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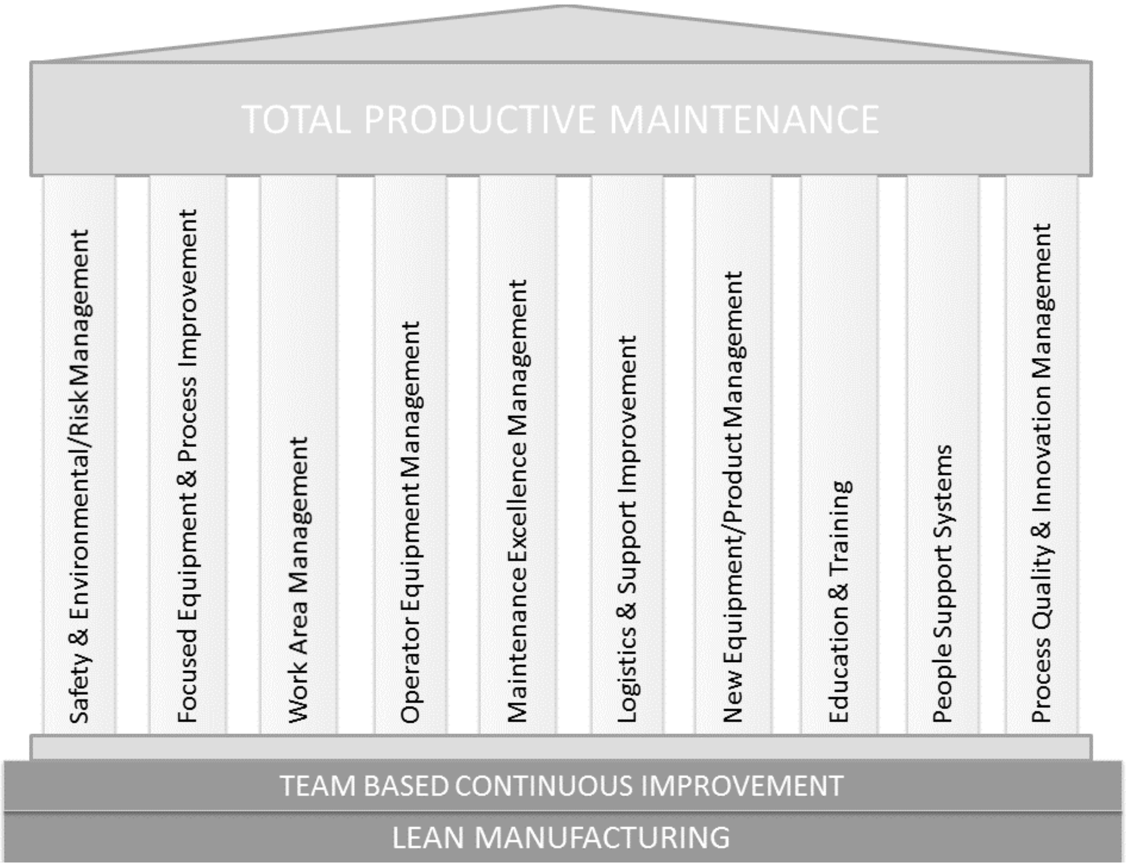

The introduction of TPM at Borealis Stenungsund

towards a world-class maintenance

Master's thesis in Production Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
The Total Productive Maintenance pillars constituting TPM^3 (Ross, 2006).

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Abstract

Maintenance has historically been associated with unnecessary costs and downtime. Lately, however, maintenance has received increased focus for meeting requirements set on high availability, reliability and process safety. The literature available and the effort that has been put often aim at improving maintenance within discrete industry. A relatively unexplored area regarding maintenance improvements and maintenance optimization is the process industry.

This master's thesis focuses on the implementation of total productive maintenance in the process industry in general and more specifically at Borealis Stenungsund. Borealis has through a consultancy firm analyzed and mapped the current maintenance state regarding which areas to develop for a successful TPM implementation. Beyond the analysis of the current maintenance system at Borealis, companies has been analyzed through observations and interviews both in the discrete- and process industry to create a picture of what generally has been proven to be successful within maintenance.

Communication, collaboration, visualization and safety have been demonstrated as most deficient at Borealis. Borealis has been provided with tools for enhanced visualization and planning. Based on literature studies and business analysis relevant future performance indicators have been developed to reflect the results of the maintenance work towards achieving the company's goals.

A gap-analysis was made on a frequently occurring maintenance activity. Applying the methods maintenance value stream mapping and single minute exchange of die revealed significant improvement potential regarding production downtime, SHE and quality. Through enhanced planning and collaboration between the maintenance- and production function Borealis Stenungsund could reach a 30% decrease of production downtime during similar maintenance activities.

The advantages of the installed computerized maintenance management system was not fully utilized where insufficient data was collected. A requirement specification was constructed with all necessary data to collect for reporting suggested performance indicators. A work method for creating sustainable change and new standards was constructed where plan do study act worksheets was combined with an improvement board to encourage continuous improvements.

Keywords: Maintenance, TPM, Lean, KPI, Implementation, Visualization, Planning, Change management, CMMS, Sustainability

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Gothenburg, Jun 2014

Peter Klas Boussard & Joshua Qvist Safonovs

List of acronyms

ANP	—	Analytic Network Process
BIS	—	Bilfinger Industrial Services AB
BSC	—	Balanced Scorecard
CM	—	Corrective Maintenance
CMMS	—	Computerized Maintenance Management System
CSF	—	Critical Success Factor
KPI	—	Key Performance Indicator
KRI	—	Key Result Indicators
MMLT	—	Mean Maintenance Lead Time
MPI	—	Maintenance Performance Indicator
MPM	—	Maintenance Performance Measurement
MTBF	—	Mean Time Between Failures
MTTR	—	Mean Time To Repair
MTTY	—	Mean Time To Yield
MVSM	—	Maintenance Value Stream Mapping
OEE	—	Overall Equipment Effectiveness
OPEX	—	Operational Excellence
P3M	—	Preventive, Predictive and Proactive maintenance
PA	—	Plant Availability
PA&E	—	Plant Availability and Engineering
PdM	—	Predictive Maintenance
PDSA	—	Plan Do Study Act
PI	—	Performance Indicator
PM	—	Preventive Maintenance
RBWS	—	Risk Based Work Selection
RCM	—	Reliability Centered Maintenance
ROA	—	Return On Assets
SAP	—	Systems, Applications and Products in Data Processing
SHE	—	Safety, Health and Environment
SMED	—	Single Minute Exchange of Die
TPM	—	Total Productive Maintenance
TRI	—	Total Recordable Injuries
VSM	—	Value Stream Mapping
VDM	—	Value Driven Maintenance

