to start. Each day in the morning meeting the team checks the column of that day to see which subassemblies should be worked on. When a subassembly is started a *Deadline -card* is placed on the board to where the deadline is.

After each day, when work is done for this subassembly, workers mark the completed work hours on the table on the bottom of the card. Card is then moved to the next day´s slot, to indicate that work is still needed for that subassembly. The table on the bottom of *Work -card* shown in Figure 29 is designed so that when workers mark for example two hours completed, they cross out the two first numbers. The green numbers will tell how many hours are left on budget for this subassembly. If there are extra hours reported, the table will show how many extra hours have been done.

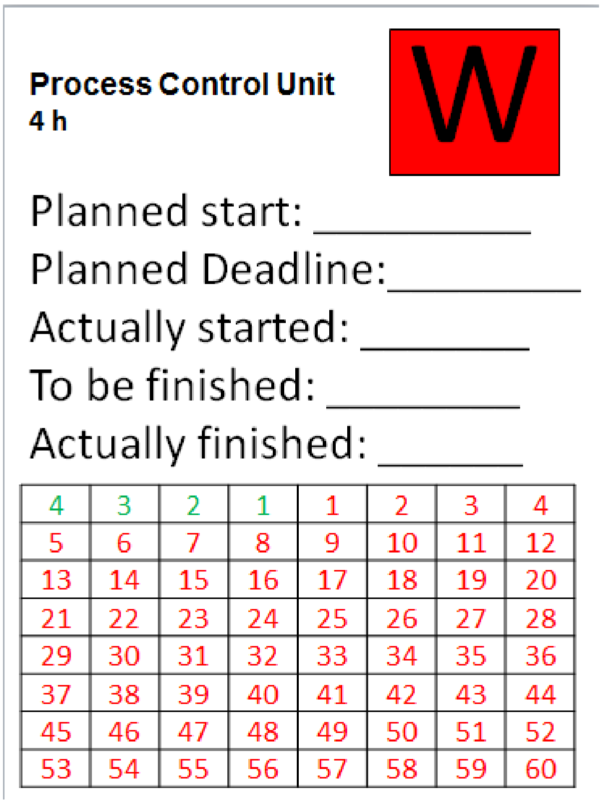


Figure 29. *Work* -card.

When a sub-assembly is fully completed, the actual finish date is marked on the card. If the reported hours differ from the planned hours by a set amount (for example by 10 %) the discrepancy should be reported, investigated and root cause tried to be found. Sub-assembly can also be marked as finished for example with a separate *Finished –card.*

In order to create pull between assembly and other departments a simple ***Kanban -card*** can be used. In the beginning of each project, the *Kanban -cards* are placed on the *Daily Work Management -board* to the slot on the matrix where picking of the parts for the subassembly should be started in the warehouse. Each day in the morning meeting of the assembly team, if there are *Kanban -card* on that day's column, the picking can be ordered from the warehouse using the card. An *Ordered –card* or some other indicator is placed on the slot when *Kanban -card* is removed to let the assembly team know when parts have been ordered from the warehouse. The rest of the design of *Kanban -card* is similar to the *Work -card* and it can be used as a *Work -card* in the warehouse team´s *Daily Work Management -board*. A simple sample design of *Kanban -card* is shown in Figure 30.

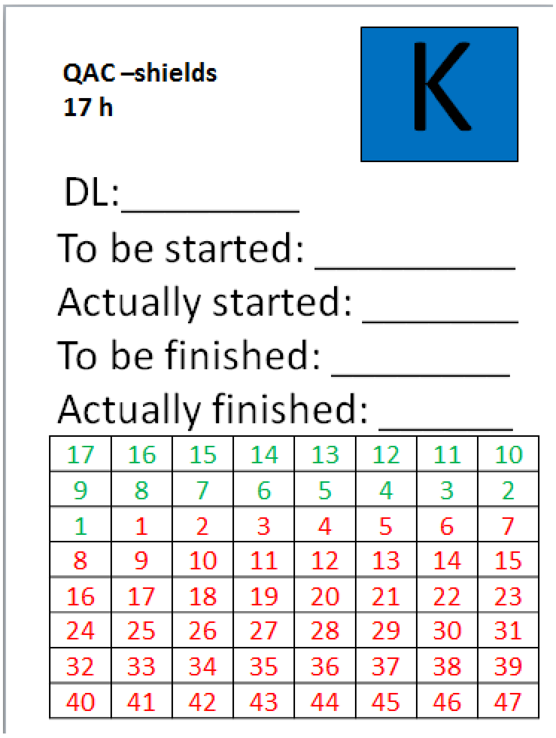


Figure 30. *Kanban* -card design (an example).

