LAMK Lahden ammattikorkeakoulu
Lahti University of Applied Sciences

Improving maintenance in high-volume manufacturing

Case: Ball Beverage Packaging Europe

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Henry Nieminen

Lahti University of Applied Sciences
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NIEMINEN, HENRY:

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ABSTRACT

The aim this thesis is to investigate the current state of the maintenance in case company and to identify process bottlenecks. After recognizing the process bottleneck equipment, situation is analyzed thoroughly by using root cause analysis. Based on the root cause analysis, improvement activities are performed and measured. Current state analysis is conducted from production downtime and spoilage data available. Final implicantions are measured by using overall equipment effectiveness as indicator.

As a result of the high volume nature of beverage can manufacturing, it is essential to keep equipment in excellent condition. Therefore, theoretical section is focusing on maintenance in manufacturing environment and connected to company's business. Moreover, background theory discusses the total productive maintenance and process improvement.

The empirical section is qualitative research based on implementation of choosed method. This study is conducted as action research to case company. The current state was measured before the implementation, similarly situation is measured two months after the new method implemented. The method was modified from the original idea of Milton Keynes plant located in England. The method, tagging system, was implemented according to Six Sigma DMAIC roadmap. Additionally, beverage can manufacturing process is explained in this section.

The results of the study are visualizing the implications after the maintenance method improvement. As a result of the tagging system implementation, overall equipment effectiveness improved significantly during the two month evaluation period. Therefore, it can be summarized that when improving company's maintenance method, it will actualize as better production figures and business result. In addition, challenges related to the maintenance in the company were also identified in communication between personnel. Implementation of the tagging system increased the amount of communication related to maintenance activities. Tag review meeting practice was established and is held on regular basis which involves whole organization as shared tags between departments.

Key words: maintenance, manufacturing, total productive management, process improvement, six sigma

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ABBREVIATIONS

TPM	Total Productive Maintenance
ROI	Return On Investment
OEE	Overall Equipment Effectiveness
AM	Autonomous Maintenance
PM	Preventive Maintenance
PDSA	Plan, Do, Study, Act
DMAIC	Define, Measure, Analyse, Improve, Control
CPM	Cans Per Minute
HFI	Hold For Inspection
BE	Back End

1 INTRODUCTION

Undeniably, nowadays manufacturing companies are competing globally and gaining the competitive edge to rivals has become essential for the business. Strategy means making things better by performing unique and well-chosen activities remarkably different than competitors. This is still valid statement from Porter (1996) how he defines the profitability for a company after two decades. By doing activities better with added value to the customer, company is able to get higher price from the product. It is not easy task to perform in some industries. For example, when trying to achieve this differentiating step in manufacturing companies where the product is exactly same, also when equipment and processes are fundamentally similar, it can be challenging. More often, pursuing operational effectiveness happens by improving processes and therefore achieving better business position. Operational effectiveness will lower the costs used in making the product. (Porter, 1996)

Global competition has forced companies to renew their processes. Continuous improvement has gained solid foundation as part of companies strategy driving towards the zero defects methodology. Japanese industry has shown it to world how operational excellence could be achieved by different methods, tools and mindsets. Quality-thinking in all areas as error-free is in the attention on manufacturing. All manufacturing companies do base their production in some sort of machinery or automation. This equipment is making the profit to the company when it is running without unplanned stops or breakdowns. When trying to achieve the best return on investement from the manufacturing equipment, it is truly essential to recognize that efficient maintenance is in vital role. (Hayes 1981)

This vital role of maintenance is also explained through production output as indicator which is strongly influenced by equipment reliability and maintainability. It has been recognized that proper maintenance system will improve equipment availability and reliability. (Sharma 2012)

Total productive maintenance (TPM) is part of Lean methodology and it focuses on getting more production by lower costs by focusing in problems and breakdowns of manufacturing equipment. TPM aims to use all the capabilities available in the company for improving quality, reliability, safety and reducing waste by integrating maintenance and operations. TPM is to find out the most value-adding activity for the workers. It also emphazises the importance of operators which are proactively taking responsibility of equipment condition. It is rarely realized that maintenance improvement will lead to cost reduction which is often multiplied in profit when comparing similar increase in company's revenue. (Levitt, 2011) TPM is the hardest part of Lean tools to implement, but at the same time it is the tool which could make the biggest difference (Rubrich 2016).

This study analyzes the effects to production equipment utilization when improving maintenance system in a high-volume manufacturing company. The background for this thesis is explained in the first chapter 1.1 and following it with introducing the case company and connection between the need for the research.

1.1 Background

From the very beginning of starting up the beverage can manufacturing in Mäntsälä in 2013 it had faced simultaneous problems with manufacturing equipment. Unplanned stops and breakdowns caused the situation where company was dragging behind the budget. There has been lot of support from internal and external maintenance companies. Nevertheless, there are problems which has stayed unsolved and are still causing down time. Not to mention the new upcoming challenges when machines are starting to age. There has been few major breakdowns which has caused production to stop for days partly because of mistakes made during the installation, but also caused by lack of adequate maintenance.

One part of the bigger problem is that working happens in shifts. There has been lot of discussion and unsatisfaction about the fact that information does not pass by between shifts. As there was not only lack of communication identified between shifts, but also between shop floor and management. The survey was conducted in the year 2014 and in the results communication was highlighted as one of the major issues. In the manufacturing facility where production figures are presented per shift, it is easy to notice that teams tend to think only how their shift is performing than seeing the big picture.

In June 2016 acquisition become real when Ball Corporation bought Rexam. There was lot of re-arragement with plants and some of the plants were sold or shut down. Extra motivation for staying in the budget comes from the fact that the demand for the cans is growing, when situation in Europe was optimized along the acquisition. Mäntsälä plant is making more and more label changeovers with different products so it becomes essential to focus on the condition of equipment. The challenge is to get more production time by avoiding unplanned stops or breakdowns and to nourish the communication about the maintenance actions.

1.2 Case Company

Until the June 30th 2016, Rexam was global leading can manufacturer with their head office based on London. In the end of June, American container and packaging company Ball Corporation made acquisition by buying Rexam. Before the acquisition Rexam had approximately 8000 employees around the globe in 25 different countries and 55 manufacturing plants. Rexam was specialized of producing beverage cans. Rexam net sales in the year 2014 were 3832 million pounds. Rexam owned leading market position in three out of four BRIC countries also in Europe, South America and second in North America. (Rexam 2016b)

Rexam as company had strong culture of sharing best practices throughout the plants. Rexam drove towards the savings by reduction of waste from manufacturing and business processes. (Rexam PLC 2016a)

After the acquision Rexam is now part of Ball Corporation, but still continues with similar zero defect culture and strategy as Rexam had. Ongoing reduction projects will be continued and therefore this thesis will be conducted to Ball Corporation.

Ball Corporation was founded in the year 1880 and is having nowadays approximately 18 700 employees worldwide in over 70 locations. In year 2015 net sales were 11 billion dollars. Unlike Rexam, Ball Corporation does have also other business capabilities with beverage can manufacturing. Other market areas are focused in household, healthcare and personal care solutions and packaging. Metal food packaging, aerosol cans and wide variety of beverage packaging solutions are part of Ball Corporations product range. (Ball 2016)

1.3 Research objectives, questions and limitations

The aim of the study is to investigate the current state of case company's process and identify the most significant areas for improvement. Through the analysis of the current state, improvement project will be established leaning to the resources available in the case company. As a result of resources available for the improvement project, study will be limited on maintenance improvement. Nevertheless, the nature of the manufacturing business is equipment oriented and therefore maintenance plays big role in succesful business execution of the company.

The main objective is to find appropriate method according to the situation of the company. Then the method will be implemented and implications analyzed in quantitative data analysis methods. The focus of the study is not in the evaluation of the project work or implementation process.

However, improvement team is vital part of the study as the root cause analysis is conducted to the area of improvement. According to the results of root cause analysis, the improvement method will be considered and implemented.

The research questions to be responded are:

1. What is the key area for improvement?
2. How maintenance should be improved in the current situation?

The scope of the research is to find method for improving maintenance process. If the choosen method is having positive impact on manufacturing indicators such as OEE, it will be possibly extended to other areas or equipments as part of the maintenance procedures. This fact works as personal motivator for conducting the thesis. Modelling the maintenance system method could be notable topic for further study, nevertheless it is not took into consideration when conducting this thesis.

1.4 Structure of the research

Theory section of the thesis is referred from books, science journals, articles and various electronical sources. Theoretical framework is based on three main pillars. In the second chapter, connection between companies' maintenance and business strategy is described. Maintenance in manufacturing environment is introduced as well. In the third chapter, Total Productive Maintenance philosophy is explained and different approaches evaluated. Fourth chapter introduces process improvement and Six Sigma methodology which creates the foundation for the project work conducted during the study. In the fifth chapter, research approach is introduced and explained, likewise the method choosed for process improvement. The history of can making and modern process are considered as well. Last two chapters are analyzing the results of the research and discussing the impact for the company by choosen metrics.

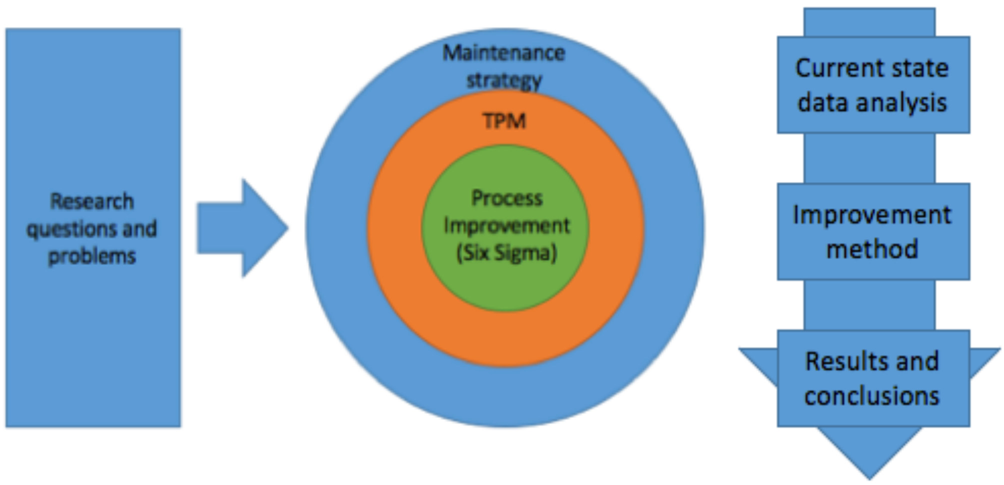


Figure 1. Structure of the reseach

Structure of the thesis is visualised in the figure 1. Solutions for the research problems are found from the background theory and deducted to practice.

2 MAINTENANCE IN MANUFACTURING BUSINESS

The history of systematic maintenance approach is fairly short when comparing it to industrial age. Considerably far, as long as 1960s' maintenance was equivalent with extinguishing fire. Maintenance of that time aimed to fix equipment as it broke down. Indicator for successful maintenance was situation where maintainers had time to sip coffee and play card. Effectiveness of maintenance was measured in time of fixing broken equipment. As late as 1970s' it was recognized that maintenance should be performed in a way which aimed to prevent breakdowns. Company's manufacturing process and strategy defines how maintenance strategy is choosed. (Laine, 2010)

Challenges are multidimensional in manufacturing environment. Where companies are trying to satisfy their customers increasing demands, at the same time they are forced to pursue for higher quality, faster responses and not to mention better performance. As trying to survive in this kind of stiff situation, companies must rethink their business processes, reorganize their production and focus on predictive rather that reactive management methods. Management concepts should be also re-evaluated to be more flexible and integrated. All these factors had forced manufacturing companies to develop production lines with complex systems where automation, integration and flexibility has been considered thoroughly. Emerging requirements has led to situation where the need for maximizing equipment availability, production cost effectiveness and safety has increased. Therefore, one of the most important challenge to be considered is optimization of the maintenance strategy. Developing optimized maintenance strategy and approach it is possible to achieve great impacts in overall. It is essential to recognize that maintenance is key factor when improving equipment availability, cost optimization, product quality, environmental issues, zero waste and energy control. (Artiba & Riane 2005)

2.1 Role of maintenance

As mentioned in introduction chapter some maintenance engineers are still focusing the simple fact, how fast they are fixing equipment when it breaks down. The role of maintenance is prevent all losses caused by equipment, not to fix breakdown as fast as possible. There are few major missions to be sustained in world-class maintenance organization. (Mobley, 2002)

According to Mobley (2002) optimum availability of equipment is the most important task. Equipment should be targeted to be online always and in operating condition. Optimum operating condition should be considered in all areas, whereas smallest problems and stops will form a huge loss when calculated together. Every small stop will effect on plant overall performance. Maximum utilization of maintenance resources is important task to be fulfilled as well, even though maintenance actions are generally minded as minor part of company's total operating budget. It is in maintenance manager's responsibility to control resources effectively, like internal and external maintenance labour, spare parts inventory and repair parts. Spare parts inventory should be controlled the way that minimum amount of necessary items are stored. One mission is to focus on optimum equipment life which is could be achieved through implementation of different maintenance programs. Even the best programs could fail and unexpected breakdown could appear. In that point maintenance organization should be ready to react rapidly.

When evaluating different maintenance types there are three main indicators which could give a hint to company what is their current situation. If production is interrupted by different maintenance reasons more than 30 percent of total occurrences, we can say that management philosophy is reactive, more or less breakdown oriented. For a comparison, it is evaluated that target for maintenance related stops for competitive manufacturing company is less than 1 percent of overall occurrences. Next indicator for inefficient maintenance is overtime amount. If overtime covers over 10 percent of total labor budget it is easy to categorize company to breakdown type. Appropriate target is approximately 1 percent of overtime. Since at some point overtime is necessary, for example special projects do require constant participation from experts, the overtime percent is never zero. Last indicator is labor usage. This is part where is recognize place for improvement when reflecting to my own experiences in manufacturing companies. Efficient management style will utilize maintainers to perform preventive maintenance actions for over 90 percent of working time. Actually, worst case is to only monitor what equipment is breaking down next. Reliability of critical plant systems is based on well-managed maintenance organization. (Mobley, 2002)

2.2 Maintenance as part of company's strategy

It has been mentioned repeatedly in literature that maintenance does own a very important role in companies' agenda, whereas it is directly related to their competitiveness. Of course, when manufacturing systems are measured in availability and reliability metrics they are corresponding to company's economic situation. Manufacturing equipment is company's most important capital asset and the main concern lies on its' deterioration and failure. At this stage some sort of the preventive maintenance is necessary for restoring and maintaining equipment in operating condition. With no doubt, goal for maintenance budget is to keep the expenses as low as possible. In real life, maintenance managers are forced to answer the question to maintain or not to maintain. Problemacy lies on the fact that it can't be predicted accurately when machine breaks down. Is equipment performing reliable after maintenance, which will cause certainly downtime for it? Is the costly operation worth it? However, if equipment breaks down and spare parts are not ready and maintenance planned, it will cause more downtime than planned maintenance. So, to maintain or not to maintain? This is situation where maintenance manager should choose his strategic approach or set-up maintenance system according to different PM methodologies. (Artiba & Riane 2005)

Manufacturing plants normally are categorized roughly to two types of maintenance strategies: run-to-failure or preventive maintenance. Run-to-failure approach is simple. When equipment breaks it will be fixed. Money spent on maintenance stays zero until equipment breaks down. Sounds reasonable, but when equipment finally breaks down it will be expensive case. The most significant costs are associated with high spare parts inventory, high overtime labor, high equipment downtime and low production availability. This approach is actually reactive, when failure appears then maintenance team reacts. Actually, quite rarely there is not preventive actions at all, like lubrication, cleaning or machine adjustments. Nevertheless, what if more than one failure appears at time? Running business like this is really risky. It has been evaluated that making preventive maintenance actions like planning and scheduling upcoming repairs is three times cheaper than waiting equipment to break down and then fix it. (Mobley, 2011)

Preventive maintenance programs are mostly based on elapsed time or hours of operation per equipment. Most commonly, there is evaluated time to failure which is called also mean time to failure (MTTF). Figure 2. indicates this life span of equipment deterioration. Figure indicates that during the startup and at the end of equipment life expectancy the number of failures will increase remarkably.