Contents

1 Introduction

Any organization that strives for success in today's highly competitive environment, where focus has shifted from performance to productivity, must overlook all parts of the organization (Powers, 1997). As the demand for higher efficiency and safer work environment has increased, maintenance has been given greater attention due to its perceived high improvement potential. This master's thesis project focuses on achieving higher technical availability and reliability by improving the maintenance performance at Borealis Stenungsund through the implementation of total productive maintenance (TPM). Increased plant reliability and availability has been studied within the Borealis group where the possible gains by improving these areas correspond to the capacity of one new plant.

1.1 Background

Borealis is a leading provider of innovative solutions for polyolefins, chemicals and fertilizers (Borealis, 2014). Borealis Stenungsund is a process-oriented manufacturer with the vision to implement Lean contributing to achieve the goals within the Operational Excellence Plant Availability (OPEX PA) program of introducing changes, learning from incidents and prevention and risk management. OPEX was introduced at Borealis Stenungsund to achieve a balance between quality, cost, reliability and safety by being a learning organization. The Lean initiative was a top management decision and was directed to each department at Borealis Stenungsund. However, the maintenance organization has received less attention than other areas, especially on workshop level. This has created a need for further improvements where several consultancy firms has analyzed the current state finding improvement areas such as low utilization of maintenance personnel, collaboration and standard and routines for the daily maintenance operations. It though seems hard to communicate the need for improvements further down in the organization and a desire for better aids to practically and strategically reinforce the maintenance organization has become evident. Stefan Andersson as Plant Availability Manager at Borealis Stenungsund has due to this searched for ways to deal with the tougher demands that are put on the organization and has taking the initiative to introduce TPM. In collaboration with the consultancy firm JMAC, a TPM Pyramid has been established as a current state analysis as presented in Appendix A (Nilsson, 2012). This will be the foundation for Borealis work in Stenungsund towards achieving a world-class maintenance where this study will further investigate how to make the suggested improvements implementable and sustainable.

1.2 Purpose

The purpose of this study is to assist Borealis reaching a full-scale TPM implementation for increased organizational and operational effectiveness. Providing a solid foundation of underlying theories and practical aids to support and facilitate Borealis future work to increase efficiency in maintenance, thus reaching higher productivity in production.

1.3 Objective

The strategy for a TPM implementation is fostered within the Lean philosophy where the objectives of this study is to adapt these theories into the area of maintenance in a process-oriented environment. This master's thesis aims further at providing theoretical solutions and implementation strategies as well as practical aids for the five selected areas at level one and two in the TPM pyramid, presented below and further described in Appendix A:

- Maintenance performance indicators
- Daily planning
- Daily maintenance report
- Productivity follow up
- Standard and routines

1.4 Delimitations

Due to the relatively short period of time it was not possible to implement the suggested solutions. All documentation and information concerning Borealis had to be approved by Borealis before publishing that had an impact on the report content. The TPM pyramid consists of five levels of maintenance objectives, where selected areas in level one and two was focused on during this master's thesis.

1.5 Clarification of the question formulation

The master's thesis will investigate how Lean principles could be adapted in the area of maintenance generally, and more specifically, how it is applicable at Borealis PA to achieve world-class maintenance.

- Which methods and tools within the Lean philosophy should be used when improving the five chosen areas in the TPM pyramid at Borealis PA?
  - How will it influence on safety, social, environmental and economic sustainability?
- How should SAP be used for planning and scheduling at Borealis PA?
- How will TPM help reaching Borealis PA's vision and strategy?
- How should the implementation be constructed to achieve a smooth transition and a sustainable implementation?

2 Theory

This chapter describes the theoretical framework and techniques used in the realization of the master thesis that is considered to claim explanation.

2.1 Maintenance strategies and philosophies

There are several maintenance philosophies mentioned in the literature possible to apply within an organization. Described are those that were considered relevant for this project.

2.1.1 Corrective maintenance

Corrective maintenance (CM) defines activities performed due to machine breakdown or other types of failure. Replacement of worn-out parts and teardowns are typical examples of CM activities. CM are often more costly than planned maintenance due to the lack of preparatory work which prolongs the maintenance process. The European Committee of Standardizations describes CM as: *Maintenance carried out after fault recognition and intended to put an item into a state in which it can performed a required function* (SS EN 13306:2001).

2.1.2 P3M: Preventive, predictive and proactive maintenance

P3M is Borealis generic definition of preventive, predictive and proactive maintenance that serves as the maintenance strategy used today (Aerts et al., 1996). These strategies are described separately below.

Preventive maintenance

The use of a preventive maintenance (PM) approach emphasizes the work towards a prolonged equipment life and the reduction of CM activities. PM is usually planned activities executed with specific intervals to sustain a process function. These planned activities require information about for example equipment needed, time for execution and task lists. Activities often related to PM are lubrication of machine parts, filter changes, calibration of instruments and inspection. PM can be scheduled activities used to minimize downtime by doing preparatory work and activities that can be performed while the process is up and running and also by performing maintenance tasks during activities such as setup/changeover while the production is stopped. PM does also advocates the inspectors (maintenance personnel or operator) ability to notice deviations using sight, hearing, smell and touch to avoid the need of CM. The inspections can be done both on a daily and weekly basis, when the equipment is or is not running (Norman, 1999). The European Committee of Standardizations describes PM as: *The maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item* (SS EN 13306:2001).