When the material team has picked the material, it delivers it to a location near the material team, marks the location on the *Kanban -card* and returns the card to the assembly teams *Daily Work Management -board*. That way the assembly team knows that they can start the work on that subassembly and they know where they can find the parts.

To identify the people working in a certain area and on each specific sub-assembly, a ***Worker -card*** could be used to represent each worker. In the morning meeting or whenever people switch tasks from one physical location to another, the worker card is placed on the *Daily Work Management -board*. A simple example of what the *Worker -card* might look like is shown in Figure 31.

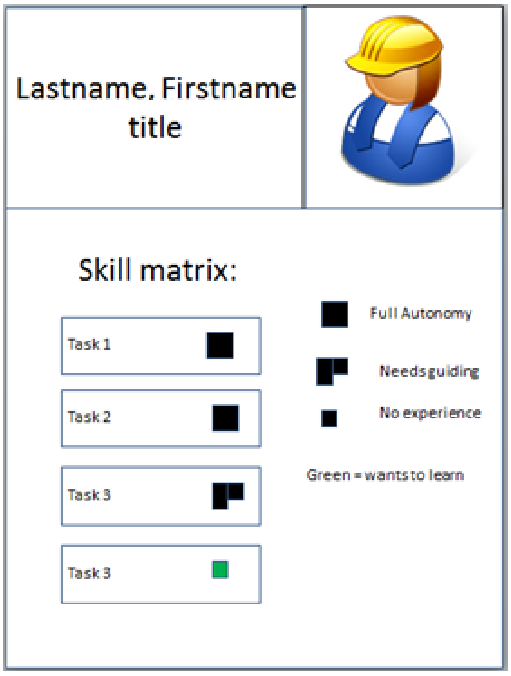


Figure 31. *Worker* -card (an example).

This card design has incorporated a skill matrix, which could help inexperienced team leaders and/or managers to more easily assign tasks. There is also a possibility to show willingness to learn some task on the worker card, so that that person can develop himself/herself.

The *Parallel Processes Daily Work Management -board* presented in this chapter is designed to do multiple things and design presented here achieves most of the attributes listed by Kattman et al. (2013, 425) and Grief (1991, 109):

- It shows the who is working on which subassembly
- It shows why they are working on that subassembly (the schedule and deadline)
- It shows when each specific subassembly is due and with a quick glance anyone can see if assembly as a whole is on schedule or not.

- It makes the schedule of the assembly visual. It shows if any start or finish of any subassembly is late from the schedule.
- The cards have visual display of work hours so that it is easy to see how many hours are already completed and how many hours are left, or how many hours over budget the sub-assembly is.
- *Kanban* -cards are used to trigger work on other departments: warehouse and own manufacturing, so that they do not have to work purely by predetermined schedule but actually can provide the assembly the right parts at the right moment, thus introducing pull.

5.2.2 Sequential Processes Daily Work Management -board

In the manufacturing department the processes need to happen in a specific sequence and there are lots of items moving through the processes at the same time. In this kind of an environment it quickly became clear that the board designed for assembly could not be used. Using Rolls Royce board (Parry et al., 2006, 80) as inspiration a second board was designed.

In this board each label represents one item moving through the different process steps. Item is entered to the system from top left and it moves down and right on the board as it moves from one process step to another. On the top of the board there is a “clock”. The current time is circled on the right side of the board. Each hour the time labels are moved one step to the right. The board requires regular maintenance to work.

The rows represent different process steps (starting from top machining, welding, drilling, and so forth). In this design, only one item can be worked on in each station at any given time, so each process only has one red slot the item (label) can be placed on. The horizontal distance between the slots is the processing time of that process. Each *Item Label* has its planned finishing time marked on it. If a item is entered into the system at the time when the time marked on the card matched the time directly above it, the item should be ready at the planned time. The design of the board is shown in Figure 32.