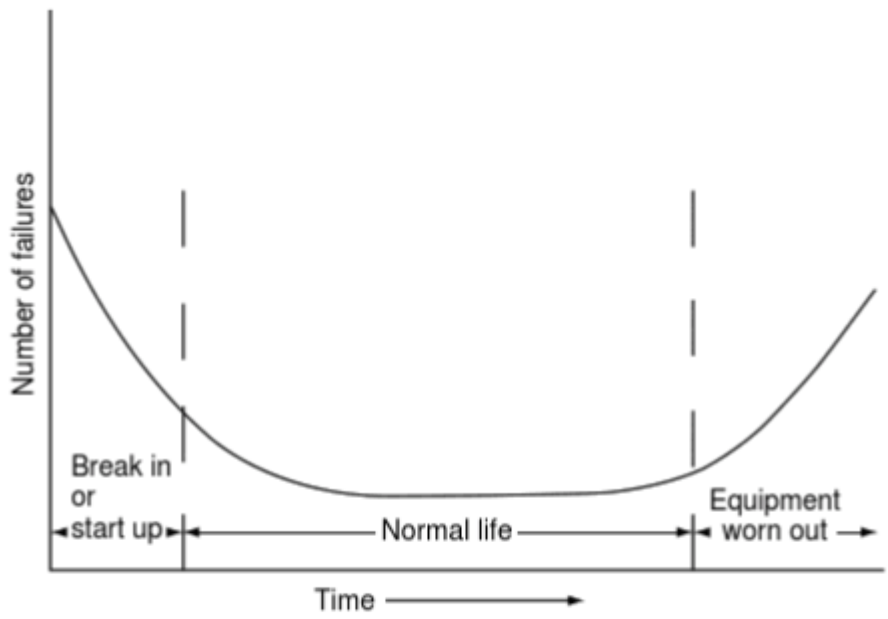


Figure 2. Mean time to failure (Mobley, 2011)

In preventive maintenance, during normal equipment operation time, condition of machinery is monitored whether is should be repaired earlied than planned. Predictive maintenance is to monitor the elements of breaking down. Especially, equipment will be inspected more carefully of vibrations, heat generation, leaks, pressures and other significant symptoms for breaking down earlier than expected. (Mobley, 2011)

2.3 Preventive maintenance economics

Like in any other investment, maintenance investement does also follow the charasteristic process of financial justification for the project. First, the initial and current expenses are compared with expected benefits. Then benefits are calculated to cost savings and increased proftis. If return on investment is calculated positive in reasonable window of time, probably project will be worth investing. It must be noted that calculated costs for the project should imply also installation, recruiment and training costs, not only the price of new equipment. Cost justification for preventive maintenance action is at highest when thinking bottleneck equipment in process. If condition of the machine is not monitored carefully, it will be tremendous cost when breaking down unexpectedly. (Mobley, 2002)

Maintenance budget is usually counted as a cost overhead, fixed sum which is reserved for staff wages, spare parts and consumables. Quite common system is also to evaluate the performance of maintenance department compared to budget. If budget surplusses, even when production suffers lack of maintenance, quality or availability, it is evaluated positively. This is wrong mindset, instead we can justify that preventive maintenance is actually investment, not expendature. Nevertheless, reliable data for justifying the return on investment should be presented before implementation. Usable indicator for improvement could be equipment performance and then translated to financial benefits. The cost of lost production time is indicator which could be translated also to lost units made and then again translated to financial data. (Mobley, 2002)

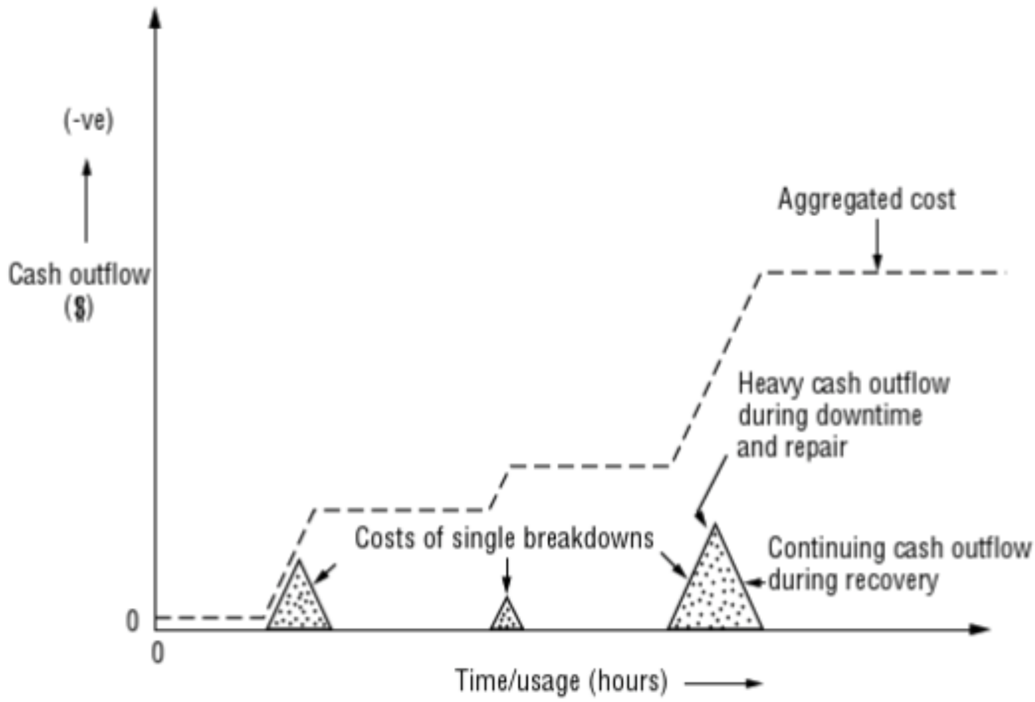


Figure 3. Cash flow diagram of lost production (Mobley, 2002)

Figure 3. presents the lost production effects to company's cash flow, which turns negative and accumulates when consecutive breakdowns

appear. It is not only the time when breakdown is causing downtime but in many cases the full performance of equipment is not established until certain amount of time, which is causing negative cash flow as well. So, based on he previous arguments, this negative cash flow could be prevented with correctly set maintenance program. If implementation of PM program is calculated as single expendature and the results will be long-term, it would not be question of implement or not? This should be kept in mind, especially when equipment is starting to get old. Figure 4. illustrates the situation of implementing PM program.

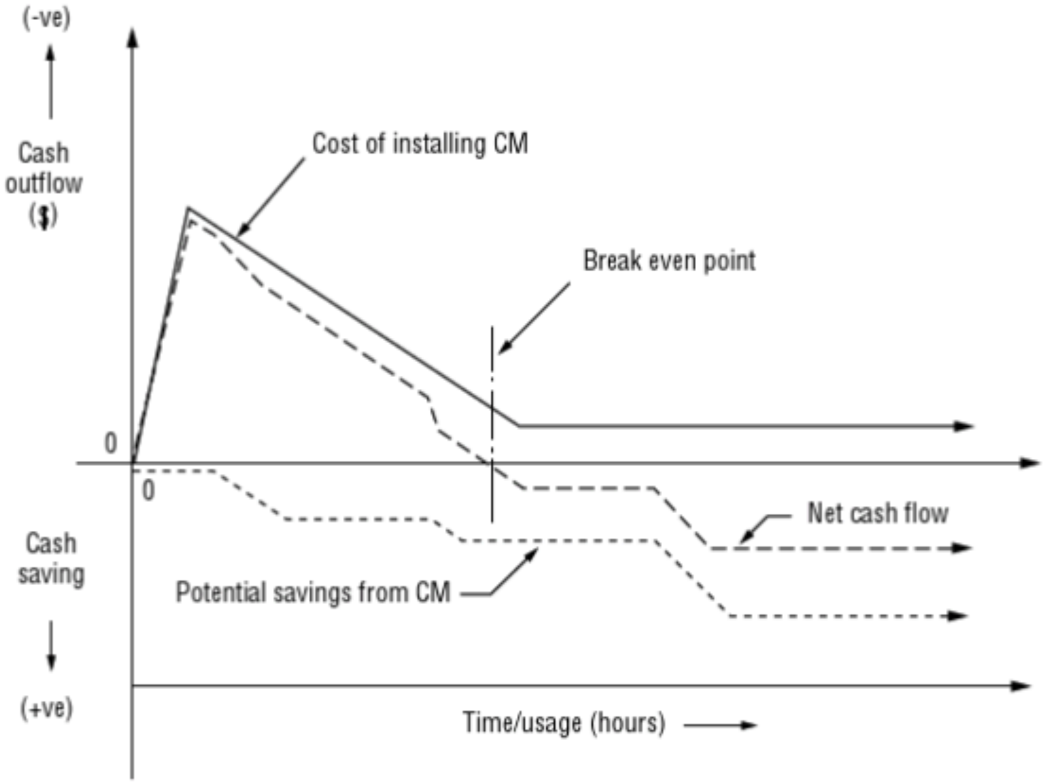


Figure 4. Typical overall cash flow in PM implementation (Mobley, 2002)

In figure 4 CM means condition maintenance which is one type of preventive maintenance, nevertheless philosophy is the same. As we can interpret the figure, potential savings will start immediately after implementation. When considering long-term impacts, we can say that cost of program will stay on stabile level, but savings and then again net cash flow are increasing during the time.

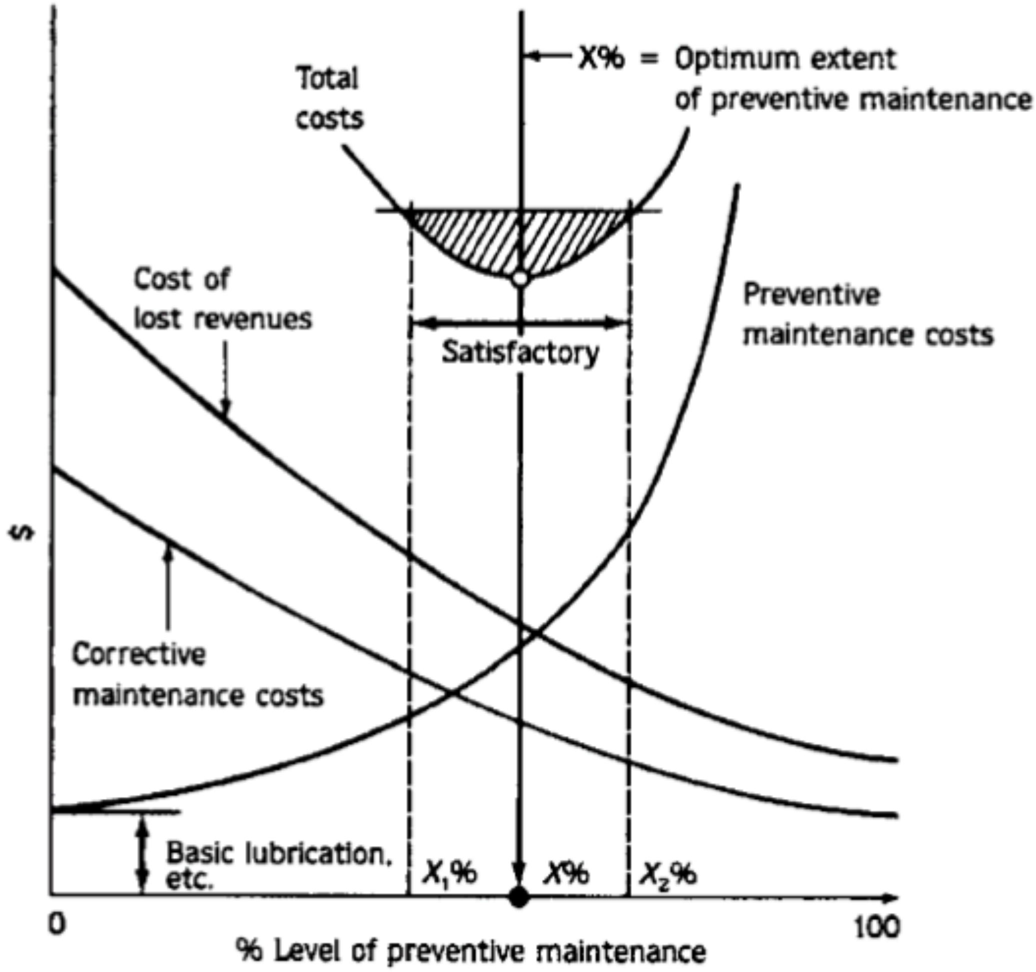


Figure 5. Balance between cost and level of PM (Mobley, 2002)

Figure 5. is illustrating different maintenance type and cost relationship. Vertical scale presents amount of money used and horizontal line visualizes the level of preventive maintenance. Cost of lost revenues curve represents downtime. We can interpret from figure 5, that when executing more preventive maintenance actions, the cost of maintenance are expectedly increasing. However, downtime and corrective maintenance are decreasing as result. Nevertheless, the curve indicates that at some point preventive maintenance costs will surpass both at level of 80%. As a result we can make assumption that finding a perfect balance of costs and amount of preventive maintenance is essential when achieving optimal result. Optimal amount of preventive maintenance is marked in total costs curve when it reaches bottom at 50%.

3 TOTAL PRODUCTIVE MAINTENANCE

TPM is holistic view of the impacts of maintenance in production. TPM means that whole organization is making commitment for sustain, develop and maintain manufacturing capacity. One of the leading principles in TPM is that every employee participates. TPM is basing on teamwork and for managers especially coaching these teams to top performance. When creating favourable environment for motivation growth we can achieve highly motivated employees playing in our team. (Laine 2010)

Total Productive Maintenance (TPM) has been developed in Japan and spread across the world by Japan Institute of Plant Maintenance. There are several similar development methods and tools with TPM like TQM (Total Quality Management) and JIT (Just-In-Time) which are supporting each other. (Tuominen, 2010).

First, Nippondenso a Japanese component manufacturer for automotive industry started using TPM in the year 1961. Actually, name was first introduced as ’Productive Maintenance with Total Employee Participation’ which is quite self-explanatory term. Soon, TPM was implemented also by Toyota and other Japanese manufacturing companies. At latest TPM spread also to rest of the world in 1990’s when competition started to demand quality improvement program implementations like TQM. (Sharma 2012)

TPM relies on five different sections, maintaining quality, productive maintenance, manufacturing technique, cleaniness & order and highly skilled employees. However, Japan Institute of Plant Maintenance defines that TPM should be implemented according to following minimum procedures.

1. Set goals which will maximize equipment effectiveness
2. Create sustainable productive maintenance system
3. Engage all departments – planning, production, quality, maintenance.

4. Involve whole organization in TPM program
5. Create focus groups to motivate and support maintenance

TPM is way of thinking that maintenance is every where, it is not anymore limited to corrective or preventive maintenance actions. In the definition of maintenance according to the TPM belongs that maintenance is emphasized in relation between companys overall income and cost structure. Maintenance should be element that increases gross productivity. Maintenance is always included as part of continuous improvement strategy and as part of companys main strategy. Daily maintenance agenda is not enough when goal is to get high machinery utilization rate and productivity figures. Certain elements should be taken into consideration according to TPM to achieve the goals set, these elements are also called as pillars. (Laine 2010)

3.1 5S

5S is pre-phase for TPM implementation by preparing optimal circumstances by minimizing the environmental effect to the work flow. 5S forms the foundation for other TPM implementation activities by making positive impact to work force motivation in early stage. Implementation of 5S is vital in terms of working safety, quality, efficiency and downtime. Although, 5S system requires constant observation to be succesful. The 5S philosophy is focusing on simplification of the working environment. There are five guidelines in 5S system: (Korkut et al. 2009)

1. Sort
2. Set in order
3. Shine
4. Standardize
5. Sustain

Sorting and arranging working environment to be logical is the first rule. Rarely used material should be disposed, needed materials and equipment should be sorted properly in their own places. This will help the work flow when everything is in order. Second rule is to arrange work stations to be used as fluently as possible to set and maintain own places for tools, machines and materials. It will improve safety in around working station and it will be more faster to find needed tool. Especially, it is imporant to have storage areas set in order according to 5S. Third rule is about setting regular cleaning practice. Clean working place helps to detect abnormalities in equipment as well it makes working more comfortable. Working place should be divided to different cleaning aresas and responsible personnel for each area to be set. In order to do cleaning in regular basis, cleaning times should be recorded and monitored. Fourth 5S rule concentrates to standardization of system. Visible system and performance monitoring should be established. Cleaning procedures and argumentation behind the system are presented in TPM board. Final setp of 5S system is to make it sustainable. 5S training should be arranged as well importance of the system should be explained to employees. Together all these actions will create a solid fountation for TPM implementatition. (Korkut et al. 2009)

3.2 Eight pillars of TPM

According to the most accepted model of TPM, consisting 8 pillars created by Nakajima 1984 who is considered as father of TPM philosophy. Pillars according to Nakajima model are:

- Focused Improvement
- Autonomous Maintenance
- Preventive Maintenance
- Education and Training
- Early Equipment Management
- Quality Maintenance
- Office TPM
- Safety, Health & Environment

(Sharma 2012)

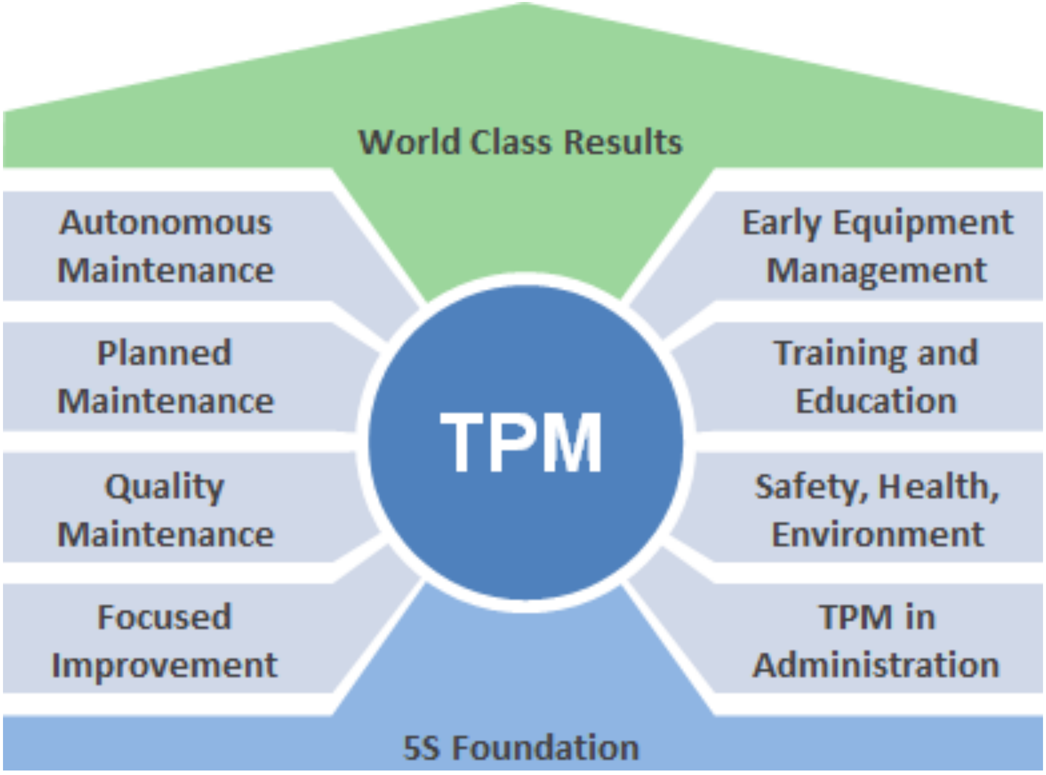


Figure 6. TPM pillars (ABMS 2016)

As introduced is figure 6, all eight TPM pillars are lying in the 5S foundation in which altogether can lead to world class results. All eight TPM pillars are explained in next eight chapters from 3.2.1 to 3.2.8 by starting from focused improvement pillar.