Predictive maintenance

Predictive maintenance (PdM) requires an analysis of the equipment, deciding what needs to be done to sustain the function performance. Techniques used for PdM can be monitoring of equipment and inspecting the equipment design to find improvement potentials. The inspection frequency is decided according to the predictive lifetime of the equipment. A central difference between PdM and PM is the fact that PdM is more precise during an inspection, mainly through the use of specific limits that affirms the status of the specific process (Levitt, 2011). PM does rather imply on the current status and not the exact severity. PdM is consequently a maintenance method going from manual into continuous/automatic inspection providing great advantages in error detection. The European Committee of Standardizations describes PdM as: *Condition based maintenance carried out following a forecast derived from the analysis and evaluation of significant parameters of the degradation of an item* (SS EN 13306:2001).

Proactive maintenance

Proactive maintenance consists of technologies used in PM and PdM where the process is scrutinized aiming at finding the sources of failure, the causes, instead of just the symptoms. The result will be a cost saving maintenance approach where you due to the analysis of the processes can decide whether if it is necessary with maintenance operation or not, instead of undertaking maintenance tasks when it is really not necessary. Borealis defines proactive maintenance as: *All actions to improve the equipment performance or reduce need of maintenance* (Aerts et al., 1996).

By the described definitions of preventive, predictive and proactive maintenance, Borealis has stated an internal P3M Philosophy to reach a total implementation of P3M:

- Implement interval based activities to prolong the life of equipment
- Be prepared with plans and procedures when faults occur
- Prevent plant downtime caused by equipment failure
- Use leading edge technology and methods to help us develop P3M maintenance
- Criticality analysis is basic when establishing a P3M system
- Consideration to security and the environment shall be of the highest priority when establishing the extent of, and intervals for P3M
- P3M shall ensure agreed equipment reliability
- P3M shall be carried out by qualified personnel
- The objective is to perform well planned P3M at the optimal long term cost
- Always consider changes of equipment to increase reliability of equipment by means of proactive thinking

2.1.3 Total productive maintenance

TPM is a methodology used to optimize the manufacturing equipment turning the majority of the maintenance work into preventive and planned maintenance tasks. A successful TPM-implementation is dependent on the entire staff involvement to continuously improve and maintain high overall equipment effectiveness (OEE) within the company. Optimizing manufacturing equipment performance could be achieved by reducing the 6 major areas of loss presented in table 2.1. However, an extended list of 11 losses is present in the literature as described by Howell et al. (2012).

Table 2.1: Six big losses (Stamatis, 2010)

1	Breakdowns
2	Setup/adjustments
3	Idle/stops
4	Reduced speed
5	Scrap
6	Start-up yield

Ross (2006) presents a TPM-temple in figure 2.1 consisting of 10 areas a company should focus on leading towards a successful TPM. High emphasis must continuously be put on Safety and Environmental aspects. TPM should result in reliable equipment with minimized risk of accidents and environmental damages. Focused improvement is used to analyze the process and pinpoint key losses, eliminate non-value added activities to free up time increasing OEE. Work area management focuses on the work place improvement and eliminating unused and waste-created equipment and introduce an effective use of equipment creating a productive work place. Operator equipment management stresses the need of autonomous maintenance suggesting that operators take responsibility for certain maintenance tasks within their area of expertise. This includes activities such as cleaning and inspection and creating awareness and understanding of the equipment avoiding failure and increasing the possibility of correction before failure. Maintenance excellence management supports the maintenance personnel by reducing maintenance costs simultaneously as increasing the process capacity. Successful TPM implementation requires companies to involve the entire organization. This includes the use of logistics and support improvement where focus is on optimizing areas such as stock levels and time from order to delivery. New equipment management stresses the fact that it is waste to reinvent the wheel. By documenting lessons learned, previous errors will be eliminated during process installation of a new product. Education in maintenance-related tasks will be a contributing factor to reach no unplanned downtime, essential within TPM. People support process ensures continuous improvement of the staff through a rigorous support system developing skills and knowledge level. Introducing process quality and innovation management creates a competitive advantage at the market, economic growth and the possibility to maintain high quality products.

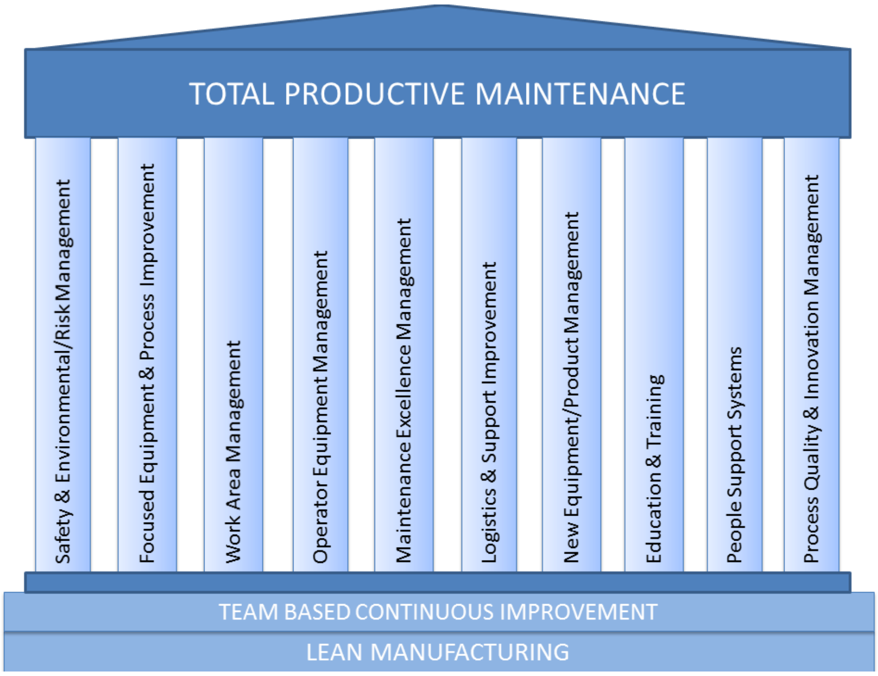


Figure 2.1: *The 10 pillars of TPM*[3] *(Ross, 2006).*

To ensure success, Howell et al. (2012) suggests that one should consider:

- Ongoing management commitment
- Increasing employee responsibilities
- Applying cross-functional teams
- Understanding and fixing root causes
- Discipline, standardization and simplification
- Focused improvement never stops

2.1.4 Reliability centered maintenance

Reliability Centered Maintenance (RCM) is a risk-based maintenance method used to optimize the distribution of PM and CM by using equipment's inherent design reliability. The reliability of the equipment is evaluated through a Failure Mode and Effect Analysis (FMEA) to determine the severity of equipment failure and to obtain proper planning (Smith and Hawkins, 2004). The idea of RCM comes from the civil aviation industry as a way to get shorter repair times and less expensive repairs and still meet the high demands put on safety and reliability. Despite the fact that saving could be reach within the aviation industry it could be very time consuming to perform failure analysis's on all equipment's, costly and less efficient for other industries where equipment failure might not be as highly required. RCM also has its advantages against PM since the reliability theory and statistics helps conclude the several types of failure characteristics that exists and could be difficult to predict (Lehan, 2012). Using condition monitoring combined with RCM could further increase the equipment efficiency. Smith and Hawkins (2004) among others agree that RCM could contribute to achieve world-class PM with increased equipment utilization.

2.1.5 Lean maintenance

Lean maintenance, as a part of the Lean philosophy, puts high emphasis on the reduction of waste. Lean maintenance is based on the combination of TPM and RCM where the overall purpose is to create the ideal balance between PM and optimal equipment lifetime. Lean maintenance applies several of the techniques used in the Lean production philosophy. Wastes, also referred to as Muda, consists of 8 categories (Liker, 2006):

1. Overproduction
2. Inventory
3. Motion
4. Waiting
5. Transportation
6. Over processing
7. Defects
8. Unused creativity

The elimination of waste in the area of maintenance manifests itself as avoidance of unnecessary maintenance work without jeopardizing the quality of work and the following process. However, maintenance can be categorized as supporting activities and does by that not add value to the customer, but is a necessity to prevent failures from occurring. Since Lean emphasize on the importance of correcting problems and eliminate the risk of reoccurrence by assessing the root cause, Lean maintenance should be executed accordingly. This appears as introducing maintenance tasks of a PM nature and reduce CM tasks in the organization. Overproduction tend to be the waste that is of greatest importance to reduce due to the effect it has and how it is affected by other wastes. Overproduction in the area of maintenance is faced through the use of effective planning and smarter use of available resources. Maintenance should be performed when desired and can be obtained by monitoring the process deciding when maintenance is needed avoiding failures and withheld required machine function.

5S, Kaizen and cleanliness and order are several other tools within the Lean philosophy highly applicable in Lean Maintenance. 5S and cleanliness and order in maintenance will most likely contribute to reduction of wastes such as transportation due to unnecessary search for tools or motion due to insufficient planning. Kaizen, i.e. continuous improvements, is highly applicable throughout the entire organization where maintenance as an already non-value adding but necessary activities definitely is an area suitable for improvement leading to increased customer value.

2.1.6 Value driven maintenance

Value Driven Maintenance (VDM) is a maintenance methodology aiming at presenting the value maintenance contributes within an organization. Haarman and Delahay (2004) present VDM out of four value drivers as presented in figure 2.2. Asset utilization describes the fact that by obtaining higher technical availability the output will increase. Higher output generates higher profit. In the area of maintenance does this manifest itself as for example investments in PM and schedule such activities to decrease the risk of CM (Haarman and Delahay, 2004). Even though asset utilization is highly requested, it is a balance between keeping the cost as low as possible without jeopardizing customer requirements such as quality, speed, dependability and reliability (Bergman and Klefsjö, 2010). Controlling the maintenance costs is thus one of the four value drivers, referred to as Cost Control, and aims through smart solutions such as optimizing the maintenance staff and by using well suited maintenance techniques such as condition monitoring keeping the technical availability high and simultaneously maintaining low costs. SHE has been given greater importance recent years. Accidents or sick leaves due to poor designed work places can be costly for any organization. Not to forget, laws and legislations that has to be followed with the risk of immobilization and subsequent fines if not. Emphasis on SHE-factors adds value to the organization and will most likely decrease the absenteeism of personnel and increase technical availability. Resource allocation stresses smarter use of resources such as technicians, spare parts, contractors and knowledge. Keeping the stock level up to date and using the knowledge where appropriate are examples on how to effective resource allocation.

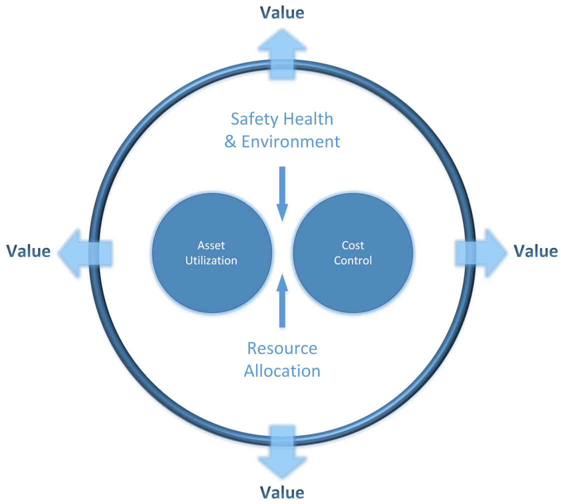


Figure 2.2: *VDM (Haarman and Delahay, 2004).*

2.2 Sustainability

Maintenance activities aim largely at maintaining high availability at the lowest allowable maintenance cost. Not to be despised, however, is the focus that is required in the area of sustainability to achieve these requirements. Sustainability in maintenance describes the impact maintenance work has socially, economically and environmentally. This is consequently together with a description of SHE in the area of maintenance.