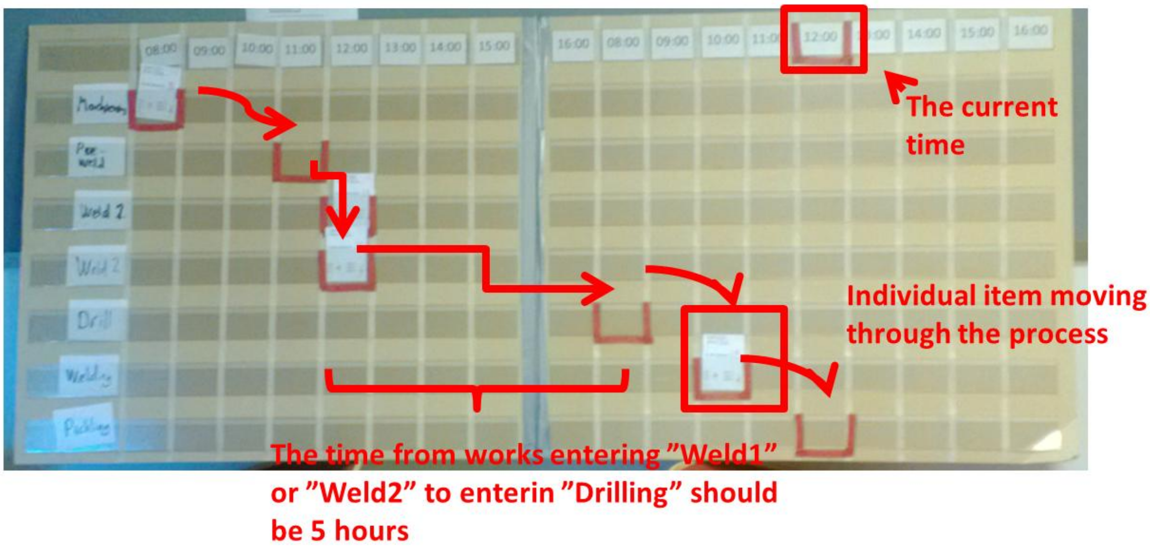


Figure 32. Sequential Processes Daily Work Management -board.

In this example the clock is now 12:00 and a card with “To Be Finished” -time of 08:00 is entered in to the board and to the first workstation. The first processing step is planned to last 3 hours. When the first manufacturing step is completed, the item is moved to the next station (if it is empty) and the card is moved to the next process step slot on the board. At that time, the clock on the top has progressed by three hours. So, if the time on the card matches the time on the top, the manufacturing of that individual part is on schedule.

A simple *Item Label* design example is shown in Figure 33. It is as simple as possible, but still has the features that make it work. It has identification and deadline details on the top and on the bottom there is room for other manufacturing specification details.