3.2.1 Focused Improvement

Focused improvement is including activities that are maximizing the overall effectiveness of equipment and processes. The main objective is to improve performance by eliminating losses. The performance and higher productivity of equipment is the responsibility of not only engineers and technicians but also operators and managers. The focused improvement methodology of restoring equipment in basic condition and practicing it creates the foundation for productivity improvement. It is essential for continuous improvement to find minor defects because eventually those will lead to major failure of equipment. Cleaning, lubrication, adjusting and tightening are vital part of exposing hidden abnormalities. Process of equipment restoration should be set as continuous action. (Sharma 2012)

Improvement activities are commonly set up for certain problematic equipment or process. Improvement or suggestions are worked through cross-functional teams where different approaches are included in contribution. As soon as improvement team has identified problematic equipment and trained for maintenance of it, team will set improvement goals. Normally, improvements are achieved in maximum of five day long kaizen event. Essential part of the event is measuring the current state performance which could be compared to future performance after improvements implemented. Focused improvement approach is executed as short-term project where improvements are implemented and timeline for follow-ups are agreed. Advantages of focused improvement are accomplished as quick gains by using cross-functional teams by promoting lean methodology. (Gitachu 2016)

3.2.2 Autonomous Maintenance

Organizing maintenance to be holistic approach from bottom to top levels starts from operators, actual machine users. Autonomous maintenance is basicly operator participation in minor maintenance tasks. The main idea behind this kind of thinking is to share maintenance tasks with maintenance personnel and to keep equipment in top shape. Autonomous maintenance is activity which involves all operators to maintain the performance, condition and cleanliness of equipment in approriate level. Operator mindset should be ”I own the machine” instead of ”I run the machine” to succesfully implement autonomous maintenance. It is recognized that autonomous maintenance is one of the highly valued pillars in TPM. Operator is in the key role of maintaining the basic equipment condition and at the same time protecting assets of the company, based on the simple fact that operator is using, cleaning and inspecting equipment daily. Operator is in the key role of discovering abnormalities of equipment. In other hand, it requires that operator is highly skilled and trained to be able to detect faults. Second, shop floor should be organized and cleaned in the way that detecting abnormalities is possible in first place. Autonomous maintenance aims to prevent situation where equipment is not utilized like unplanneds stops and breakdowns. The main focus should be in maintaining basic condition of equipment. (Sharma 2012)

Reporting maintenance activities made is vital part of autonomous maintenance. Whenever operator is performing maintenance tasks or daily checks, it should be reported. For example, if operator finds abnormalities from equipment it must be reported in the maintenance system. Constant monitoring of equipment is foundation for autonomous maintenance and zero defects philosophy. (Laine, 2010)

Normal TPM route for autonomous maintenance implementation is separated in 7 step program according to Toyota.

1. Perform initial cleaning and create metrics system for monitoring cleanliness.
2. Eliminate factors causing disorder and improve accessibility in maintenance locations.
3. Create standards for cleaning and equipment inspection.
4. Perform a wide scale equipment inspection.
5. Arrange training for operator checks and equipment inspection.
6. Organize working environment according to TPM principles: (productivity, zero defects, continuous improvement)
7. Organize autonomous maintenance to be systematic (monitoring, reporting, controlling and continuous improvement) (Laine, 2010)

When maintenance operations are more or less moved to operators' responsibility, it might cause some challenges in organization. The implementation of autonomous maintenance system has challenges recognized similarly when implementing anything new in an organization.

Operators might feel that their workload is getting bigger which will possibly decrease their motivation. Most likely this will lead to conversation between workload and proper wages. Second, skilled maintainers might feel that their work is undervalued and fear of resignation might occur. One motivation for resistance could be also solidarity between operators and their workloads. Change management skills from managers are essential when planning to implement autonomous maintenance system. It is important to create positive athmosphere and expectations of upcoming routines and to explain the long-term benefits. One cornerstone of implementing autonomous maintenance system is to start moderately and increase maintenance tasks to operators as their skills improve. The risk of too rapid implementation cycle and too high expectations from operators might cause system failing and causing more disadvantages than advantages. (Laine, 2010)

Autonomous maintenance will benefit the whole organization. Operators will have more responsibility of equipment they are using and their skills will increase as they participate more in maintaining equipment. Basic maintenance tasks are performed by operators, such as cleaning and lubrication. Whenever abnormalities appear, those can be identified and considered to be part of next maintenance event before causing severe breakdown. Eventually, more skilled maintenance personnel are available for more higher-level maintenance tasks, when operators are focusing on minor tasks. The most important advantage is that lifespan of equipment is increasing and deterioration is prevented. (Gitachu 2016)

3.2.3 Preventive Maintenance

Preventive maintenance or planned maintenance is making scheduled maintenance actions for obtaining optimal equipment and process conditions. Planned maintenance actions are targeted to achieve zero failures, zero defects and zero abnormalities. Secondarily, it is aiming to improve the quality of maintenance department personnel. Yet, the objective is to increase equipment availability. There are different types of maintenance actions available in different situation, which are to reduce maintenance tasks overall. (Sharma 2012)

Preventive maintenance consists different approaches.

Breakdown Maintenance (BM)
Is activity performed when equipment is failing, stoppage or when performance is hazardous.

Time-Based Maintenance (TBM)
This is preventive maintenance activity which is set to be made frequently on daily, weekly or monthly basis. The aim is to prevent sudden breakdown of equipment by maintaining it regularly.

Usage-Based Maintenance (UBM)
This type of preventive maintenance activity is based on number of certain production metrics like operating hours, number of products made and number of processed parts. It is in some cases more convenient to schedule maintenance actions according to stress of production than time-based.

Condition-Based Maintenance (CBM)
This is more specific version of usage-based maintenance by focusing on variation, wear and degration of equipment. For example, worn out die-set should be replaced before quality of the product degrades

Predictive Maintenance (PM)
Predictive maintenance is furthermore activity of monitoring all other metrics concerning equipment like voltages, currents, flows, deviations and clearances.

Corrective Maintenance (CM)
Corrective maintenance activities take place when equipment is having abnormalities effecting negatively into performance. The objective of corrective maintenance is to eradicate failure modes by continuous improvement actions, autonomous maintenance for example. It aims to

reduce amount of maintenance tasks performed by using TPM framework and corrective actions.
(Sharma 2012)

3.2.4 Education and Training

Education and training pillar forms the foundation for whole TPM activity in organization. Since, the operators' skills and knowledge acquired for maintenance is essential and will define the effectiveness of the TPM implementation. Eventually, education and training pillar is supporting others pillars and bringing content to them. The training could be conducted in various ways. Training methods in manufacturing facilites could be arranged as on the job training, off the job training or one point lesson. One point lesson is widely used and recognized to be one of the most efficient tool for skill transfer and learning. One point lesson is rapid learning through pinpointed view of equipment structure, function or mtehod used. It is important that one point lesson is visual and could be practiced repeatedly during the day. Especially, when there is lack of time for training, one point lesson could be solution to be followed. One point lesson is highly suitable for learning minor maintenance tasks conducted by operator. Free discussion and analysis of the specific problem and one point lesson made is also typical approach for this way of learning.
(Sharma 2012)

3.2.5 Early Equipment Management

Early equipment management also called as maintenance prevention is actually preface before using or purchasing equipment to consider their reliability, maintainability, safety and operarability as well as estimated maintenance costs. TPM approach not only consider reliability and maintainability when purchasing new equipment but aims to overall system improvement by prevention of all other losses. Equipment with effective maintenance prevention should not in any case produce nonconforming products or break down. (Sharma 2012)

Practical ways of early management are collected from previous maintenance experience as collaboration with engineers and machinery suppliers. By ensuring equipment to reach optimal performance, the positive impact on profitability will be secured as reduced maintenance costs. There are some factors which should be considered from the very beginning when desingning new equipment. Initially, accessibility to parts, lubrication, cleaning and inspection are in key role. Early management should notice also ergonomical placing, feedback mechanism and safety features. Not to mention placing of machinery considering changeover procedures. Before installation of new equipment, operator concerns should be adressed. (Gitachu 2016)

3.2.6 Quality Maintenance

Quality maintenance is maintaining process and product in certain specifications. Quality maintenance is strongly formed by the combination of other pillars. Monitoring and inspecting equipment condition is in vital role. Quality maintenance aims to react before equipment variation or defects take place. (Sharma 2012)

The main objective is to get specification first time right by finding root causes of failure modes rather than using quick fixes. It is important to undestand that when defected product appears it will cause lot of extra work down the value chain or process. Fishbone diagram or 5 why root-cause-analysis are well structured methods for finding root cause or bottlenecks from manufacturing process. (Gitachu 2016)

3.2.7 Office TPM

Office TPM or administrative TPM are supportive functions or activities like logistics and warehousing. As mentioned earlier TPM is methodology for whole company and office is strongly part of it also. Accordingly, it is important to improve continuosly office funtioncs as well, since they do have implicit impact on manufacturing operations. (Sharma 2012)

Additionally, horizontal co-operation in organization according to TPM principles will increase understanding of implementation benefits. For example, if spareparts warehouse system is improved as support process it will have a positive effect on the manufacturing process. (Gitachu 2016)

3.2.8 Safety, Health & Environment

Safety, health & environmental pillar is counted in as from sustainability point of view. Manufacturing industry is globally huge source of pollution, as a result TPM does have strong emphasis in this area. Of course, this pillar aims to prevent any human or equipment errors leading to injuries or accidents. Zero safety and zero environmental accidents will be achieved by identifying and eliminating any abnormalities. (Sharma 2012)

In practice, workers must be safe when working in manufacturing site. The value for the customer should not be done by the benefit of workers health or life. It has been noticed that correlation exists between productivity and safe working environment. However, if accident or near-miss situation occurs, the investigation of equipment should be done by cross-functional team to work towards more safe environment by placing guards or instructions. Not to mention compulsory personal protective gear or first-aids kits around the working area. (Gitachu 2016)

3.3 Six big losses

As TPM aims to minimize all potential losses in manufacturing, it also emphasizes the quality of product and process. When improving equipment effectiveness according to TPM methodology, we are actually looking into six big losses which are derived from three main categories of manufacturing parameters. In TPM identifying connection between losses and effetiveness is fundamental (Almeanazel 2010). In next chapter 3.4, the connection is explained more closely in the form of OEE calculation.

1. Downtime Losses

   Downtime from the process point of view means that output of production is zero. When output is zero, the period of time under examination is the amount of time when equipment is not running. Downtime losses could be separated in two different categories.

   a. Downtime could appear when equipment fails or breaks down. Breakdown losses are measured from the actual breaking down of equipment to the point where it is fixed, up and running again.
   b. Second reason for downtime loss could be setup and adjustment time. These losses appear when product or process have to be changed for different reasons. The most typical reason for setup and adjustment time losses are changeovers, exchange of dies, jigs and tools. This loss type generally is consisting setup, start-up and adjustment downtimes. (Almeanazel 2010)

2. Speed Losses

   Speed losses are cases where equipment is not performing as it should be in referenced speed. Speed loss could be identified as lower output of equipment. This is measured as comparing theoretical working load to actual.

   a. Reduced speed of equipment caused by quality variation when operating original speed.
   b. Minor stoppages and idle time are considered also as speed loss when appering regularly. Usually, this types of stoppages are forcing to reduce the equipment speed. (Almeanazel 2010)

3. Defect or Quality Losses

   Quality loss happens when process output is not considered to be good according to quality specifications.

a. Quality defects are material losses and also requires labor when products are reworked or scrapped. Calculation of this type of losses could be done by comparing quality products to the total production.
b. Yield losses are such as raw material losses caused by supplier quality defect. It could be also quality defect produced in starting up after adjustments or changeovers. (Almeanazel 2010)

3.4 Overall Equipment Effectiveness

As introduced in chapter 3.3, six big losses in TPM are stricly related to ideal performance and zero loss methodology and OEE calculation is way to measure how succesfully losses are controlled. OEE could be described as the ratio between actual equipment output and the maximum equipment output in optimal manufacturing conditions. (Almeanazel 2010)

In manufacturing industry OEE is viewed as key performance measure considering all kind of processes and equipment. In the year 1988 Nakajima introduced OEE as TPM performance measurement system which focuses into manufacturing equipment by offering clear overall metric. In todays’ manufacturing world it has become essential tool for productivity measurement. Traditional metrics are insufficient when handling problems and identifying required improvements for increasing productivity. Originally used metric for availability was loading time, but since the Nakajima days, OEE calculation has evolved by the fact of adequate metrics in some areas like material input, labour and planned downtime. Nevertheless, the accuracy of OEE is depending on the quality of collected data. (Sharma 2012)

Overall equipment effectiveness is simple way to measure current status of production. Higher productivity could be achieved by utilization of man, machines, material and methods. OEE consists three essential parameters, Availability (A), Performance (P) and Quality (Q). (Karthick, Kumar & Vivekprabhu, 2014)

Figure 7 indicates how traditional six big losses are connected to OEE calculation. Recommended six big losses are rephrased to more explanatory form from traditional.

Overall Equipment Effectiveness	Recommended Six Big Losses	Traditional Six Big Losses
Availability Loss	Unplanned Stops	Equipment Failure
	Planned Stops	Setup and Adjustments
Performance Loss	Small Stops	Idling and Minor Stops
	Slow Cycles	Reduced Speed
Quality Loss	Production Rejects	Process Defects
	Startup Rejects	Reduced Yield
OEE	Fully Productive Time	Valuable Operating Time

Figure 7. Six big losses (Vorne Industries Incorporation 2016)

OEE calculation is done by following pattern which is presented in figure 8.

Figure 8. OEE Calculation (Vorne Industries Incorporation 2016)

Availability is the first OEE factor having impact on total OEE. Availability is calculated from the ratio of planned production time and actual run time (Vorne Industries Incorporation 2016).

Availability = Run Time / Planned Production Time

Planned production time equals to the time that equipment is expected to produce good units. It comes from planned stops like maintenance days or similar schedule losses subtracted from all time available (Vorne Industries Incorporation 2016).

Planned Production time = All Time – Schedule Loss

Run time is calculated by subtracting stop time from planned production time. Stop time or downtime is defined as unplanned stops, breakdowns or planned stops like changeovers (Vorne Industries Incorporation 2016).

Run Time = Planned Production Time – Downtime

For example, if beverage can decorator is planned to run 24 hours per day and changeovers and breakdowns take 5 hours from day, availability will be (24-5) / 24 = 0,79 = 79%

In performance rate calculation there is two main factors needed, ideal run rate and total output including defects. Ideal run rate is designed maximun speed for equipment to produce good parts (Almeanazel 2010).

Performance = (Total Output / Run Time) / Ideal Run Rate

For example if decorator ideal running speed is 1500 CPM (cans per minute) and total output is 1596000 cans then the calculation is executed as follows, (1596000 cans / 1500 cans per minute) / (19 h * 60 min) = 0,93 = 93%

Quality is last factor of OEE calculation. Quality rate indicates the effect of rejected parts produced compared to total output. These are products to be scrapped or reworked (Almeanazel 2010).

Quality = (Total Output - Defects) / Total Output

For example if decorator produces 188000 cans which does not meet the quality standars the OEE value will be calculated, (1596000 - 188000) / 1596000 = 0,88 = 88%

Eventually, we can calculate the total OEE value for the decorator example used.

OEE = 0,79 * 0,93 * 0,88 = 0,64 = 64%

To gain Japanese World Class PM Excellent Award plant has to achieve total OEE over 85%. Calculation of OEE should always be modified and concerned according to the process under investigation. In most of cases calculation model is choosed based on available data collection and analysis method. Especially, when there are many different products, batches are short with large amount of changeovers. Naturally, quality of the raw material have an impact on performance. Therefore, there is possibility for greater variation of OEE average. Nevertheless, it is not crucial when OEE calculations from same process are conducted similarly and then could be compared as long-term results between each other. (Laine, 2010)

In figure 9, typical OEE structure of beverage can manufacturing process is visualized and presented. Factors highlighted in yellow are differentiating from normal efficiency calculation of equipment. As we can interpret the visualization, the planned shut down is counted as only factor effecting on planned production time or loading time as in figure 9.

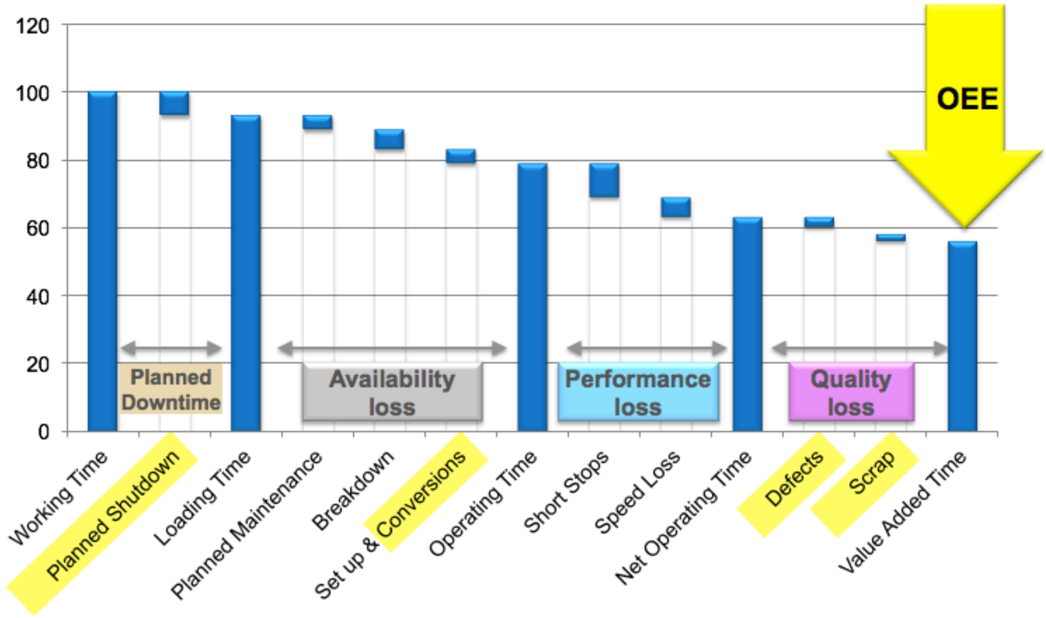


Figure 9. OEE Model (Macey, 2015)

OEE is indicated with yellow arrow, which is subtraction from total working time from availability, performance and quality factors. OEE is translated as value adding time which means the total time when good parts had been produced. By subtracting value added time from working time we could calculate the possible time available for operating time by using TPM implementation for example.