2.2.1 Safety, health and environment

Maintenance workers have highest reported accidents and injuries within today's industry where common causes for accidents is crushing and falling (Lind and Nenonen, 2008). In 2006, 10-15% of all occupational accidents in the European Union were related to maintenance operations (Kosk-Bienko and Milczarek, 2010). Dangerous work methods and work while machines are in motion as well as misinterpretation of work instruction and accidental engine-startups are factors that frequently contribute to these accidents. Other factors that could enhance the risk of an accident is poorly maintained and defect machine safety devices, work guidance, risk assessment, employee education and safety management. Safe work methods are highly stressed for minimizing work related accidents where safe best practices and education should be emphasized. Working under pressure can further increase hazard and unconscious risk-taking where good management supervision and a developed safety culture could help reveal unsafe work methods and create new safe standards.

Safety risks on site can be divided into three main areas according to Lind and Nenonen (2008) where ergonomics are the most frequent while injuries are the most severe. Poor machinery and process maintainability is related to ergonomic risks. Ergonomics could also be related to quality of work as Ylipää (2000) appoints the relation ergonomics has on performed work where a good work environment helps the worker to focus properly on the task performed. Cultural changes can be successfully reached by investing in the internal customer (humans) before the external (production in maintenance). Poor tidiness and order, and storing of goods in walking and working areas are work environmental risks while slipping, tripping and falling from heights as well as tools falling from heights are risks for injuries.

Lind and Nenonen (2008) also highlight the human factor as a cause for enhanced risk i.e. through planning, management and execution of operations. Yet, it is important to keep in mind that human errors will always occur whether they are experienced or not. Properly installed safety management systems where risks are eliminated through risk assessments and inherent safety must be introduced. One must also change the mindset towards the idea that the system is flaw full that allows humans to make errors and not humans themselves.

The presence of risk is always there; long going studies describes the relationship between near misses and accident where data collected from numerous industries shows a similar outcome where approximately 600 near misses leads to one sever accident as visualized in figure 2.3 (Williamsen, 2013). By having a properly installed safety management system where near misses are analyzed and risk assessments made, actions can be taken to eliminate the risk from reoccurring.

"If you think safety is expensive you should try having an accident"

Safety is not highly emphasized within the Lean philosophy in the extent that it ought to be since lack of safety will increase the risk of waste (Savasta, 2003). Since direct and indirect cost of accidents could be expensive it should be more considered within Lean for an increased focus on waste reduction and a safer and healthier work environment (Manuele, 2007). However, even if Lean does not express the safety factor within waste reduction it could be stated that tools such as 5S where cleanliness and order decreases the risk of tripping and falling, and have a positive effect on the workplace where continuous improvements are made to obtain a better workplace (Longoni et al, 2013; Fridlyand, 2006). By reducing unnecessary and repetitive motions it is also possible to reduce fatigue (Grover, 2012).

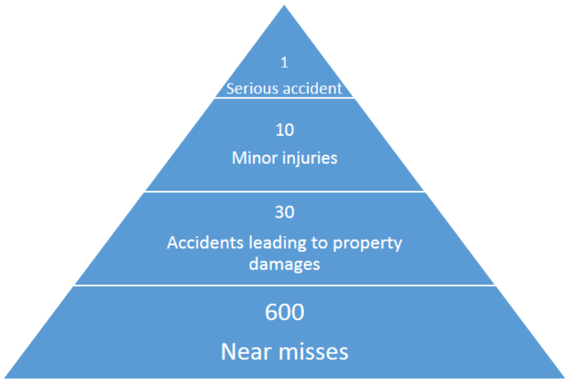


Figure 2.3: *Accident pyramid (Williamsen, 2013).*

Sustainability of maintenance

The demands put on organizations regarding sustainability are pushed further than ever before. The maintenance strategy should consequently be selected and designed to effectively increase the sustainability commitment by reducing the economic, environmental and social impact. Lean maintenance embraces this specific mindset by for example highlighting the importance of waste reduction.

Yildirim and Nezami (2012) do present several different maintenance methods and the impact those have on sustainability. Lack of qualitative maintenance can have a tremendous impact economically. Poor maintenance planning can result in lack of vital spare parts that may lead to increased risk of failure and reduced reliability. A failure will almost certainly lead to a lag in production, increased scrap rate and loss of sales. Lean maintenance may also, where a large focus is on turning CM into PM, assist an organization towards a reduced environmental impact. Fewer breakdowns will decrease the energy consumption due to start and stop activities and instead achieving a smooth, durable production up time. It will also level the quality and minimize scrap rate.

Social impact focusing on how the influence on the surrounding community can be minimized to maintain a healthy state of today's society as for future generations as well as the impact maintenance work has on the personnel. Qualitative maintenance will most likely result in a more stable process and a safer environment with fewer accidents and other interventions as a result.

2.3 Measuring progress

To make it possible to discern the direction of progress and the direction the process tends to be heading, it is necessary to measure performance. In the literature, this is described by financial metrics such as the DuPont-model and OEE, but also through other performance measures which as far as possible should be balanced, monitored by different types of scorecards.

2.3.1 DuPont model on return on assets

The DuPont-model can be applied to analyze a company's performance as the product of net profit margin and total asset turnover, i.e. the return on assets (ROA) (Soliman, 2008). Each factor can be divided into smaller, more detailed elements to manage to optimize the outcome on each level reaching as high ROA as possible. In the area of maintenance, the DuPont-model ROA can locate causes related to maintenance such as breakdowns or insufficient planning. The DuPont-model does also express the return on equity (ROE) which includes an additional factor to ROA, an equity multiplier (EM), expressing the ROE-formula as: ROA – Interest Expense/Average Assets) *EM. ROE allows a company to evaluate how efficient assets, expenses and debts are managed.