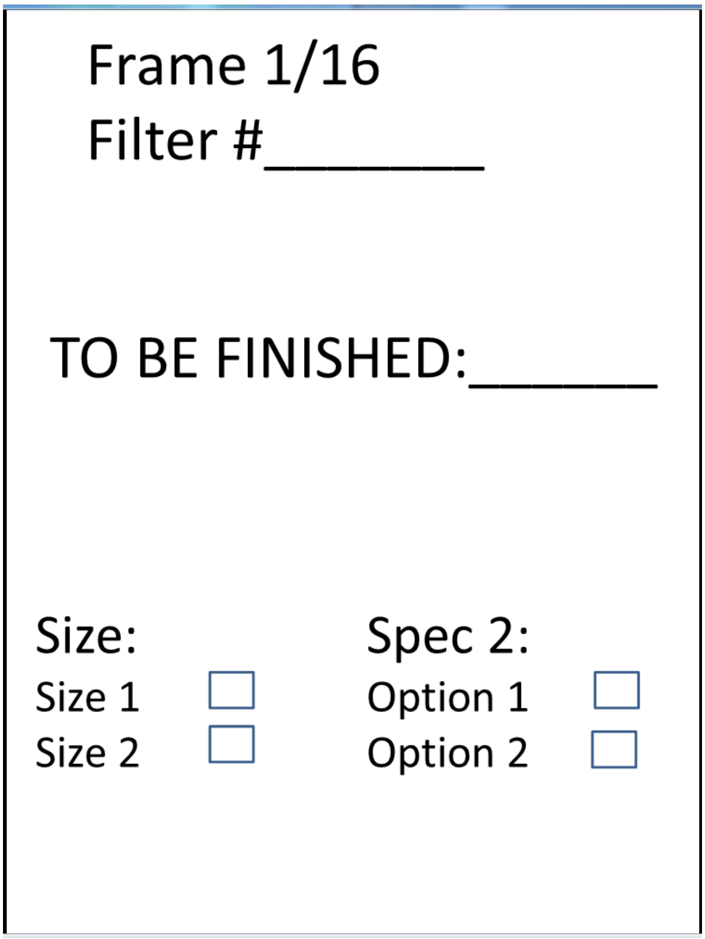


Figure 33. *Item Label.*

On the backside of the label (Figure 34) there are places where the actual, more detailed *In* and *Out* times can be entered. This makes it possible to track the processing times for each individual part and also the time this individual item has spent in any intermediate warehouse.

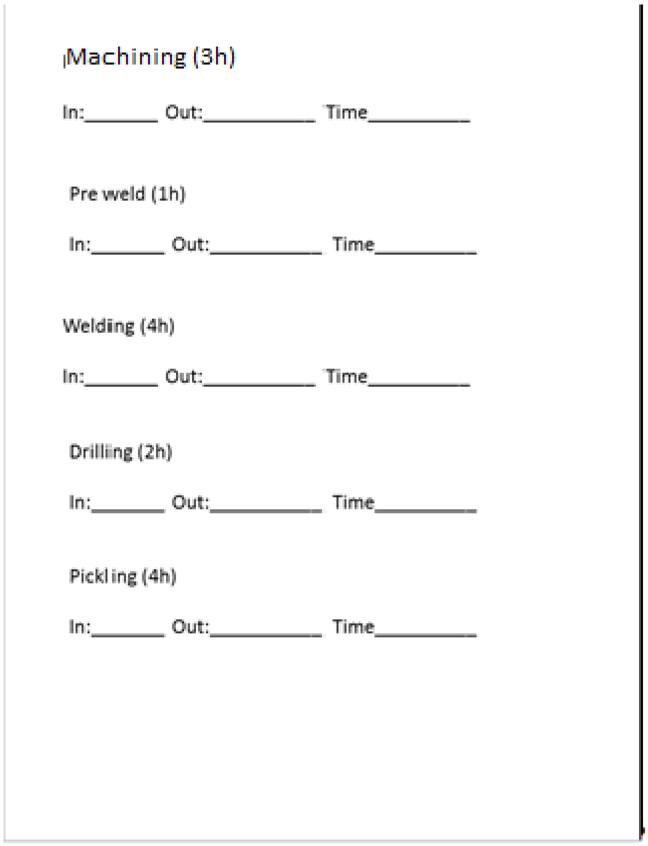


Figure 34. The backside of *Item Label*.

This is only one way of accomplishing a more visual work scheduling tool. The most important thing are not the details of the board, but that it makes it visually clear which projects are on time and which are not.

The *Sequential Processes Daily Work Management -board* presented here answers at least three questions presented by Kattman et al. (2012, 427) and (Grief, 1991, 109). It shows what is being worked on at which workstations and when each item is due. The board forces the items to move from one process to another according in one-piece-flow. In real life some kind of an intermediate warehouse (supermarket) design can be used.

5.3 Continuous improvement

Continuous improvement is one of the most essential elements in lean. The challenge in the Lappeenranta factory seems to be that it is hard to identify stoppages and discrepancies between what is and what should be in the processes. This seems to be partly due to the nature of work and processes and partly due to the attitude towards defects and problems.

Problems and defects seem to be considered as normal part of work. Different workarounds and all kind of tricks seem to be done in different parts of the factory to “get things done”, but little focus is put on fixing the root causes. Often it seems that the root cause of the problems is already known but it has just not been fixed for some reason or another.

This thesis has outlined a method for controlling continuous improvement. The method includes simple Continuous Improvement Cards that workers fill in each time they recognize a stoppage of certain length or a discrepancy in the process. A card can also be filled for example every time a schedule is not met or work hours are above some set limit.