In practice, when evaluating the OEE result it has to be remembered that results could vary in different manufacturing facilities. For example, places where changesovers consume significantly time from production time it is challenging to improve OEE. Accordingly, OEE target should bet set by prevalent manufacturing process. More important is to improve OEE result incrementally than try to achieve something that is not possible. (Laine, 2010)

Laine (2010) states that improving OEE, the plant will get more products to be sold with same amount of people working in same time frame. If advantages of OEE improvement could not be utilized in other words if extra products manufactured could not be sold it is in management responsibility to balance with capacity and investments so that overproduction does not appear. In the situation when market demand is growing, improving OEE is way to get more production capacity without expensive investments. In this case cost per units is decreasing. Estimatingly, OEE improvement by 3-7% will double companys earnings before interest and taxes. Generally, maintenance costs are 5% of company's revenue. Nevertheless, if savings does hit the maintenance budget by 10 to 20 percent, the effect in OEE might be negative. Usually, when this happens the savings gained from cutting maintence costs are smaller than profit lost in production.

Costs of TPM are often divided into traditional accounting categories like direct maintenance costs, spare part costs, external maintenance costs and labour costs. It rarely happens that lost profit is calculated in, which is actually the biggest missing opportunity for gained return. Maintenance costs could be divided into three different categories, lost profit, indirect costs and direct costs. Lost profit could be counted in as part of maintenance cost in accounting system when we identify that breakdown, changeovers, slow cycles, reduced speed, process defects and reduced efficiency are caused by lack of proper maintenance actions. Indirect maintenance costs are rejected process outputs and material costs. Resource consumptions like, energy and water costs are usually calculated in. Unavailing equity like fixed assets, working capital and interes expenses are calculated as indirect costs. Direct costs are salaries, spare parts, equipment, bought-in services which are certainly considered as part of accounting. (Laine, 2010)

4 PROCESS IMPROVEMENT

Continuous improvement or process improvement is a philosophy which was presented by Deming as improvement ideas that are increasing successes and reducing failures or defects. Otherwise, improving processes is seen as enhancing creativity, gaining operational excellence and competitive edge in market. Clear fact is that involvement from all levels of organization is needed. Process improvement or continuous improvement does not necessarily need great investments. Especially, when looking in the history of continuous improvement, initiatives came from the shop floor people, not from the management. Positive organizational changes were rewarded as early as in late 1800s. Nowadays, we can define improvement by different measures but when talking generally improvements, they are targeted to eliminate waste in processes. Improvements could be gained through different tools and techniques. (Bhuiyan & Baghel 2005)

One of the earliest process improvement methods developed is the Deming cycle. The Deming cycle was modified from the original idea of Walter Shewart's three step process to continual improvement, hypothesizing, executing an experiment and testing the hypothesis. The Deming wheel is more evolved version of Shewarts method. The Deming cycle consists four different steps, Plan, Do, Check/Study and Act. PDCA/PDSA is method for both short-term and long-term organizational learning and improvement. The Deming cycle has created a solid foundation as companies' process change and improvement methodology. In the planning stage current state analysis is made and process is described. Additionally, problems are identified and action plans are made. In Do stage plans are implemented in different ways, for example process pilot projects is commonly used method. Data from pilot or trial is collected and documented. In the Study/Check stage project is evaluated whether it is heading on right direction or if it needs still adjusting. In the Act stage improvements are implemented as part of organizations standard working procedure. It is introduced to all organization levels as the best practice at the moment. Then cycle returns back to Plan stage when new opportunities are identified. The Deming cycle is presented in Figure 10. (Evans & Lindsay, 2015)

Figure 10. Deming cycle (The Deming Institute 2016)

According to Power (2010) it is not essential for all industries and companies try to thrive process improvement culture. Actually, it could be irrelevant in certain business areas like startups. Not to mention companies which are competing in high-end product development industry, for example Apple or Google. They do not necessarily focus on operational excellence, whereas they are trying to maintain industry leadership instead by bringing the most innovative products on market. When considering strategic priorities, they might change over time due various factors like economic cycles, leadership changes and other organization changes. When taking a view where process improvement usually comes tempting are situations when short-term business is going strong and companies want to aim in the future with new investments or acquisitions.

If company is suffering drastic turndown in economy, usually process improvement is first place for savings. In my opinion this is totally wrong mindset. Why company does not try to achieve benefits without reducing labour costs or maintenance budget? This is certain way to complete doom when you are losing your best assets, your skilled and talented people.

Nevertheless, according to Power (2010) I agree that it is vital to understand where and when improving processes is critical. The idea of improving processes is also to keep timing and focus correct and turning it into as part of company’s competitive strategy.

There are various different methodologies available for companies to choose the most attractive process improvement method for their needs. Especially, Total Quality Management (TQM), Six Sigma, Business Process Re-engineering (BPR) and Operational Excellence has been the most popular approaches lately. Despite which methodology the company will lean on, it is factual that they will include diffent toolsets, yet principles included are quite close each other. In this case study the process improvement approach is done based on Six Sigma DMAIC roadmap. (Sokovic, Pavletic & Kern Pipan, 2010)

4.1 Six Sigma

Six Sigma came famous when Motorola was first to implement it succesfully in mid-1980s. After that it came popular in other big companies and wave of mass implementations started. Six Sigma is an effective and precisely set approach in improvement of manufacturing product and processes. The foundation of Six Sigma is strongly based on total quality and continuous improvement principles. Originally, Six Sigma was to improve four key metrics, quality, productivity, cost and profitability. Nevertheless, Six Sigma is bringing new tools and variations to improvement implementation process and philosophy. Performance improvement is behind hard work and it requires the engagement of whole organization to gain reduction of defects, better employee skills, efficient operations and overall more fluent work flow. Six Sigma’s fundamental purpose lies on improving organizational processes. It aims to find root causes and corrective actions, reduction of cycle times, higher assets utilization and return on investment. Six Sigma seeks to explain the financial benefit when making improvement approach. Since, it might be financially crucial step toward the more competitive positioning in the market. The toolset of Six Sigma is actually in the problem solving methodology called DMAIC. (Evans & Lindsay, 2015)

Six Sigma offers structured problem solving path which relies on quite common route according to known quality revolutionists like Deming, Juran and Crosby. Many common themes are building a foundation for Six Sig problem solving and improvement methodology. First, problem is redefined and analyzed. In practice, collecting and analyzing the data and studying the problem from different viewpoints are the main activities to be done. Second, events or meetings where brainstorming, free thinking and generating ideas is in focus to develop solutions or improvements. Next step in this path is to evaluate and select the most potential idea which will lead to most value-adding situation. Eventually, final step is to implement this strictly choosen idea and present the advantages of it to the organization. The main principle behind the DMAIC methodology is – define, measure, analyze, improve and control. (Evans & Lindsay, 2015)

When following DMAIC process improvement pattern, first in the beginning the problem is defined. This leads to project selection and setting up the Six Sigma project team. Project team is build-up as cross-functional, all departments and specialist whom are adding-value to the project are involved. Definition of project scope and problem is clearly defined, usually it consists improving some part of the process or reliability of equipment. Project scope should also define the impact to quality and customers. At the beginning current state of errors, performance, customer complaints and all other relevant metrics should be described. The definition phase should also imply the expected level of performance after the project. Likewise the project team, schedule, resources and project management should be addressed. (Evans & Lindsay, 2015)

Measure phase focus is in internal processes and how measurement of critical to quality charasteristics is done. The understanding behind the causality between process performance and customer value is essential at this stage. This is also the data collection point where procedures for gathering facts are set. The most important data is collected from existing manufacturing processes and practices as well as from employees of an organization. Also, factors that need to be monitored and controlled during the project and eventually in post-project stage should be considered. When collecting data it must be remembered that what type of data we need, where it can be found, how it will be collected and last what are questions we try to answer? (Evans & Lindsay, 2015)

In analysis stage the most common mistake is to skip immeadiately into solution or improvement without consentrating the real root cause. At this point on DMAIC roadmap it is essential to ask, why? Why defects, lack of performance or variation occurs? The hypothesis of relationships between different factors are identified and measured to verify are statements related to the problem valid. In the analysis phase Six Sigma lean on statistical analysis methods and thinking. Through the quantitative analysis it is confirmed that conclusions of root cause are reasonable. (Evans & Lindsay, 2015)

The final step focuses to maintain the achieved improvement. Maintaining, in this case means that new working standards or procedures are established. Monitoring the results, reviewing the performance of key measures and checking the overall situation periodically is vital part of this last phase as well. (Evans & Lindsay, 2015)

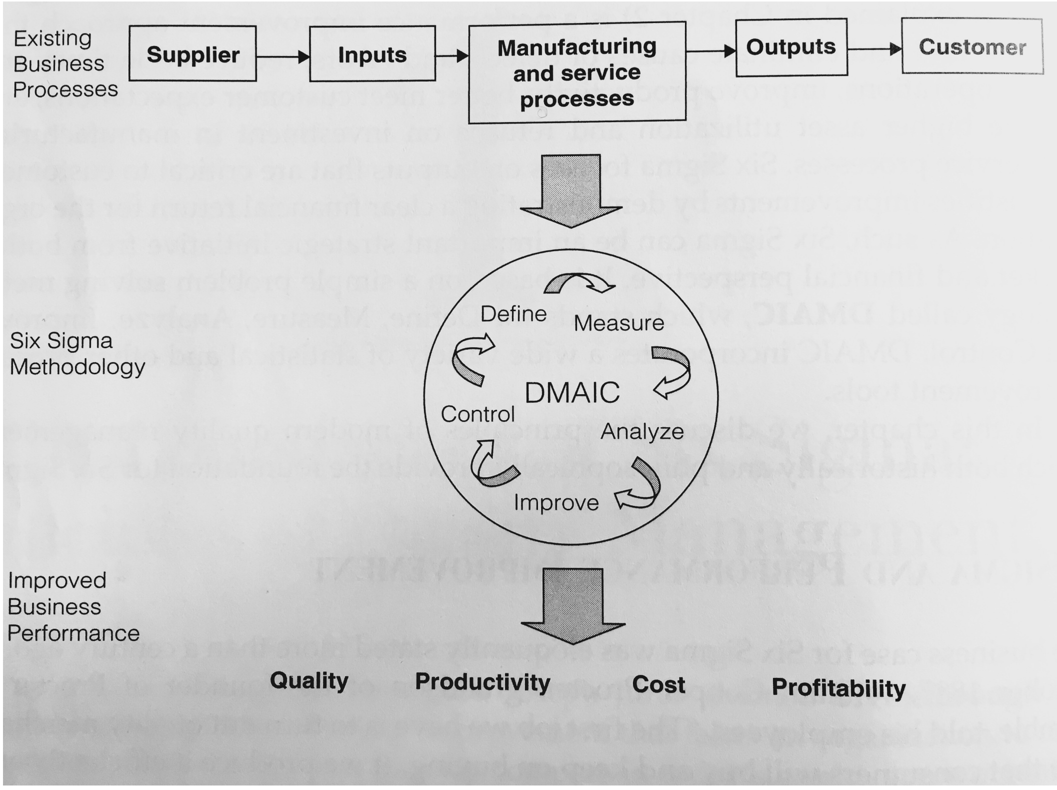


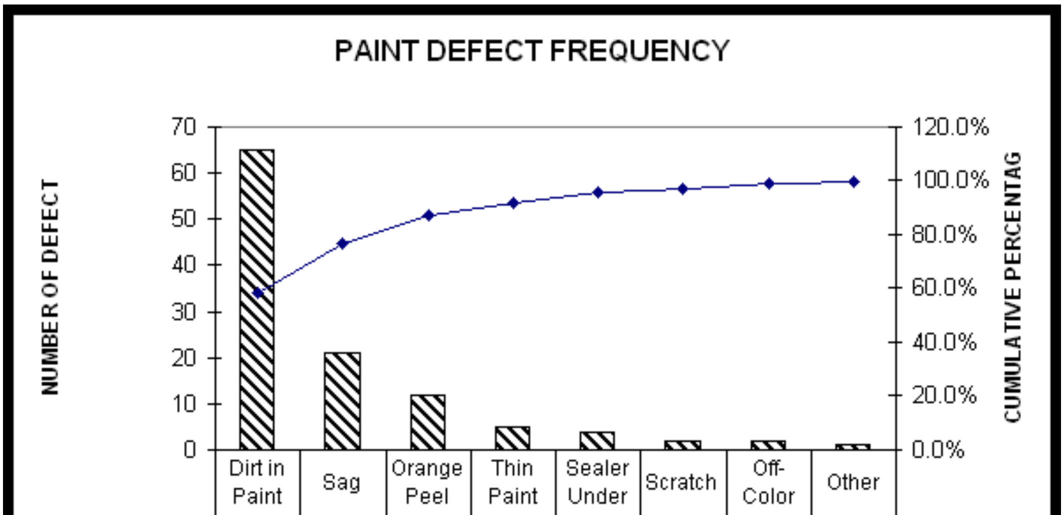
Figure 11. Six Sigma and Process Improvement (Evans & Lindsay, 2015)

DMAIC methodology is summarized in figure 11. It presents very simplified pattern of relationship between Six Sigma, process improvement and factors which will cause increase in business performance eventually.

4.2 Pareto analysis

Pareto analysis came famous by Vilfredo Pareto, Italian economist who notified in the year 1906 that 85 percent of the wealth in Milan was distributed only to 15 percent of the people. Pareto analysis helps in identification of major issues which could be caused only from few causes. Pareto analysis also called as Pareto principle states that minority of causes or inputs in most of the cases are leading to a majority of the results or outputs. It could be also called as 80/20 rule. (Koch, 2008)

Especially, when choosing direction to improvement project, Pareto analysis will be useful tool. In a Pareto distribution, observed causes are sorted from highest count to lowest. The great idea behind the Pareto diagram is a histogram where you can identify the most significant problems. Pareto diagram could be also used for monitor the progress of improvement project. Pareto diagram is really simplified tool for showing the important data and root causes behind the high costs or issues related. For example, quality data could be analyzed throughout Pareto diagram and few major issues could be identified and root cause analysis and improvement project establishment should be considered. (Evans & Lindsay, 2015)



	Dirt in Paint	Sag	Orange Peel	Thin Paint	Sealer Under	Scratch	Off-Color	Other
Defects	65	21	12	5	4	2	2	1
Percent	58.0%	76.8%	87.5%	92.0%	95.5%	97.3%	99.1%	100.0%

Figure 12. Pareto diagram (MoreSteam 2016)

We can interpret from example chart figure 12, that 80 percent of defects are coming from dirt in paint and sag. Actual percentage in that point is 76.8, but the majority of defects are focused in those two causes. Cumulative frequency curve is also shown in chart to visualize the relative magnitude of defects.

4.3 Root cause analysis

Especially, in the analyzing phase of the DMAIC roadmap, different methods for finding root causes are essential. Root cause is defined as condition which is allowing defect to happen, when this particular cause or condition is fixed then the problem is eradicated permanently. Five why technique will lead eventually in the real root cause after asking five times why. The idea behind five why is to go behind the symptoms and identify source of the problem. Brainstorming activities with improvement teams and all relevant persons is key to evaluate every possible option and cause for the problem. Cause-and-effect diagram is one popular way in problem solving process. Cause-and-effect diagram (Figure 13) is visual tool also called as fishbone diagram or Ishikawa diagram. There is horizontal line which ends to problem under investigation. From the main line there are several branches, possible causes listed. The diagram identifies most likely causes where improvement team selects the most obvious cause and focus on that and further data collection. (Evans & Lindsay, 2015)

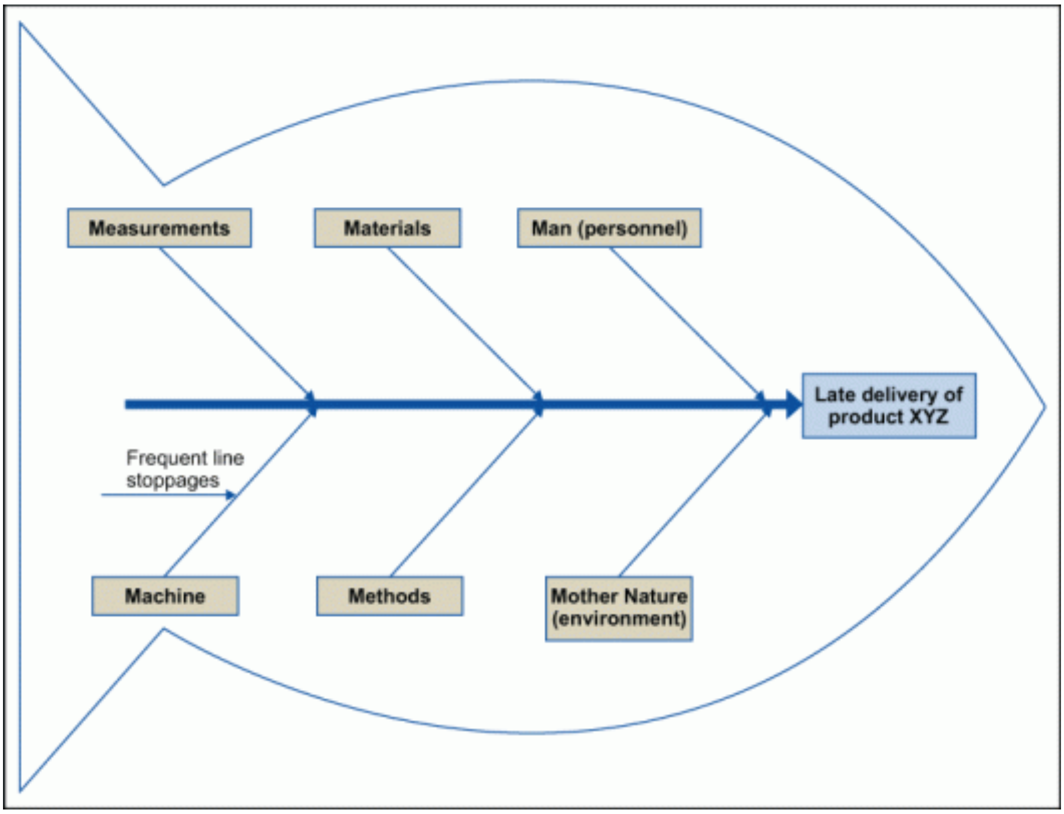


Figure 13. Cause-and-effect diagram (iSixSigma 2016)

5 RESEARCH APPROACH AND METHODS

This research is conducted as action research. Typical action research is process which aims to change or improve things. Research topic could vary from organization procedures to understanding behind processes and activities. According to Tappura (2009) objective of action research is to change existing activities and to solve problems in organization. Quite often, workers are active part of the research. However, researcher is also taking part to the action behind the research. Action research process includes typically planning, action and evaluation phases. In action research, earlier experiences and historical data are analyzed. Mostly, action researches are qualitative approaches, nevertheless there is no valid reason for utilizing quantitative methods. Improvement needs are directly related to process or organizationin in question. The improvement project is usually established by the employees of organization. Improvements are taken into practice and results are visible in every day work.