2.3.2 Overall equipment effectiveness

An ideal factory operates at 100% speed obtains 100% quality at 100% capacity i.e. an OEE figure of 100%. An OEE figure below 100% indicates that loss or wastes are present in the process. OEE is the common measure between production and maintenance and presents and indicates where waste could be eliminated. OEE should be calculated in every attempt to adopt Lean and TPM since it measures equipment- and process-related waste (Makigami, 2014). Measure and visualize OEE can be done either for separate production units or for the entire plant. The OEE could be measured in numerous ways and it is therefore important to state what the OEE will measure (Makigami, 2014).

Following definition is used during this project:

*OEE=equipment availability*performance efficiency*rate of quality*

An OEE figure above 85% is generally defined as world-class performance while process industry usually reaches a higher figure (above 95%) than discrete manufacturing due to its nature (Vorne, 2013).

- Equipment availability: time which an item (production unit) is performing its required function as a percentage of the total planned production time.
- Performance efficiency: the speed that a unit runs at in percentage of its designed speed.
- Rate of quality: Percentage of 100% quality products produced by a unit, this should be accounted as deviation from planned quality. Lower quality products and scrap are to be included in this equation.

2.3.3 Key Performance indicators

Progress needs to be measured to distinguish if an organization is fulfilling its vision and goals. By combining several measures yield indicators that serve to highlight conditions or a questions that needs to be solved. Parmenter (2007) divides these measures into three categories as presented in figure 2.4. The inner core, key performance indicators (KPIs), is the most critical aspect for any organization to focus on, aiming at improved performance level. KPIs are combinations of measures that support an organization to define and measure progress towards organizational goals and are usually measured on a daily or weekly basis (Smith and Hawkins, 2004). Performance indicators (PIs) are complementary measures to the KPIs. Key result indicators (KRI) on the other hand, do not provide a specific guidance on how to act for improving the result of these indicators (Parmenter, 2007). KRIs are result indicators that reflects the outcome of the KPIs and PIs which creates a link between the performance measures. KRIs are usually reviewed on a monthly or quarterly basis (Parmenter, 2007).

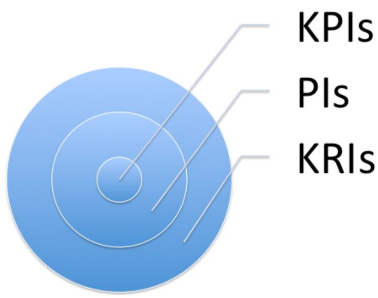


Figure 2.4: *Performance measurements (Parmenter, 2007).*

Sondalin, M. (2004) claims that the main reason for implementing KPIs should be to support business goals and operating strategy. KPIs should be created with a top down approach while the operational progress should be conducted with a bottom up perspective. By this, it is possible to create a KPI pathway where KPIs are created from top down with relation to each other and when starting the organizational work from bottom up the management will be able to notice how the KPIs are affected by the performance at shop floor level. The KPI Pathway together with its levels and links is visualized by Sondalin (2004) through the organizational pyramid presented in figure 2.5.

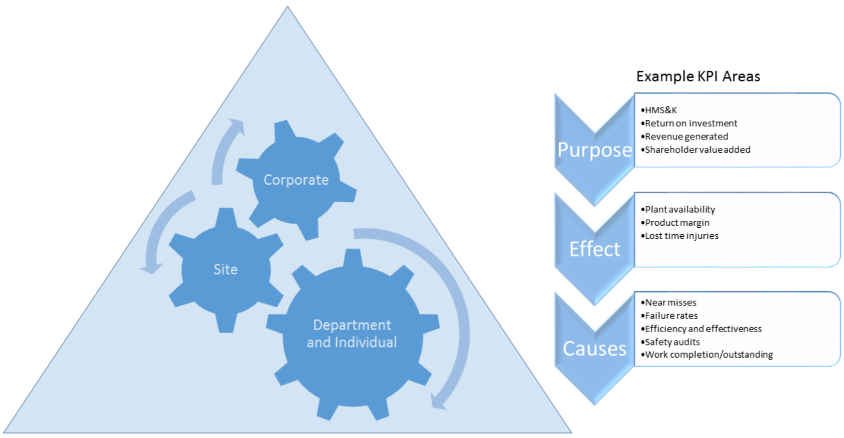


Figure 2.5: *The KPI pathway (Sondalin, 2004).*

Each level of an organization needs adapted performance measures reflecting the achievements to create changes according to the KPIs intendant purpose. If the KPIs are constructed with links between departments, shop floor level KPIs will have a positive effect on top management level reaching the organizational targets.

By using appropriate KPIs at each level in the organization it is possible to direct control and take actions accordingly. Instead of using KPIs as a quick and effective way for controlling operations, they often end up as figures in the annual report presenting a company's profit margins or shareholder value. The figures are often difficult to interpret by all levels in an organization and after reviewed forgotten. Another reason why KPIs does not meet the intended purpose is since they might be irrelevant, improperly used or one too many. Idhammar (2014e) suggests that three KPIs is a proper amount to begin focusing on before proceeding to the subsequent KPIs.

Parmenter (2007) on the other hand claims that organizations believe they are using KPIs but they do not reach results since they are misleading or have a lack of focus due to the high amount of KPIs applied. Kaplan and Norton (1996) suggest a maximum of 20 KPIs while Parmenter (2007) suggest the 10/80/10 rule that implies 10 KRIs, 80 PIs and 10 KPIs.

Maintenance performance measures

Whether if the KPIs are linked to the maintenance department or the production area it is of great importance that the chosen KPIs are up-to-date and not focusing on past routines and old habits. The KPIs should provide information about the direction the department is heading and if the processes are running as expected. Muchiri et al. (2011) suggests that the maintenance KPIs are decided and chosen having in mind the important interaction between the maintenance function and other related functions within the organization.