The *Continuous Improvement Card* is based on a sheet used in one of the benchmarked company. It was modified and it went through several improvement circles during this thesis. The card is presented in Figures 35 and 36. This specific card was designed specifically for continuous improvement in the purchasing department, but with small modifications it can be used in almost any department. This card design elements are:

- The identification details on the top.
- The length of stoppage in the process is visually shown.
- On the bottom more detailed information of what happened is filled in.
- If the worker has an idea of a quick-fix for this problem, it can be described on the card.
- If the root cause is identified to be on another department is marked on the card and the card is sent to that department for so that root cause can be fixed there.

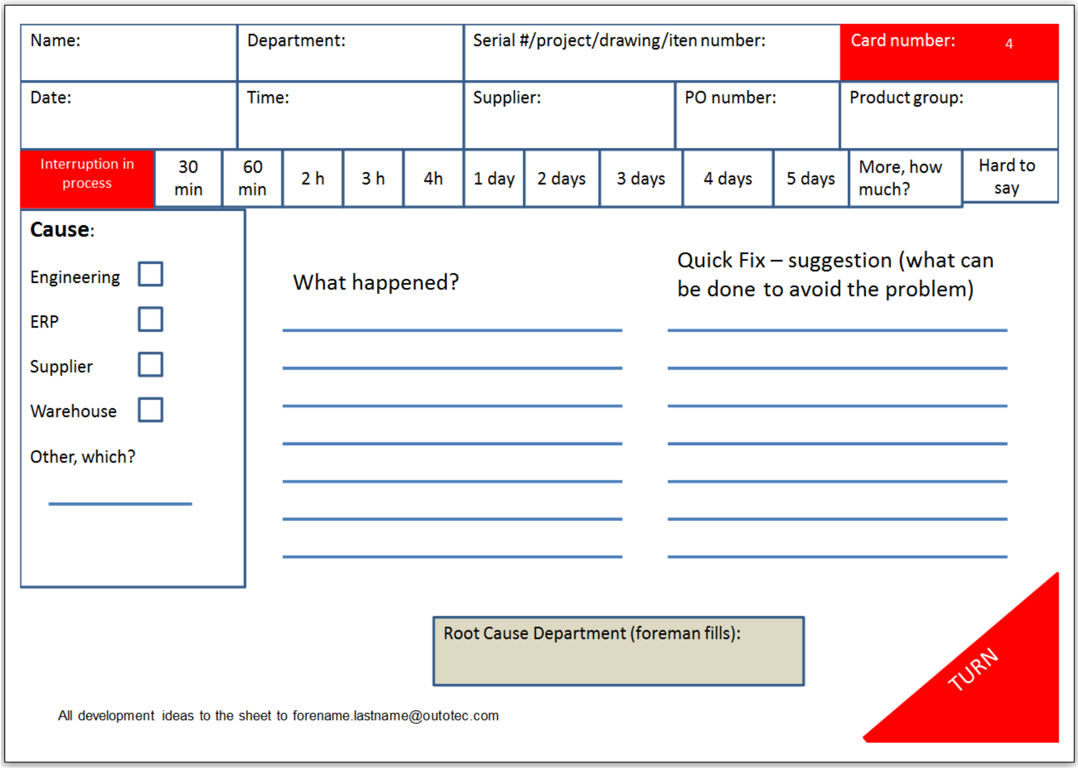


Figure 35. Continuous Improvement Card, side 1.

On the Side 2 of this card design there is a “5 Why?” template, which is supposed to be filled by team leader together with the reporter if it is possible. The side 2 might not be needed but it is partly there because it trains both team members and management in lean principles of identifying root causes of waste and in lean terminology.