In this study, understanding the role of maintenance is essential to form a improvement method which ties whole organization together. Action research is the most suitable option for the case when improvement is made as project type of approach. Implementation of the method follows Six Sigma DMAIC roadmap and different analysis tools related. Holistic approach for the case is formed from the maintenance strategy point of view and charasteristics of TPM methodology.

Quantitative metrics are reasoned according to the nature of manufacturing process and improvement. In this case, indicators are OEE measurement, downtime measurement, spoilage amount and maintenance activity as number of tasks generated.

The improvement method, tagging system, for the problem was modified from the original idea of Milton Keynes plant, England. Tagging system is introduced in chapter 5.3.

5.1 Maintenance in Ball Beverage Packaging Europe

Like in any modern manufacturing plant, also in Mäntsälä plant, maintenance activities are following some of the most popular maintenance philosophies. Actually, it is easy to detect that there is part of TPM, part of PM and part of methods typical for can manufacturing plant implemented for maintenance system overall.

Maintenance department is quite typically structured in Mäntsälä plant. Under the maintenance manager, team is divided to electrical and mechanical maintenance supervisors, following with electricians and day maintainers. In shifts, approach is more straightforward. In every shift, there is one electrician and two maintainers. Figure 14 visualizes the structure of maintenance in Mäntsälä plant.

Figure 14. Structure of maintenance department

As mentioned, maintenance department is doing preventive maintenance actions. These actions are including daily, weekly, monthly, yearly PM tasks made by maintainers or operators. Safety checks and daily maintenances are followed in daily basis by shift managers. Target for daily safety checks and maintenance is 100%. The maintenance information system in use is ArrowMaint which focuses on doing task lists and scheduling maintenance activities. Maintainers and operators are permitted to do entries and write down fault notifications. However, it is identified that it is covering mostly day staff tasks than shift maintainers and operators.

Maintenance budget is made based on 8+4 forecast, where production figures are correlating to maintenance budget. After 8 months, the current situation is evaluated and compared to planned forecast whether there is shortfall and bigger investements are postponed for the remaining 4 months. When budget is surplussing there is this room for investments or bigger maintenance tasks and spare parts. Therefore, motivation for improving production output with adequate maintenance will eventually come directly from the budget.

From my personal point of view, this approach is troubled. If company is making more cans, it will get more to maintenance budget. In the end, question is that how high production figures are achieved? By running the machines with full speed until breakdown or time to time with planned maintenance to maintain equipment efficiency at desired level. This is tricky question because it actually indicates the maintenance strategy quite straightforward and tells the mindset of maintenance department and plant management. Is the management pursuing short term profit or long term growth?

5.2 Introduction to beverage can manufacturing process

History of beverage can manufacturing reaches back to the year 1935 when first beer cans came to the market by American brewery Gottfried Kruger. The first beverage cans were made out of tin and there was no opener in the lid. Aluminium beverage cans rolled out to the market in 1960’s. Since that, the market share of aluminium cans as beverage containers has skyrocketed across the world. The first tear-off can opener was invented in the 1963 by Ohioan Ermal Fraze. Current opening mechanism was invented in the year 1975 by Dan Cudzik. (Suomen Palautuspakkaus Oy 2016a)

Beverage can manufacturing process is really straightforward process, but particularly volatile for the unplanned down times and breakdowns. Simply, because of the straightforward nature of the process, if some equipment in between front end and back goes down, it will cause the down time and efficiency lost for whole production line. Production is usually divided into two main areas, front end and back end. Front end includes all the processes before the printer. Back end consists the area from printers to packaging and final inspection of product. Layout of the process is explained more detailed in the Figure 15 (VISY 2016).

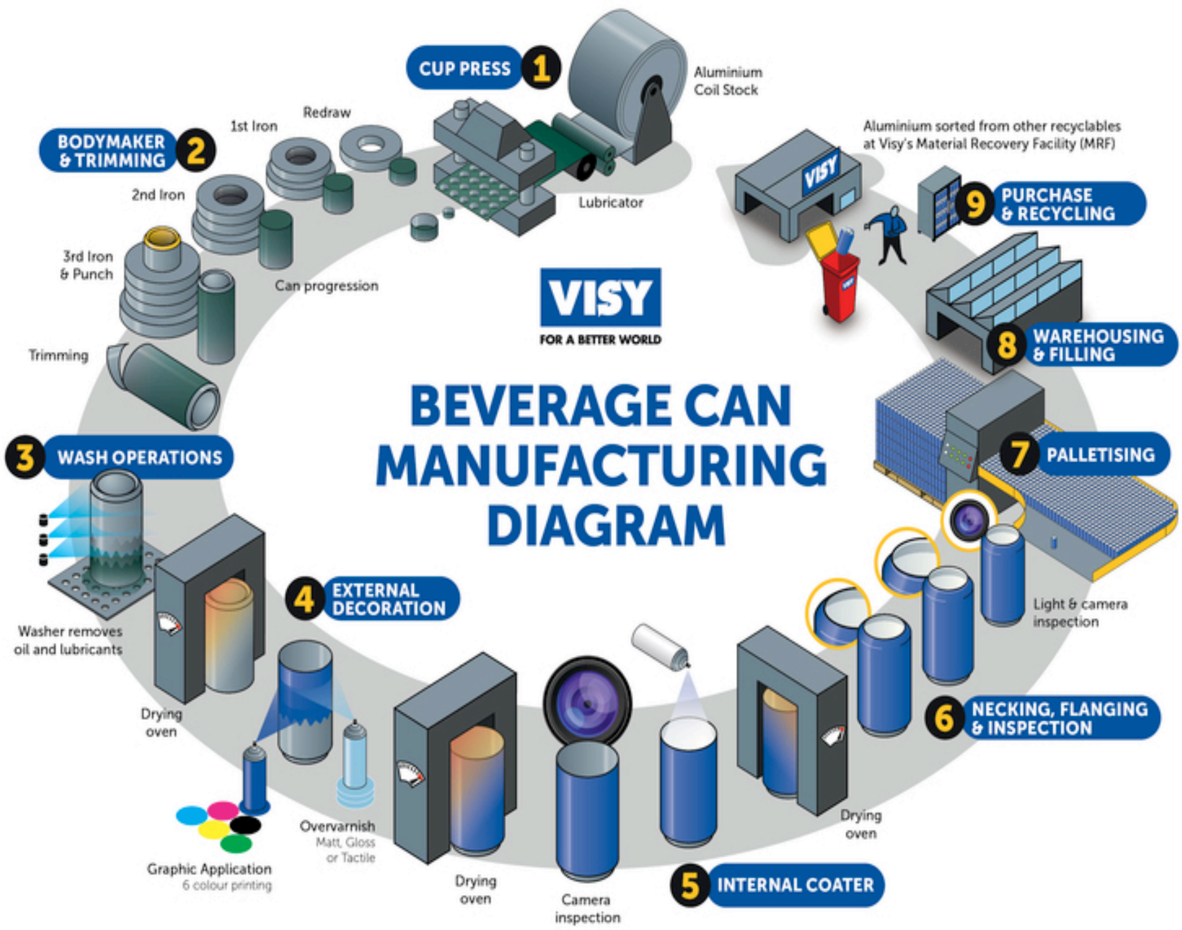


Figure 15. Beverage Can Manufacturing (VISY 2016)

Front end area starts with the 10000 kg aluminum sheet coil feeded into lubricator from uncoiler mandrel. Lubricator lubricates the surface of the aluminum so that it will endure the upcoming shaping of cupper. Cupper includes die set of 14 similar tooling which cuts and punches the sheet into a form of cup. Cups will continue their flow towards the next equipment and the left over metal sheet from cupper, skeleton, will be sucked to the vacuum chute and to the scrap baler. Cupper makes approximately 200 to 220 strokes per minute. So when calculated 14 cups per stroke times 200 it is in total 2800 cans per minute (CPM).

Next phase is shaping the cup into a form of can. It happens in bodymakers, in Mäntsälä plant there are 11 bodymakers in total with top speed of 340 to 360 CPM per machine. In this stage can get its form by drawing the punch through redraw ring and 3 differents sizes of dies which will stretch the wall of the aluminum so that it reaches the final height and wall thickness according to the specification. Each bodymaker will create a can with rough edge, so it needs to be trimmed. Trimmer cuts the rough edge of the can, by spinning the can through the blade cartridges.

Next, trimmed can is washed from all the oil and lubricants used in shaping process and alternatively some treatment is applied for mobility of the can. Can is dryed in the last section of the washer oven.

Then bright washed can is decorated by printer with 8 different optional colours. Printer machine is operating at mechanical maximum speed of 2000 CPM and in Mäntsälä there are 2 printers, but rated speed is set to 1500CPM each. After the ink is applied into the surface by the customer design requirements the overvarnish is applied to cover the inks or to create additional effects. In this point, inks and overvarnish are still wet, so they need to be dried in pin oven in 200 celcius degrees.

After printing, cans are sprayed inside with lacquer to cover the aluminium of corrosive beverages like energy drinks and soft drinks, not that much of lacquer is applied to beer products. Lacquer is dried and cured in the inside bake oven, to vaporize possible solvent residues. Maximum speed for single spray machine is 400 CPM, in Mäntsälä plant there are 14 inside spray machines in total, seven per line.

In next phase, the neck of the can is shaped in necker flanger machine in 12 differents stages step by step. At this point, the aluminium is so thin and fragile that neck needs to be shaped bit by bit to stay intact. Maximum speed for one necker is 3000 CPM, Mäntsälä holds two of them.

After necking process cans are inspected by inside inspection camera to be sure that there is no foreign substance, dirt or residue of previous process materials inside the can. Label verifier is located right after the inside inspection camera to secure that there is only one desing of label in the line at once.

Finally cans are palletized, stacked into layers of 391 cans each, usually consisting 22 layers per pallet. Final step is visual inspection of the pallets, performed by quality control before sending complete pallets into warehouse to be shipped.

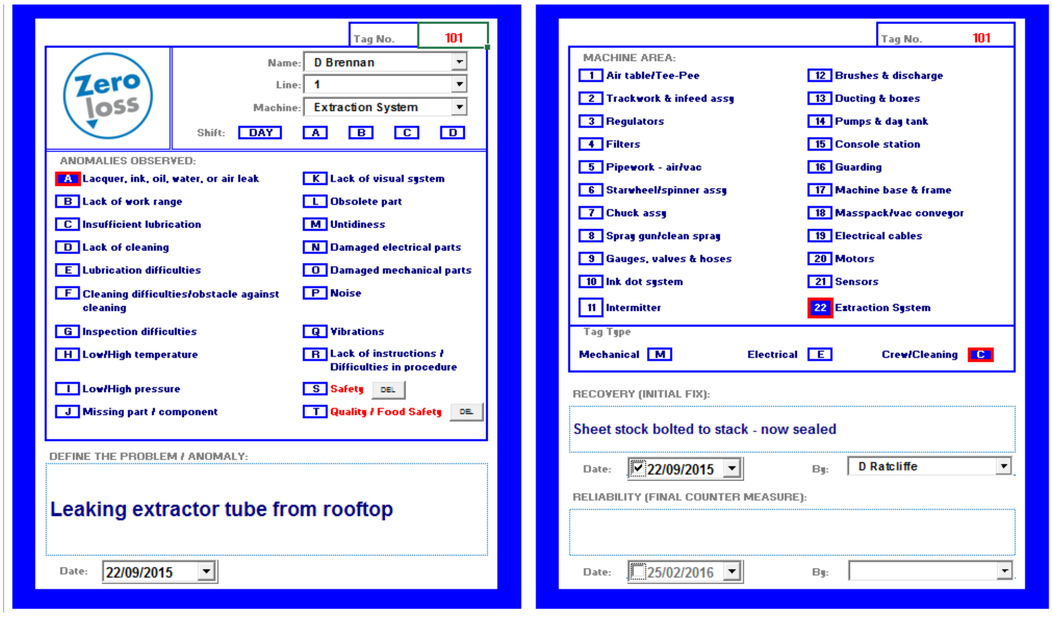
If quality defects appear pallets will be put aside for further investigation. These pallets are called Hold For Inspection pallets (HFI spoilage). HFI pallets are either scrapped or reworked. Reworking happens through offline sorting which requires extra manning. Scrapped pallets are sent back to aluminium sheet supplier to be recycled.

5.3 Tagging System

During the year 2015 several improvement projects were launched in Mäntsälä plant by different initiatives and actual need for improvements were recognized. Nevertheless, many of projects were focusing on changeover time which are planned downtimes everytime. How come the sudden unplanned downtimes have not gained bigger attention? As discussed in theory chapters, unplanned downtimes will create huge amount of downtime when calculated together. Situation at the beginning of the 2016 was that the crew I was working in had not initiated any improvement actions. As a result, I travelled to England in March 2016. My destination was Milton Keynes plant, which is one of the oldest still functioning plants in Europe, to see how they are coping with old equipment. Primarily, the reason for my visit was to explore their maintenance practices and to see if there is something valuable for Mäntsälä plant to be implemented. As a result the tagging system was noticed and potential of it was recognized. Especially, because it was based on operators' daily actions and moreover proactive approach than reactive. There was typical characteristics of TPM based autonomous maintenance actions identified. I noticed also that it was involving not only maintenance management but whole organization and therefore the communication between shopfloor and management was immediate.

The foundation of tagging system is in operator's ability to observe any anomalies in equipment and come up with proper solution.

The idea behind the tagging system method is to create a tag whenever anomaly is detected. Tag is simply a piece of cardboard with different categories of defects and problems. Optimal situation is to have operators filling a tag and finding corrective action immeadiately by themselves. If operator could not solve the problem, it will be forwarded to more skilled maintenance personnel.



Tag No. 101

Zero loss

Name: D Brennan
Line: 1
Machine: Extraction System
Shift: DAY A B C D

ANOMALIES OBSERVED:
A Lacquer, ink, oil, water, or air leak
B Lack of work range
C Insufficient lubrication
D Lack of cleaning
E Lubrication difficulties
F Cleaning difficulties/obstacle against cleaning
G Inspection difficulties
H Low/High temperature
I Low/High pressure
J Missing part / component
K Lack of visual system
L Obsolete part
M Untidiness
N Damaged electrical parts
O Damaged mechanical parts
P Noise
Q Vibrations
R Lack of instructions / Difficulties in procedure
S Safety DEL
T Quality / Food Safety DEL

DEFINE THE PROBLEM / ANOMALY:
Leaking extractor tube from rooftop
Date: 22/09/2015

Tag No. 101

MACHINE AREA:
1 Air table/Tee-Pee
2 Trackwork & infeed assy
3 Regulators
4 Filters
5 Pipework - air/vac
6 Starwheel/spinner assy
7 Chuck assy
8 Spray gun/clean spray
9 Gauges, valves & hoses
10 Ink dot system
11 Intermitter
12 Brushes & discharge
13 Ducting & boxes
14 Pumps & day tank
15 Console station
16 Guarding
17 Machine base & frame
18 Masspack/vac conveyor
19 Electrical cables
20 Motors
21 Sensors
22 Extraction System

Tag Type
Mechanical M
Electrical E
Crew/Cleaning C

RECOVERY (INITIAL FIX):
Sheet stock bolted to stack - now sealed
Date: 22/09/2015 By: D Ratcliffe

RELIABILITY (FINAL COUNTER MEASURE):
Date: 25/02/2016 By:

Figure 16. Tag example

Different defects related to equipment condition are vital to be detected and therefore operator is the optimal choice for monitoring if any strange noises, oil leaks, vibrations or smells are appearing. Tags are collected from different crews, operators and maintainers. After filling the tag, it will be typed into a tag register which holds all the tags. From the tag register the status of the tags could be followed and changed according to the situation. In Milton Keynes plant, tagging system was very visual and tagging board was established next to equipment in question.