Idhammar (2014e) suggests dividing the KPIs into leading and lagging indicators. Leading implicates measuring critical events to correct it before any disasters (proactive) occur, while lagging KPIs implicates the reason why or what went wrong after the accident occurred (see table 2.2 for examples of leading and lagging indicators). The maintenance leading KPIs can further on be categorized into work identification, work planning, work scheduling and work execution whereas maintenance lagging KPIs can be divided into measures of equipment performance and measures of cost performance (Muchiri et al. 2011). Coetzee (1997) uses another classification of the MPMs dividing it into maintenance results, productivity, operation purposefulness and cost justification.

Table 2.2: Leading and Lagging indicators (Munchiri et al. (2011) and Idhammar (2014e))

Leading indicators	**Lagging indicators**
Manpower efficiency	No. of failures
Work order turnover	OEE
Backlog size	Availability
Quality of planning	Direct Maintenance cost

Parmenter (2007) on the other hand implies that categorizing indicators as leading and lagging can be confusing and advocates the winning KPIs categorization of KPIs, PIs and KRIs. Even though there are numerous indicators to choose from, The European Federation of National Maintenance Societies (EFNMS) has decided to use 14 maintenance indicators for benchmarking between European industries, presented in table 2.3 (UTEK, 2004).

Table 2.3: European industry benchmarking performance measures (UTEK, 2004)

I:01	Maintenance costs as a % of Plant replacement value
I:02	Stores investment as a % of Plant replacement value
I:03	Contractor costs as a % of Maintenance costs
I:04	Preventive maintenance costs as a % of Maintenance costs
I:05	Preventive maintenance man-hours as a % of Maintenance man-hours
I:06	Maintenance costs as a % of Turnover
I:07	Training man-hours as a % of Maintenance man-hours
I:08	Immediate corrective maintenance man-hours as a % of Maintenance man-hours
I:09	Planned and scheduled man-hours as a % of Maintenance man-hours
I:10	Required operating time as a % of Total available time
I:11	Actual operating time as a % of Required operating time
I:12	Actual operating time / Number of immediate corrective maintenance events
I:13	Immediate corrective maintenance time / Number of Immediate corrective maintenance events
I:14	Overall Equipment Effectiveness

PM is the key to evolve and successfully improving according to the stated KPIs (Raleigh, 2007). A solid PM strategy allows the focus to be shifted towards the KPIs and direct the effort to minimize the gap between the present and goal state (Muchiri et al., 2011). Finding the critical success factors (CSF) ease the composition of the winning KPIs for each business objective. The CSFs were first stated by Kaplan and Norton (1996) but has later been reviewed by Parmenter (2007) and extended to cover six areas as presented in figure 2.6.

From extensive analysis and workshops Parmenter (2007) manage to, after discussion with over 1500 participants in KPI workshops, cover most organization types in the public and private sector. Following KPI characteristics were defined:

Figure 2.6: *Critical success factors (Parmenter, 2007).*

- Nonfinancial measures (not expressed in dollar or euro)
- Measured frequently (e.g., daily or 24/7)
- Acted on by CEO and senior management team
- Understanding of the measure and the corrective action required by all staff
- Ties responsibility to the individual or team
- Significant impact (e.g., affects most of the core CSFs and more than one BSC perspective)
- Positive impact (e.g., affects all other performance measures in a positive way)

2.3.4 Balanced scorecard

The Balanced Scorecard (BSC) founded by Kaplan and Norton (see figure 2.7) in the mid-90s is a tool designed to support organizations towards a balance between the financial and non-financial goals. The financial perspective define the long-term goals determined by the organization to meet the shareholders requirements and should be a result of the achievements on the basis of the non-financial measures. Kaplan and Norton (1996) term the non-financial goals as learning and growth, internal process and customer. Learning and growth focuses on measures such as empowerment and how to improve the personnel in terms of productivity and the level of expertise. Internal process is the way the company should control the internal processes to create customer value by for example optimizing the equipment performance and delivery-on-time (Parmenter, 2007). The concluding perspective, Customer, includes measures such as customer satisfaction, loyalty and new acquired customers (Hjärtberg and Järnemar, 2006). The reason behind the use of BSC in an organization is to create consistency in the strategy, focus on operational change or development of management skills. A focus mainly on the financial measures hinders the company from progress towards their long-term goals. By including the non-financial goals the awareness of what the company aims to become in the long run is increased and stirring away the focus from the short-term goals. Parmenter (2007) introduce two additional perspectives; employee satisfaction and environment/community. Employee satisfaction deals with positive company culture, retention of key staff and increased recognition. Environment/community stresses the importance of supporting local businesses, connecting with future employees and community leadership (Parmenter, 2007).

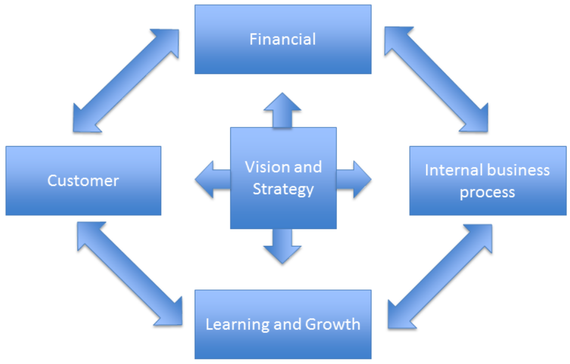


Figure 2.7: *Balanced scorecard (Kaplan and Norton, 1996).*

The BSC can also be used specifically in the area of maintenance. Alsyouf (2006) presents an adapted BSC model that includes, besides the goals presented in figure 2.7, suppliers, employees and the local community. Alsyouf (2006) provide a solution to translate the strategy into operational terms and recognize the importance of the maintenance function within a company. The presented BSC model does also combine a bottom-up/top-down approach oppose to the formerly BSC by Kaplan and Norton (Alsyouf, 2006). By changing the view on maintenance from a cost burden to a profit generating function, especially in industries where stoppages results in high monetary losses, one can improve the Overall Equipment Efficiency.