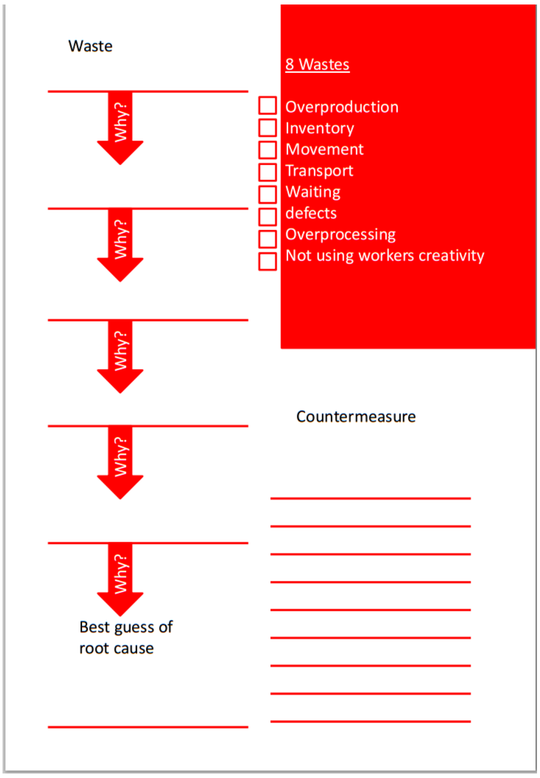


Figure 36. Continuous Improvement Card, side 2.

5.3.1 "War room"

There are at least two kind of problems that are expected to rise using the Continuous Improvement Card. First category is those that can be solved by simple changes in the work environment, work instructions or other things that the team and its leader can independently change. All of these problems can be solved quickly without consulting too many other departments. Those problems can be assigned to the team members using for example the *Accountability Board* presented in this thesis.

There is however other problems that need to be solved in other departments such as previous process step or some other entity. To solve these problems a "war room" should be established. A "War Room" is a place where representatives from each department and support group have a meeting for example each week or once every two weeks. Each department brings one or two problems that they would like to be solved to the war room and the group assigned them to the correct persons and/or departments.

5.4 Other visual elements and tools

It is impossible to make a comprehensive list of all visual elements that can be included in daily operations, because they should be literally everywhere. The tools in this thesis have been designed to include as many visual elements as possible, but with imagination more visual elements can for sure be added.

The managers and leaders should keep in mind that lean philosophy integrates visual elements everywhere and try to constantly find new ways of making their charts, instructions, markings on items and surroundings on workplace more visually clear. Visual elements should be added as one focus point of the Gemba walks, at least in the first steps of the lean journey.

5.4.1 Visual controls at Gemba

Visual control elements should be everywhere in the shop floor. The only restriction is the imagination and creativity of leaders and workers. This thesis focused on the visual management of the assembly and manufacturing processes but there are several areas where it is easy to see that visual controls could be applied, for example:

- Acceptable inventory levels painted visually on walls/racks/etc.
- Separate color coded areas/containers/tags for goods in the different stage of the process (for example raw material, semi-finished and finished goods).

5.4.2 Accountability board

According to Mann (2010) it is important to keep accountability of all the different tasks that rise daily. To do this, a simple but still effective *Accountability Board* was designed. The design and outlook of the board is trivial. An example of a possible layout is shown in Figure 37. The purpose of the board is to keep track of unresolved tasks. This design has weeks on columns and responsible persons/entities on the rows. Each individual label represents an individual task. The movable red indicator shows the current time and every task on the left side of the indicator is late and everything that is on the right side is still to be done.

Figure 37. Accountability board (an example).

The *Accountability Board* is a draft of a tool that could be used. It shows clearly what is being done by who and if each individual task is on schedule or not. Same kind of design can be used by each separate team to keep track of improvement tasks of that team on its team board. This *Accountability Board* can also be applied in the continuous improvement war room to keep track of tasks assigned to each department. To include PDCA -cycles in continuous improvement related tasks for example different colors or other identification can be used for tasks that are on different stages of improvement cycle.

5.4.3 Team boards

One of the fundamental ideas of lean is to know what is happening at the workplace and to share as accurate information as possible. A white board could be assigned for each team and/or for each department and placed as close to the actual workplace as possible. The information on the board should include at least the schedule of that team.

For the assembly department it should consist of visually managed schedule of when the project should be ready and which subassemblies are still to be done and in which order.

For the manufacturing the board should hold the information about the parts that are to be produced and in which order. Team boards should also have the 5S reports of that team's area and a list of ongoing improvement projects and their statuses.

5.5 Environmental issues

Sustainability is the core value of Outotec and it should have a strong role in the lean project as well. Sustainability should be seen as an additional value, which customers, society at large and stockowners value as suggested for example Hines et al. (2004). Be adopting this mindset, lean and environmental values can co-exist and have synergic benefits rather than clash and contradict each other as for example Rothenberg claimed.