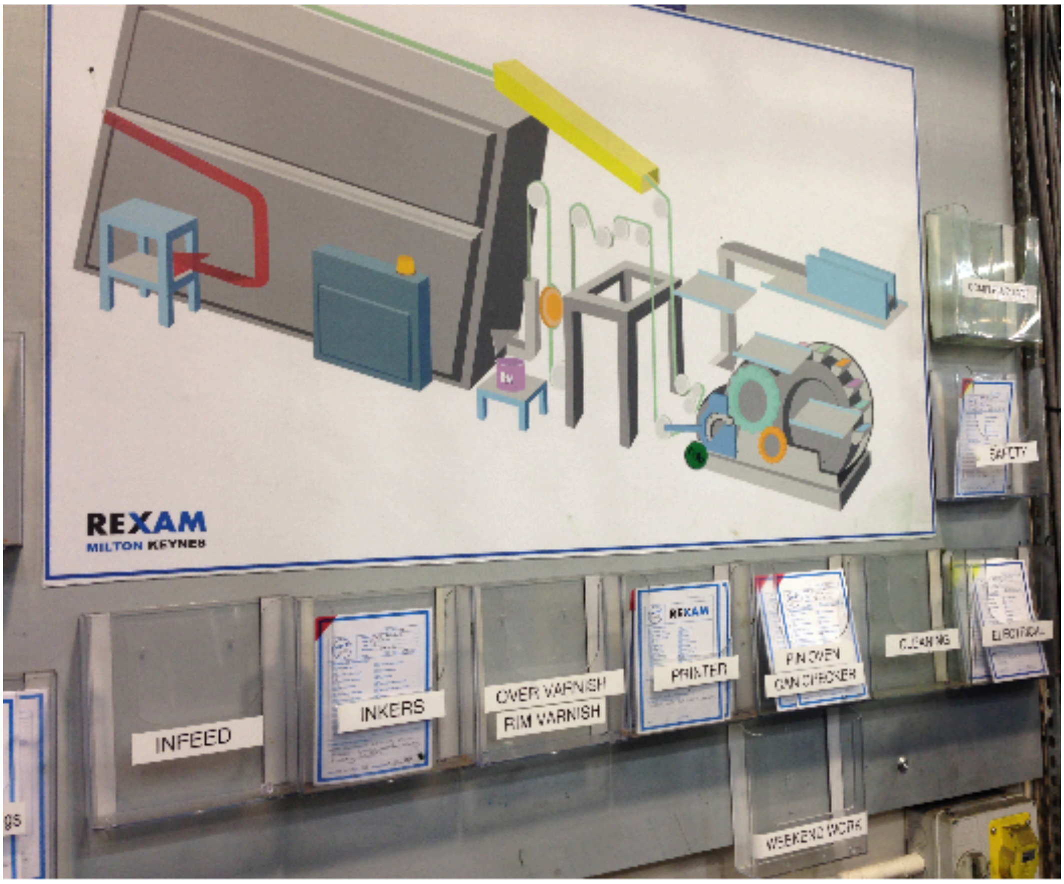


Figure 17. Tagging board example in Milton Keynes

The tagging system project started in 25th of April 2016 by kick-off meeting. In the kick-off meeting, improvement team was established containing two operators, shift manager and shift maintainer. Project was supervised by maintenance manager, production manager and zero loss coordinator. I worked personally as project manager.

Before starting the actual implementation project, the defining phase had to be conducted. The area for the improvement was choosed according to different production KPIs. When examining the data in chapter 6.1 it became obvious to choose both decorators as target of improvement project.

Project was implemented in 6 different phases according to Figure 18 project plan.

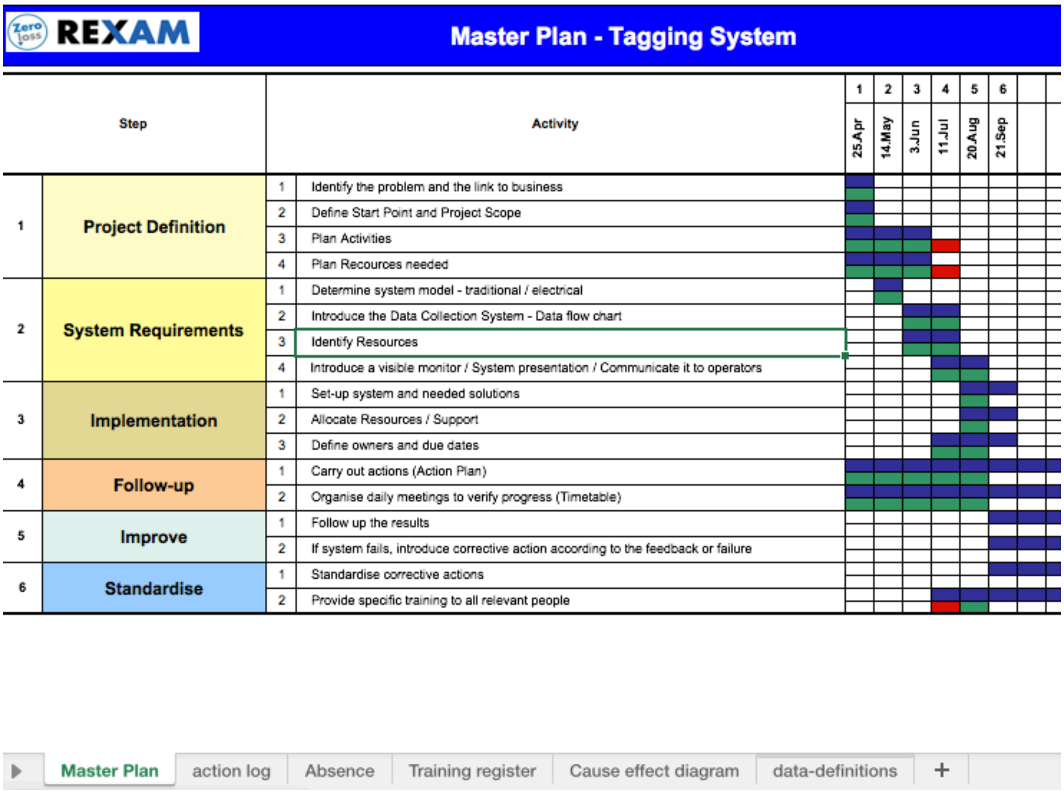


Figure 18. Project plan

First, project was defined and requirements for the method were determined. Then system was implemented and all users were trained. Then data analysis meetings were set as follow-up step states. Next cycle of implementation is improving, which was only partly fulfilled because of estimated project time. Project will continue as pilot to the August 2017. We can say that due the date, method will be standardized and second improvement cycle will be possibly made.

As mentioned earlier, the system should generate discussion and increase communication, but most importantly train operators to find abnormalities and report of them. Via detecting abnormalities it is possible to gain more production time when proactive approach is done by operators. If and when upcoming faults are detected on early phase, it is easier to combine maintenance actions to planned downtime events. Based on the simple fact that operators know their equipment best and they spend more time with equipment than anybody else. Figure 19 presents the data flow in the tagging system. Actually, it presents flow of tag data after anomaly is detected.

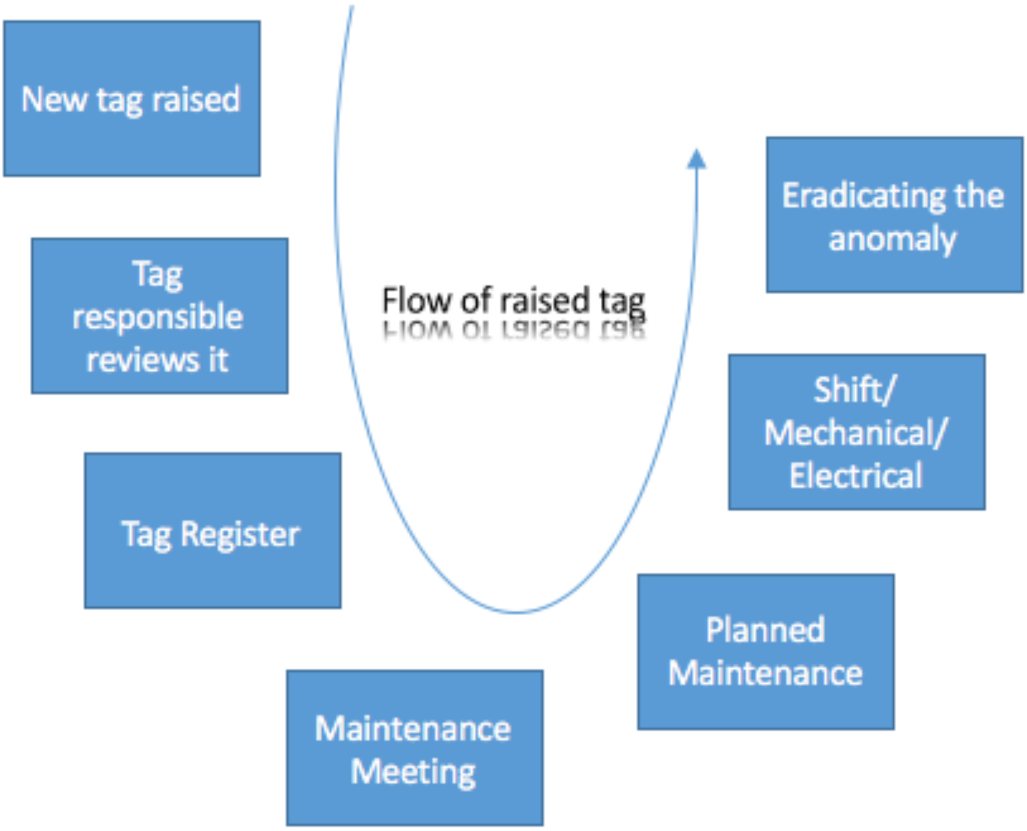


Figure 19. Tag flow

First, after anomaly is detected it will be reviewed by designated person of the tagging area whether the tag is eradicated already or it needs further actions. Anyhow, after reviewing the tag it will be typed into tag register. Tag register is register which is based on MS Excel and it holds functions for exporting different charts and summaries of tag situation. Figure 20 and 21 captured from the tag register are visualizing the system.

Figure 20. Tagging system user interface and functions

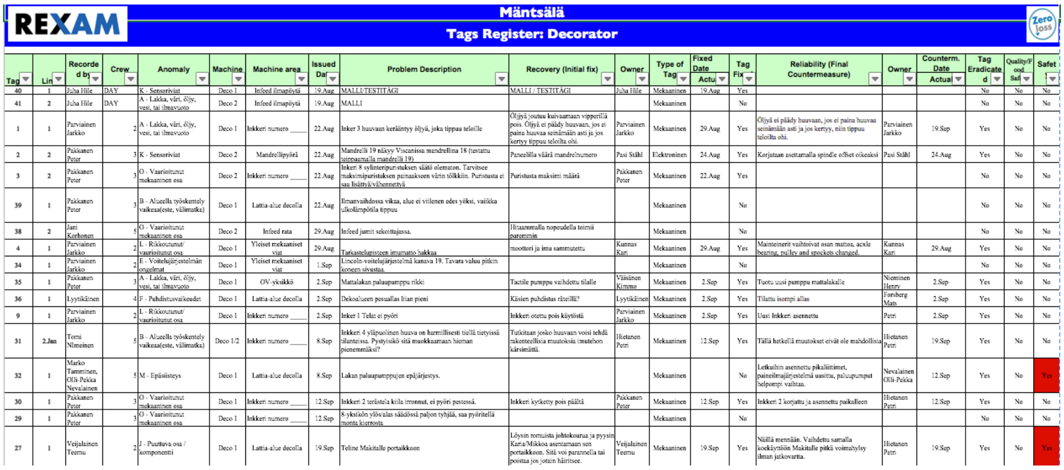


Figure 21. Summary of tags

Tags could be analyzed and sorted by the anomaly, area and crew. It is possible to view also tags related to safety, quality and food safety.

Next in tag flow, tag is brought to maintenance morning meeting which are held from monday to friday. In the meetings, it is decided what are possible countermeasures for the anomaly and who will be responsible for fixing the tag. Optimal situation for fixing tags is when there would be downtime anycase, like planned downtime or changeover. Actually, anytime that it would not interrupt normal manufacturing situation. The type of tag determines whether it is sorted out by mechanical, eletrical or crew personnel. Eventually, the main target is to eradicate the tag, so that same fault or anomaly woud not appear in any possible case.

Project was implemented to roll-out phase at 20th of August 2016. After the implementation to shopfloor, using the tagging system was started immediately by operators and person who was designated to tag collection and as main user for tag register. In chapter 6, the results of the tagging system maintenance improvement method are presented as before and after in OEE metrics and maintenance activity.

6 RESEARCH RESULTS AND ANALYSIS

The original challenge was to gain more production time by avoiding unplanned stops or breakdowns and to nourish the communication about the maintenance actions. However, to get that point it was essential to find out bottleneck of the process and analyze the root causes, before taking any actions towards improving maintenance. According to research results we can state that bottleneck was found. Equipment downtime from both back end lines and HFI spoilage indicators were choosed as bottleneck investigation paretos. In addition, root cause analysis of bottleneck revelead more specific factors causing production losses. As relying on the analysis of the current situation tagging system method was implemented. Next, OEE results before and after implementation were recorded and analyzed. Nevertheless, also the communication and co-operation in maintenance were mentioned as problems. Therefore, maintenance activity was measured in bottleneck area by comparing before and after situation in maintenance tasks generated. In following chapters 6.1 and 6.2 results are analyzed thoroughly. More profound analysis and conclusions are discussed in the chapter 7.

6.1 Bottleneck and root cause analysis

The bottleneck was identified simply by using pareto diagram to see from choosed indicators which are the most major causes for production losses. Data was exported and analyzed from information systems monitoring production and quality figures such as HFI and production downtime. Downtime is essential factor to be analyzed, because it does have direct influence on plant performance. HFI spoilage is indirect factor, which is causing rework activities like sorting, scrapping and warehouse reservations. As combining these two, it will form a comprehensive review of current situation.

Machine	Time Elapsed	%	Speed	Downtime effect to production
Spray Gun #14	1806:55:16	13,14%	320	2,80 %
Spray Gun #12	1758:34:31	12,79%	320	2,73 %
Decorator #1	1626:03:00	11,82%	1500	11,82 %
Spray Gun #13	1555:32:31	11,31%	320	2,41 %
Spray Gun #16	1385:14:49	10,07%	320	2,15 %
Spray Gun #15	1121:52:34	8,16%	320	1,74 %
Spray Gun #17	1119:52:14	8,14%	320	1,74 %
Spray Gun #11	1099:33:13	8,00%	320	1,71 %
Necker #1	985:11:08	7,16%	1500	7,16 %
Palletizer #1	799:46:08	5,82%	1500	5,82 %
IBO #1	305:34:56	2,22%	1500	2,22 %
Decorater #1 Oven	185:03:49	1,35%	1500	1,35 %
Camera #1	03:02:18	0,02%	1500	0,02 %
Mixed Label #1	00:00:22	0,00%	1500	0,00 %

Table 1. Downtime Pareto BE Line 1

When analyzing data from the year 2016 to identify bottleneck and major downtime sources, we can see it from the table 1. Spray gun #12 and #14 has beed down more than decorator #1 but the effect to production efficiency is not as significant.

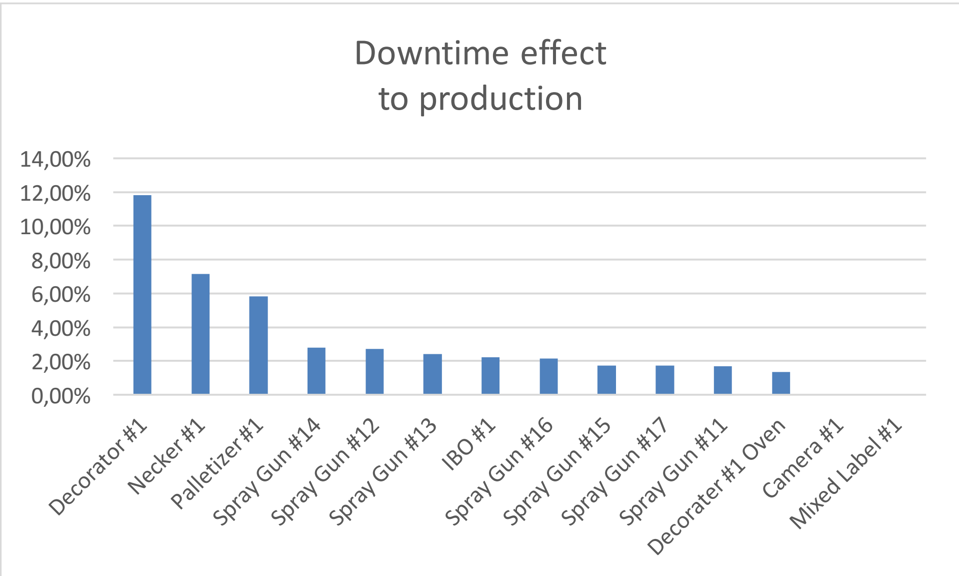


Figure 22. Downtime Pareto BE Line 1

Pareto diagram indicates clearly the largest source of downtime when speed of equipment is considered as one of the calculation parameters. It is justified to compare it that way, because spray guns are working as one unit with 7 guns in series. Even if 2 guns are down, the output is still 1600 CPM and there is no significant effect to production flow.

Machine	Time Elapsed	%	Speed	Downtime effect to production
Decorator #2	1981:21:33	13,80%	1500	13,80 %
Spray Gun #27	1918:31:12	13,36%	320	2,85 %
Spray Gun #26	1282:54:31	8,93%	320	1,91 %
Spray Gun #23	1269:22:04	8,84%	320	1,89 %
Spray Gun #21	1252:53:58	8,73%	320	1,86 %
Spray Gun #22	1244:23:19	8,67%	320	1,85 %
Spray Gun #25	1238:09:00	8,62%	320	1,84 %
Spray Gun #24	1194:28:02	8,32%	320	1,77 %
Necker #2	1093:06:51	7,61%	1500	7,61 %
Palletizer #2	1078:11:11	7,51%	1500	7,51 %
Mixed Label #2	307:43:45	2,14%	1500	2,14 %
IBO #2	235:44:53	1,64%	1500	1,64 %
Camera #2	135:25:29	0,94%	1500	0,94 %
Decorator #2 Oven	111:34:44	0,78%	1500	0,78 %
Light Tester #2	15:17:34	0,11%	1500	0,11 %

Table 2. Downtime Pareto BE Line 2

Also when analyzing data from table 2 downtime pareto BE line 2, it is obvious that decorator #2 is effecting the most significantly on production downtime.

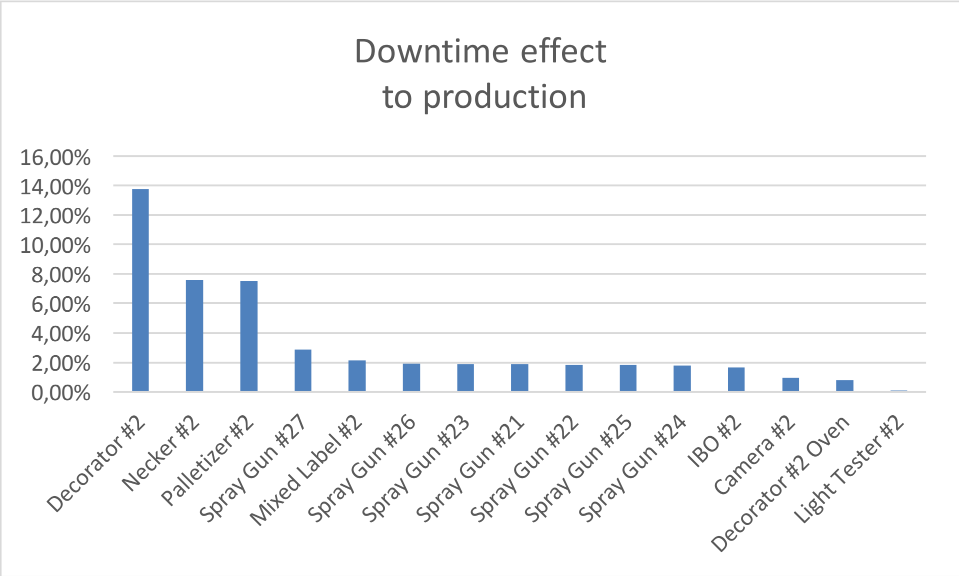


Figure 23. Downtime Pareto BE Line 2

Pareto diagram (figure 23) is illustrating clearly that decorator #2 is similarly bottleneck machine as decorator #1 is in line 1. Therefore, based on downtime data from both lines we can state that best platform for improvement will be decorator area.

In addition, it is relevant to consider HFI spoilage as one indicator for choosing equipment to be in the focus area of improvement. Because, defects causing HFI spoilage are in some cases related to equipment malfunction. Therefore, maintenance actions are effecting indirectly to HFI spoilage. Figure 24 shows HFI spoilage chart from 2016. HFI chart is divided by areas, HFI reason groups and eaches are in vertical axis. HFI chart data is collected from both lines. When comparing HFI reasons, it is evident that decorator area is causing almost twice as much HFI spoilage as next two reasons, packaging and front end.

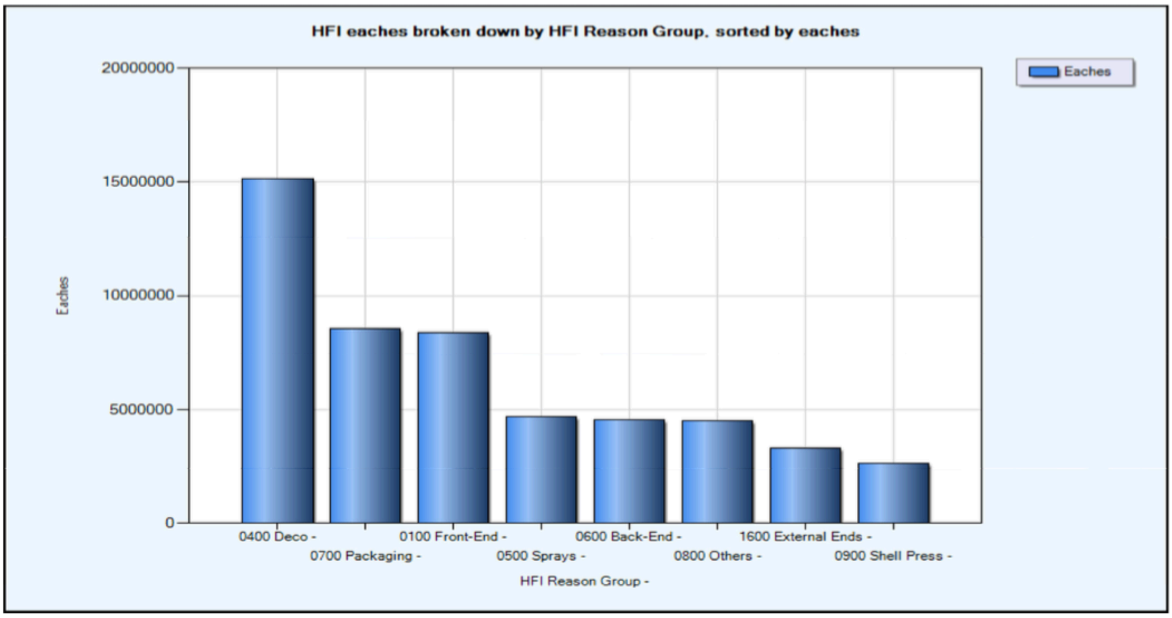


Figure 24. HFI Spoilage chart

When summarizing downtime data and HFI spoilage data together we can state that decorator area is causing most of the downtime and HFI spoilage. Leaning on the bottleneck analysis results the action research method was targeted and implemented to decorator area.

To examine more closely decorator related problems, improvement team made root cause analysis of reasons causing decorator downtime. Root cause analysis was made by using tool called cause and effect diagram. Figure 25 is showing the diagram which is emphasizing the most common and influential issues. Problems were categorized in five different sections, man, machine, method, material and environment. Distinctly, the most of the problems were allocated to method category. Improvement team had change to give different weight to different problems. In the method category most influential causes were, lack of proper preventive maintenance, lack of training, co-operation and communication between shifts and day staff. Efficiency of maintenance system was mentioned also as well as in man category and operator personal skills were emphasized. When calculating scores together, the causes influencing most the problem are from highest to lowest method, man, environment, material and machine.

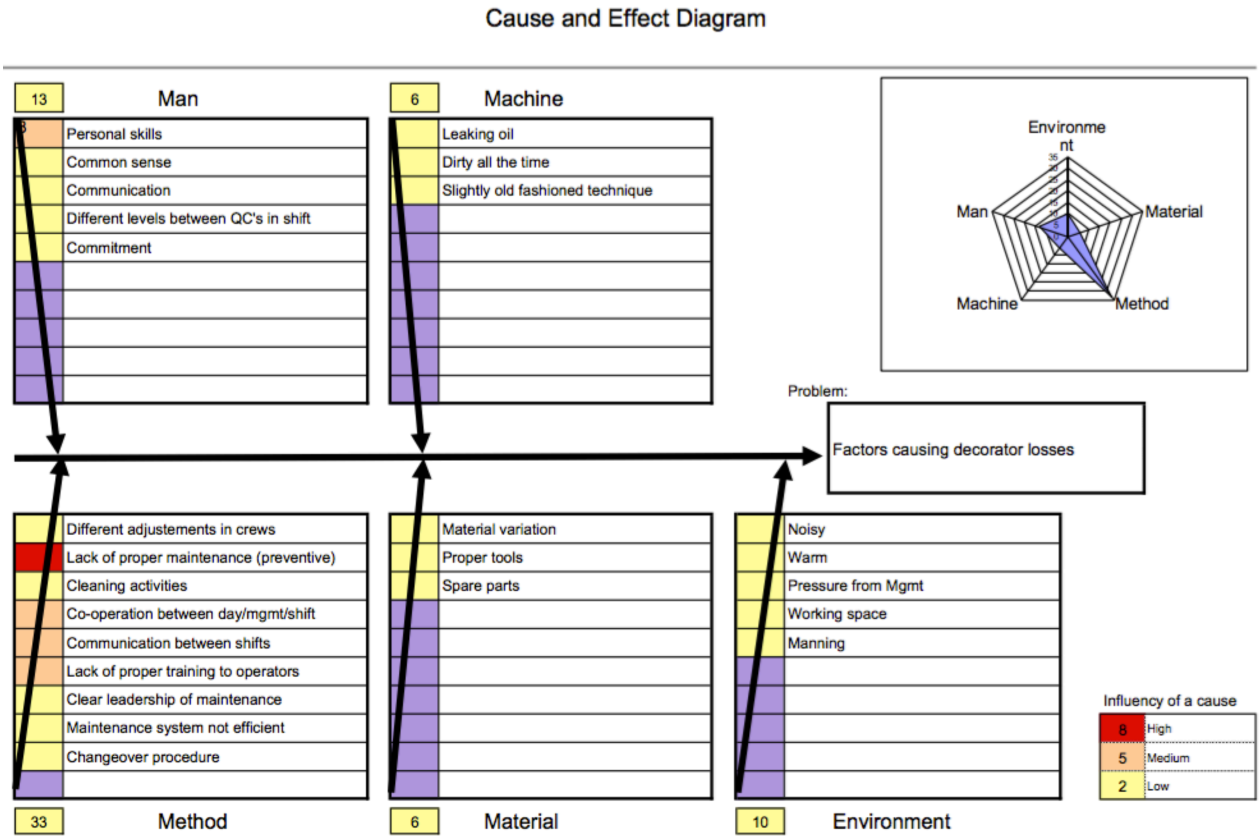


Figure 25. Cause and effect diagram of decorator issues

Overall, when putting together the data and evaluation of the decorator related problems and root causes, it can be identified that tagging system will be applicable method for implementation. Since, it is involves whole organization and therefore increases the communication and co-operation between departments. Likewise, the most influential cause, lack of proper maintenance will be addressed by operator involvement and proactive approach. Nevertheless, if operator can't fix the anomaly, in this case tag, it will be relocated to more skilled personnel. As such, the principles behind the tagging system should cover the issues raised in the root cause analysis. Anyhow, the situation after the implementation will be evaluated in chapter 6.2 OEE measurement and analysis.

6.2 OEE measurement and analysis

OEE measurement reaches back to October 2015 until to the day when tagging system was implemented to production in 20th of August 2016. Since, both decorators were selected to tagging system project, lines were separated into individual results to see if there is any variation between lines. In the OEE chart black dotted line is marking the point of tagging system implementation. Blue bar stands for machine availability, which means time for production after unplanned downtime and changeovers. Red bar visualizes machine performance after reduced speed and small stops. Green bar means spoilage or quality in this case, which is formed of startup rejects and direct production rejects. Therefore, decorator infeed and discharge can differential is calculated as machine production spoilage.

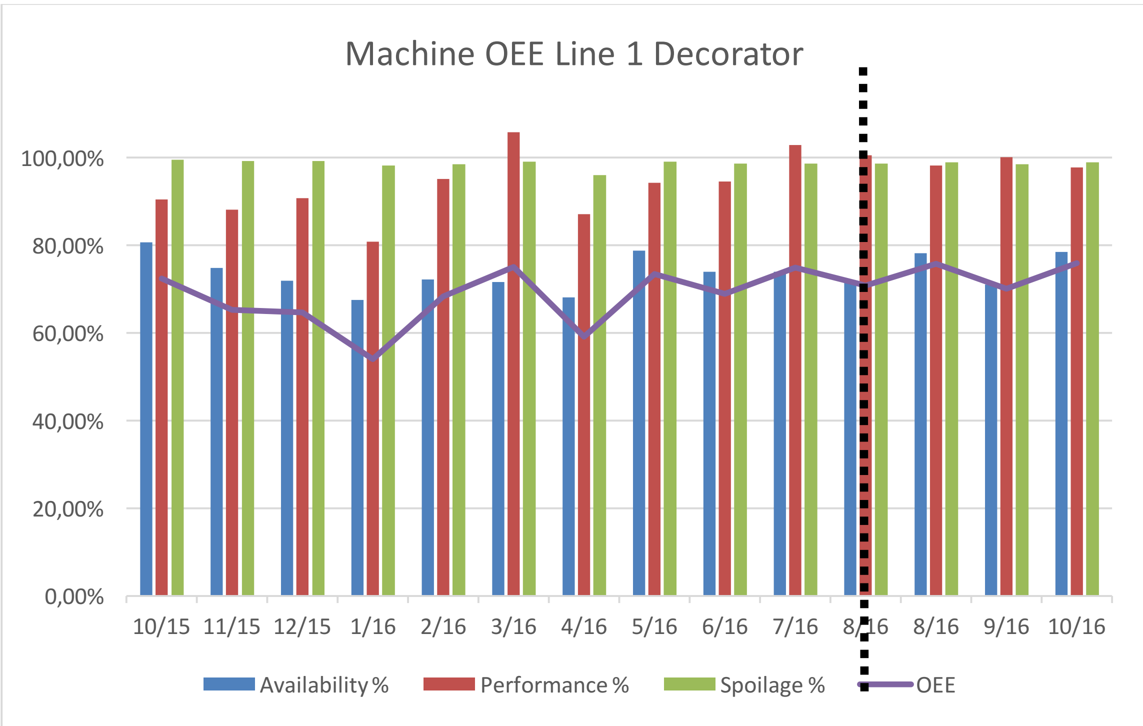


Figure 26. OEE Line 1 Decorator

When interpreting the overall OEE trend we can state that there is no significant visual improvement. However, plot is slightly above the average before improvement project. As the chart visualizes, availability is dragging in lower level than performance and spoilage, which indicates that there must be certain amount of equipment failures and changeovers. At few points, performance pillar is exceeding the 100 percent limit. It means that equipment has been running faster that the rated speed 1500 CPM. When examining results, it is obvious that the most beneficial OEE factor for improvement is availability. Because if availability increases it will release more production time and through that the performance could have potential to increase as well. It had to be considered also that performance might actually decrease slighty when more production time is acquired by availability increase. Anyway, production output might increase even performance factor is slightly reduced. Performance losses are typically from speed losses and small stops. The performance trend seems to be more stabile after tagging system implementation. To analyze more closely OEE results, it is worthy to separate OEE factors.

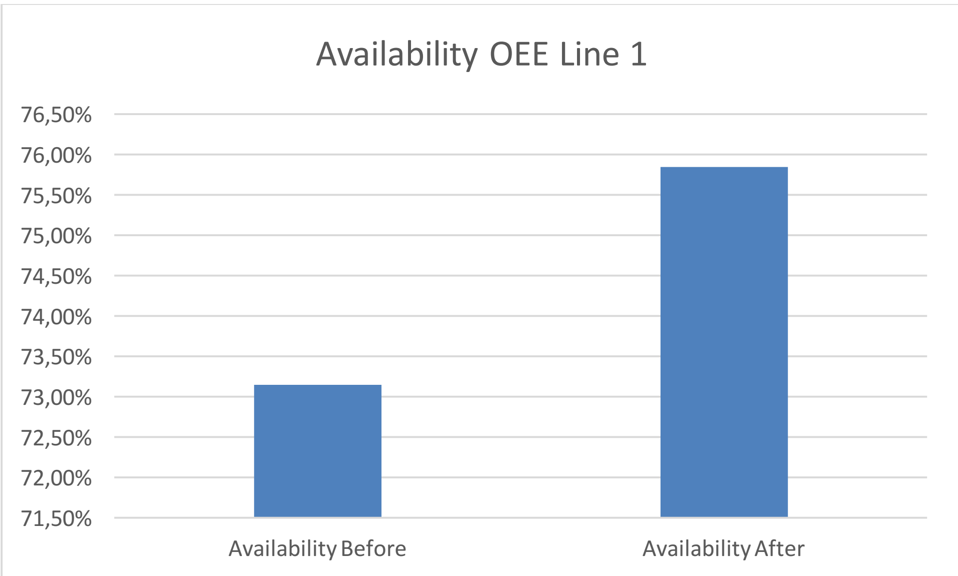


Figure 27. Availability OEE Line 1

Availability chart (figure 27) is showing 2,69 percent increase in availability factor, from 73,15% to 75,84%, which is significant change when translated to amount of production time available. When calculating for example daily availability improvement average per day it will be from one day 1440min * 0,0269 = 38,7min. When calculated to actual cans produced it means 38,7min * rated speed 1500CPM = 58 104 cans.

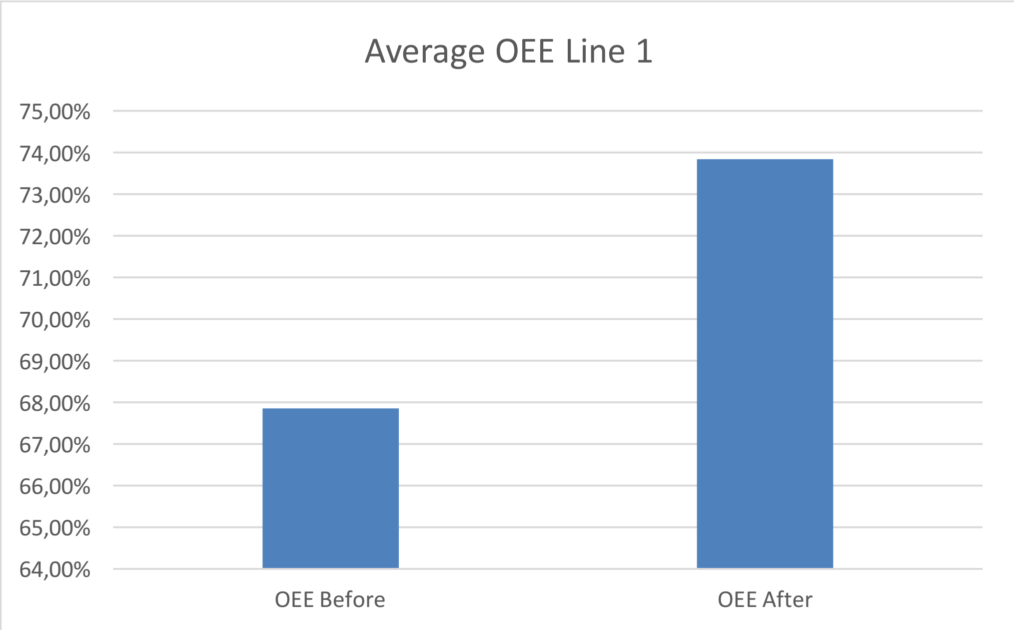


Figure 28. Average OEE Line 1

Results (figure 28) from line 1 decorator is showing that availability improvement is having a positive impact to OEE. Average OEE increased from 67,85% to 73,85%.