5.5.1 Environmental issues in 5S

As first environmental lean step the, 5S model should be reviewed with environmental mindset. All waste areas should be made as accessible as possible. Waste sources should be identified and color coded containers placed to where workers will rather put any waste straight to the containers than leave it to the workplace. Waste and environmental issues should be added as one point to be observed in 5S audits.

6 FURTHER RESEARCH AND ACTIONS

If lean adaptation is to be successful, it needs to be viewed as a journey and not just as an implementation project. The first stage of lean adaptation is well on its way and it seems to be going well.

It is difficult to say from the outside and in advance which tasks should be done next, because that depends greatly on the things and problems Outotec finds out on the way. It would seem that the biggest difficulties on the journey might come from the attitude towards and the difficulties in identifying discrepancies in the process. Outotec needs to create systematic way of monitoring if its processes are going as planned and a method of making adjustments to the processes when needed. It would seem that there is no good way of applying “on-line-monitoring”, instead workers and leaders need to be trained to monitor the process themselves, find out the root causes and fix them. The focus needs to always be kept in fixing the root causes instead of the symptoms. Figuring out the root causes will be difficult, but with training there is no reason why it should not work. One possible way of monitoring discrepancies is presented in this thesis, but people on the factory floor need to modify the tools themselves to make sure that they fit to the exact processes. In the future similar tool could be created for example using RFID tags or barcode readers. It would automate (RFID) or make the data gathering as simple and convenient for the workers as possible.

Lean end environmental objectives seem to have synergic advantages. This thesis did not study the process itself and in line with Outotecs strategy one logical next study subject would be to study the environmental impact of Outotecs manufacturing process and to incorporate the most potential hazards to the lean metrics.

If Hoshin Kanri policy deployment is not already in use, it should be started in manufacturing through all levels of employees and clear lean objectives should be set as targets.

7 CONCLUSIONS

The purpose of this thesis was to give an “outsider´s view” of the tools that could be implemented following the lean manufacturing philosophy. The task was not easy. Lean philosophy emphasizes the in-depth understanding of the process and that any tools should not be blindly copied from other companies but rather the ideas behind them should be adopted. The tools presented in this thesis support lean manufacturing well. The tools, if updated regularly, make the processes visible and also make it visually clear to see if the process is deviating from what was planned. The tools are quite general but they should be adaptable to Outotecs manufacturing process. To create more precise tools from “outside”, without precise knowledge of the processes, would be against lean principles.

During this thesis many kaizen cycles have been done for all of the tools. Potential improvement points were been found and improvements made after each cycle. If further cycles were made, more improvement could have been made. Lean is often described as being journey. The tools in this thesis have just begun their journey. They should be reviewed critically but with an open mind. If the tools (or any element of them) described in this thesis are implemented they should be improved in the Gemba by the people who actually use them.

The nature of assembly and metal workshop are quite different. In the workshop it was easy to see how parts could flow from one process to another. The processes were in quite strict sequence. Pull could be implemented using quite simple kanban and supermarket tools. On the other hand, the assembly seemed not to be linear at all. Several different subassemblies could be worked on at the same time and even though some processes had to be in certain order, quite many subassemblies could be done, or at least started even if the previous one was not yet completed. To visualize the processes two different daily management boards were developed. The inspiration for the boards came from the benchmarked examples, but the tools were not copied directly. The boards went through several development cycles. Their content, different features and functionality were discussed with both people working in the factory but also people outside the factory floor to keep the ideas as fresh as possible.

Organization structure at manufacturing is already arranged in teams and this should support the lean transformation well.

Outotec´s values provide a good foundation upon which a lean process can be built. The values could be used as a kind of a “North Star” to give direction in lean activities. Naturally, some additional guidelines need to be created by management, for example “Zero defects” could provide additional guidance.

The visual management tools developed in this thesis support lean. The tools are not by any means finished and a lot of development work need to be put in them to make them work in the real environment. Because knowing the process thoroughly is one of the core principles of lean, it would have been impossible to refine the tools further and still follow the lean philosophy. With the limitations of not knowing the processes well enough, the objective of the thesis was met.

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