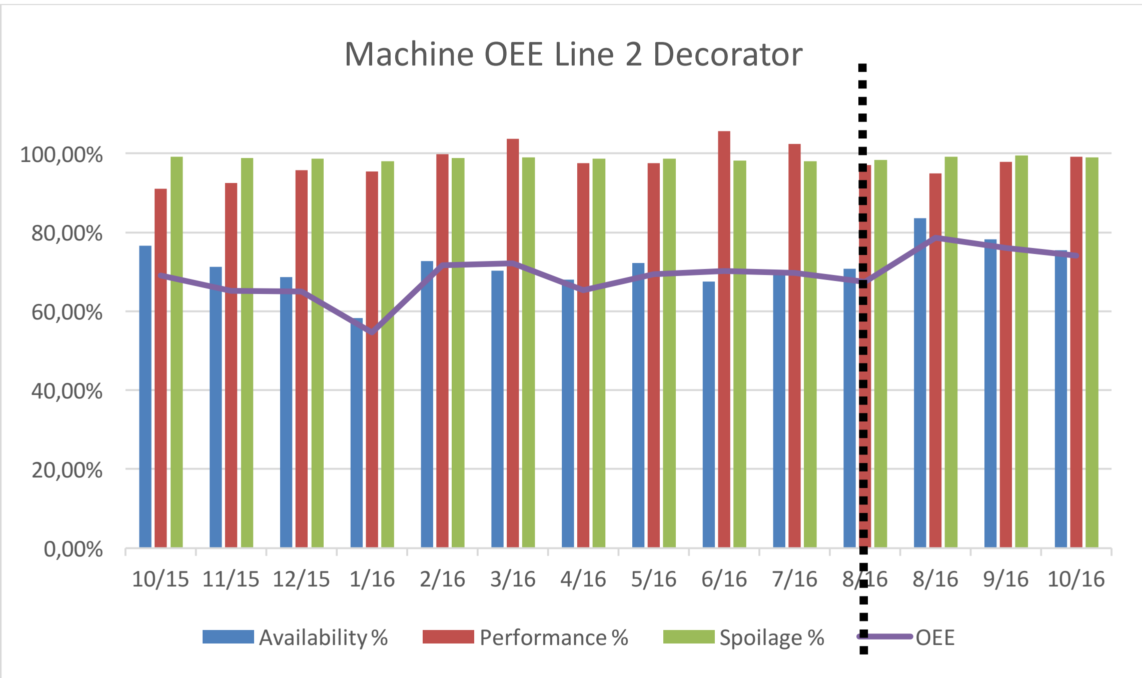


Figure 29. OEE Line 2 Decorator

Results (figure 29) from line 2 are following similar pattern with line 1. OEE trend is slightly improved and variation is focused in smaller range.

Availability factor is improved as well, whereas performance factor has stayed almost in the same level or even lower. Earlier performance results are exceeding 100 percent limit, which indicates that decorator has been running faster than rated speed 1500 CPM. Possible cause for running higher speeds could be explained trying to cover losses in equipment availability. Similarities with line 1 results are easy to identify, when inspecting results more closely before and after implementation.

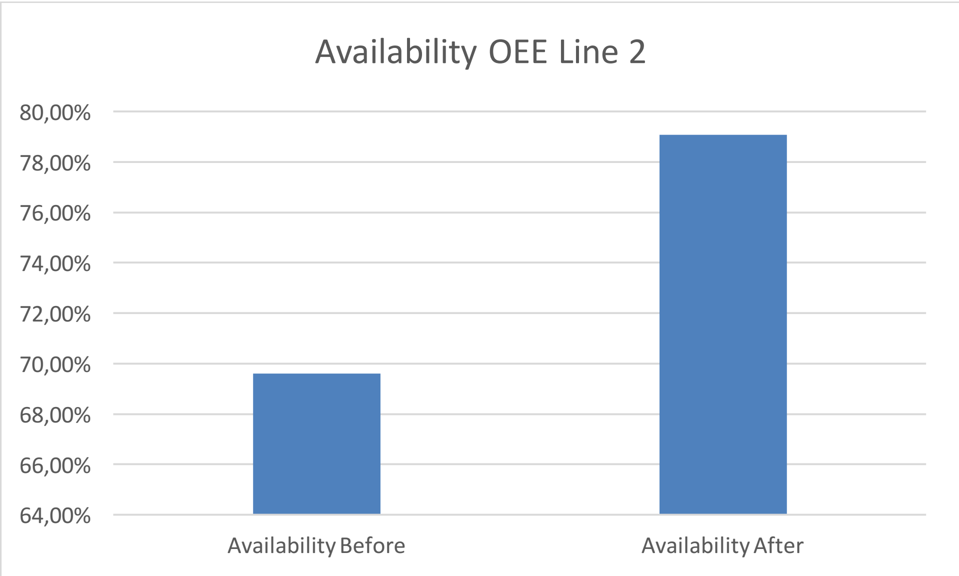


Figure 30. Availability OEE Line 2

Availability factor (figure 30) increased in line 2 by 9,46%. Average improved from 69,61% to 79,07%. Change is really significant to production volume if the improvement in availability is utilized to performance advantage. Similarly, when calculating benefit in time and production output: it will be from one day 1440min * 0,0946 = 136,224 min. When calculated to actual cans produced it means 136,224 min * rated speed 1500CPM = 204 336 cans.

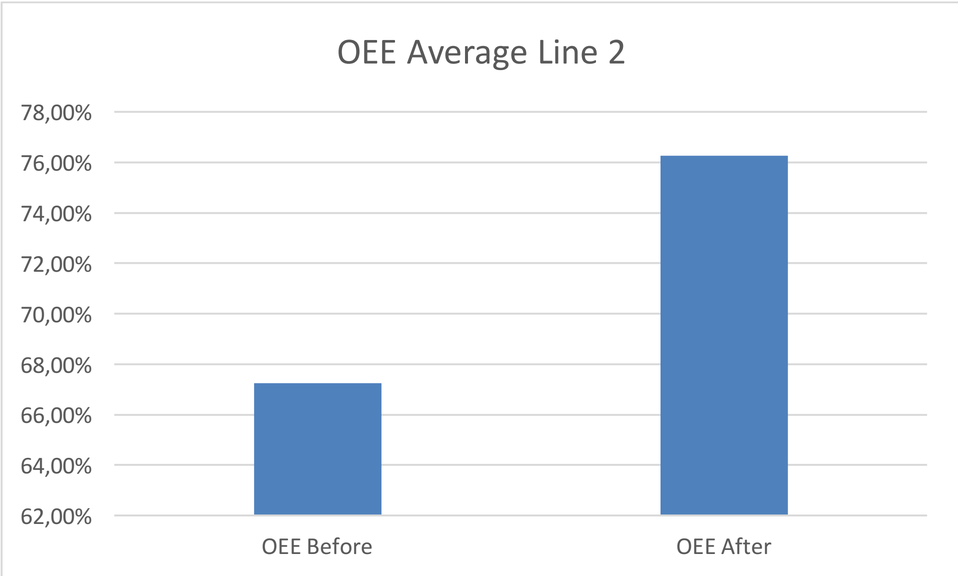


Figure 31. Average OEE Line 2

Average in line 2 (figure 31) improved from 67,24% to 76,25% causing 9,01% positive impact to overall equipment effectiveness.

Summarized, OEE average increased in both lines after the implementation of tagging system method. When calculating the production improvement figures together and forecasting the average improvement based on the data acquired for the time period of one year per line:

Line 1: Daily improvement (58 104 cans) * (365 days) = **21 207 960 cans** or
21 207 960 cans / 1500 CPM (rated speed) = **14 138,65 mins** = **9,81 days available for production.**

Line 2: Daily improvement (204 336 cans) * (365 days) = **74 582 640 cans** or
74 582 640 / 1500 CPM (rated speed) = **49 721,76 mins** = **34,53 days available for production.**

Whether the positive results are caused by the tagging system or not, it is evaluated in the chapter 7.2 validity and reliability.

6.3 Maintenance activity

It is essential for succesful maintenance to notice abnormalities before bigger breakdown appears. Therefore, raising maintenance tasks or activities was choosen one sub-indicator to see how much system changed and activated maintenance department. Earlier maintenance activity was measured from existing maintenance system, ArrowMaint. Raised tasks for decorator area were collected from years 2015 and 2016 and compared to activity generated with the tagging system.

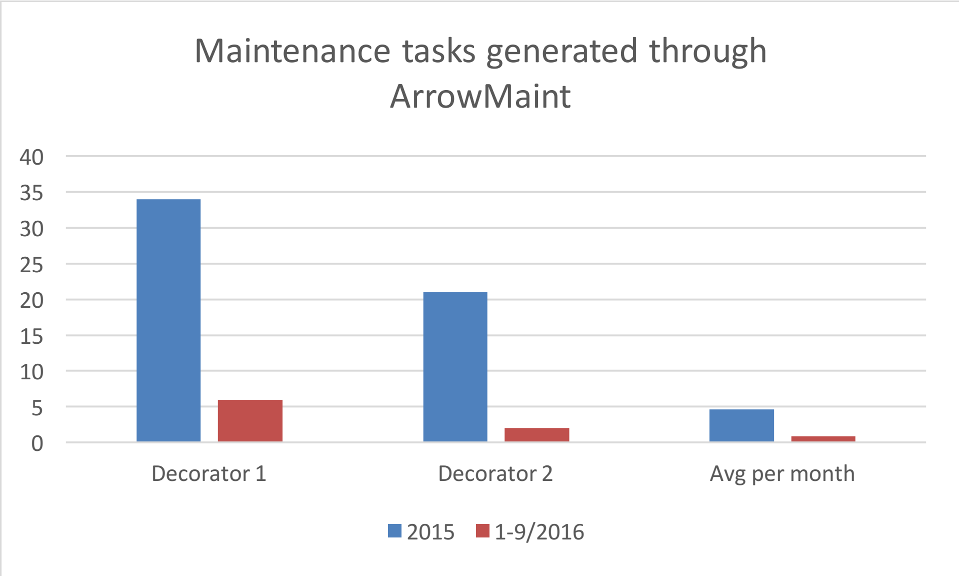


Figure 32. Earlier maintenance activity in decorator area

Figure 32 shows that trend of noticed abnormalities has decreased drasticly during the year 2016. Nevertheless, when comparing activity in the year 2015 to figure 33, we can state that tagging system has improved identification of abnormalities in decorator area. Average of tasks has increased at least twice to situation before tagging system implementation.

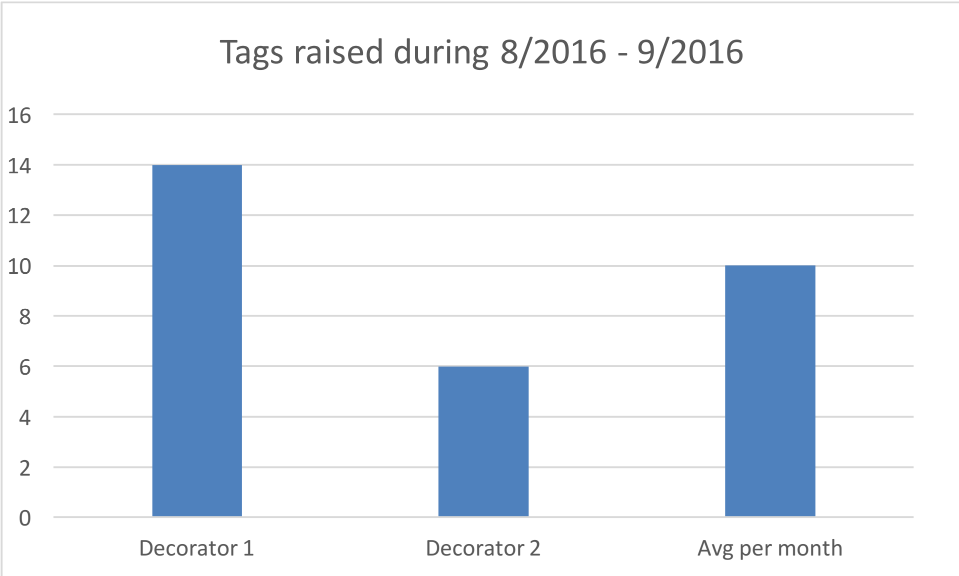


Figure 33. Tagging system maintenance activity

7 CONCLUSIONS

This final chapter includes three sub-chapters, first starting with discussion 7.1. Discussion and conclusions chapter summarizes the findings and results of the study. Likewise, it also highlights research questions and challenges before conducting the study. Situation after the improvement project is analyzed as well. Chapter 7.2 evaluates the validity and the reliability of the study, whereas the are some uncertainty factors in the changing environment of manufacturing facility and process. Chapter 7.3 is the final chapter of this thesis. It evaluates possible topics and phenomenas for further study.

7.1 Discussion and conclusions

The original challenge when starting the study was to get more production time by avoiding unplanned stops or breakdowns and to nourish the communication about the maintenance actions. Supporting this challenge to be solved, research questions were positioned as follows:

1. What is the key area for improvement?
2. How maintenance should be improved in the current situation?

The reasearch results found out that key area for improvement was decorator area equipment, which was lacking in different maintenance activities. Problematic issues like, lack of co-operation, communication and preventive maintenance were mentioned in the root cause analysis by the improvement team which was established for the project.

Based on the root cause analysis, method for improving these earlier mentioned issues were implemented. Tagging system method is originated from Milton Keynes, England beverage manufacturing plant, which is one the the oldest plants in Ball Corporation. System was slightly modified to respond the needs better in Mäntsälä plant and implemented according to Sig Sixma DMAIC roadmap. The theory of tagging system is deducted to practice from TPM approaches like, focused improvement and autonomous maintenance. The holistic view to improvement cycle of implementation is based on continuos improvement philosophy.

Situation was evaluated as OEE metrics before and after implementation of the method, to see actual implications by factors: performance, availability and quality. During the two month evaluation period, OEE results were positively increased. Significant improvement was noticed especially in the equipment availability factor, which is result of improved production time of machine. Availability factor is measured from the total time avalaible after unplanned stops, small stops and lower speeds. Therefore it can be said that equipment was able to run rated speed with smaller amount of unplanned stops.

From the author's point of view in project manager position, it was great situation for learning, to see how project work is handled. However, there was not that big emphasis on project work. Since, there was great amount of attention focused on company's maintenance activities, it showed how influential maintenance is to manufacturing companies business result. As stated before, equipment with professional operators maintaining them, is the greatest asset a company could have. Without proper maintenance, equipment condition will degrade and cause huge expenses to company in the future. Quite often maintenance is separate department which is rarely in focus. However, culture change towards more proactive maintenance activities would be beneficial to many companies. Significant observation from this project was that, by almost zero budget, it is possible to obtain great benefits by improving maintence activities even in short period. By involving whole organization to change, it will create new attitudes to see that maintenance is actually part of all core processes in manufacturing environment.

7.2 Validity and reliability

Validity defines how well choosen indicator is applied to the case or how well the phenomenon can be measured by using it. Study can be stated to be valid when it is focus to right group and questions are correctly positioned. Validity also shows how well researcher performed. If there is no new or correct information available after study, it is not valid. Reliability indicates that if research method is correct. It also measures if study is easily repeated and whether the results would be same. When study is repeated in same circumstances, the results should be same, if not then study is not reliable and results are random. (Hiltunen, 2009)

The validity of the study is based on the indicators and equipment choosed under study. Relation between maintenance, equipment and overall equipment effectiveness is immeadiate. Therefore, it is justifiable to say that study is valid.

The reliability of study results can be evaluated from different angles. Those information systems, where data was collected, are reliable and possibility for acquiring inaccurate information is neglible. However, the data was collected only from two months time of period, which is not sufficient. Final evaluation after the improvement project will give the most reliable data whether the method choosen was succesful or not. Nevertheless, overall equipment effectiveness as improvement indicator is commonly used in similar TPM projects. OEE result is giving reliable data as long as data is collected in the same way every time. Data analysis should be made similarly as well. There was no room for human errors since information systems are collecting automated data from equipment operation. Based on this information we can say that study is reliable from the two months of time when data was collected. However, certain factors like production planning are effecting to changeover times and then there is slightly space for reliability improvement.

7.3 Further study suggestions

There is probably some kind of future for the implemented method, as it was improving the current situation based on two months of time quite significantly. Since, project will continue as pilot for one year, the ultimate decision for modelling the method for other areas in the plant will be made in the August 2017. Further study could measure, what were the final implications of the executed project. If the results were encouraging then there is reason to expand it. However, the possible topic for further study could be around the modelling of improvement method.

For the case company's point of view, it would be beneficial to interview employees and ask their opinions about the tagging system after one year of period. It is possible that improvement ideas might be generated. Eventually, the most interesting thing from the author's perspective is to see what is the status of the system after one year of operational time and what are the overall equipment effectiveness indicators telling to company.

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