Only assessing the direct maintenance costs does not give maintenance the advantage of being an effective and competitive function for reaching overall business objectives. Having a more holistic view on maintenance it will be possible to create performance measurements that reflect maintenance contribution to business objectives. Alsyouf (2006) has set up criteria for creating a strategic performance measurement system that reflects the maintenance contribution:

- Asses the contribution of the maintenance function to the strategic business objectives
- Identify weaknesses and strengths of the implemented maintenance strategy.
- Establish a sound foundation for a comprehensive maintenance improvement strategy using quantitative and qualitative data.
- Re-evaluate the criteria that are employed in benchmarking maintenance practice and performance with the best practice within and outside the same branch industry.

Whenever to form maintenance performance systems there are several potential indicators to consider when providing management with qualitative data, indicating the maintenance function's input such as efficiency of maintenance activities and also to what extent the stated goals are reached. Alsyouf (2006) mention several different categories that need to be considered and evaluated when constructing the performance measurement system. These categories include:

- Organization
- Administration and human resources
- Craft and skill development
- Budget and cost control
- Work management and control
- Shop level planning and scheduling
- Maintenance approaches (i.e. strategies, policies or techniques)
- Computerized Maintenance Management Systems (CMMS)

By observing the maintenance function as a black box it is possible to measure and calculate theoretical efficiency for every input resource to each maintenance function category. This is done by dividing the theoretical input for each function by the actual output. Examples of this could be labor efficiency where planned hours are divided by actual hours used for a specific work (Alsyouf, 2006).

Whether the BSC is used in the production or to balance the maintenance unit, Kaplan and Norton (1996) states following as potential reasons behind the use of the BSC:

- Clarify and update strategy
- Communicate strategy throughout the company
- Align unit and individual goals with strategy
- Link strategic objectives to long-term targets and annual budgets
- Identify and align strategic initiatives
- Conduct periodic performance reviews to learn about and improve strategy

2.4 Lean maintenance methods

Maintenance functions can be optimized and improved with the use of several methods and techniques described in the literature. The ones deemed relevant during the project is described as follows.

2.4.1 Maintenance vale stream mapping

VSM is used to map where in the process value and non-value added time is present by visualizing the steps from customer order to delivery. To map the process one has to observe the process to notify where wastes appear. During the observation data will be collected to create a current state map that will function as a starting point to create a future state map with reduced non-value adding time creating more value to the customer. Liker (2006) describes the mapping of the current state as to see that things are far from optimal and will function as a guideline in the process of creating an effective future state. In the pilot project of mapping the process it is important that the detail level just roughly presents the process to understand the information flow and level of activity. It is the future state that should be detailed enough to create an effective and stabilized process (Liker, 2006).

In the area of maintenance, MVSM is used to locate the non-value adding time from equipment breakdown until completion of repair. Mean maintenance lead-time (MMLT) defines the total time for all maintenance activities between failure and completed repair. Mean maintenance lead-time for maintenance breakdown operations can be calculated as MMLT = Mean time to organize (MTTO) + mean time to repair (MTTR) + mean time to yield (MTTY) (Sawhney, Kannan and Li, (2009).

- MTTO: Mean time to organize (Time required to coordinate tasks to initiate the maintenance repairs)
- MTTR: Mean time to repair (Time required to repair and maintain the equipment)
- MTTY: Mean time to yield (Time required to yield a good part after maintenance)

Within the MMLT is MTTR the only activity adding value to the breakdown maintenance process.

- Value added time = MTTR
- Non-value added time = MTTO + MTTY

The creation of a MVSM is carried out in seven steps as described by Sawhney, Kannan and Li (2009) where a framework for drawing the map with information and communication symbols are recommended.

2.4.2 Single minute exchange of die

Single minute exchange of die (SMED) is a process created by Shigeo Shingo (1989) that originates from the Lean philosophy where the aim is to reduce die-change time to less than 10 minutes. SMED is essential within the Lean philosophy and a necessary technique reaching for continuous flow and aiming at producing upon customer orders and one-piece flow. Setup operations can be divided into internal and external activities. Internal activities are executed when the process is stopped, while external activities can be performed while the machine is up and running. The fundamentals of SMED are to transfer internal activities into external activities and minimize the remaining internal activities. This enables the change to be organized and partly performed without affecting the process. Shigeo Shingo, the founder of SMED, recognizes eight techniques that should be considered when implementing SMED (Shingo, 1989).

1. Separate internal from external setup operations
2. Convert internal to external setup
3. Standardize function, not shape
4. Use functional clamps or eliminate fasteners altogether
5. Use intermediate jigs
6. Adopt parallel operations
7. Eliminate adjustments
8. Mechanization

The fundamental reason for implementing SMED is to reduce lead-time and cut maintenance cost, while maintaining high quality. Decreased buffer sizes and inventory is possible when implementing SMED and systematically observing operations as a result of the reduced setup time (Shingo, 1989).

Applying SMED in maintenance gives further benefits to the production system. SMED in maintenance can increase the production capacity available and increase the utilization of labor hours. The objectives for SMED in maintenance are to reduce the equipment downtime while being able to carry out necessary maintenance tasks (Vaughn, 2009). Vaughn (2009) suggests that SMED is used at maintenance tasks that fulfills following criteria:

- It takes a long time to perform.
- It occurs on several pieces of equipment in the plants.
- It occurs frequently.
- It is on bottleneck production equipment.

Vaughn (2009) also describes the steps that maintenance SMED implementation consists of:

1. Document the "as is process."
2. Move internal (static) to external (dynamic) work.
3. Convert internal work to external work.
4. Create a pre-PM plan.
5. Simplify internal work – standardize.
6. Verify PM quality.
7. Complete post-PM activities.

Figure 2.8 presents a typical "as is" process for a planned maintenance activity. The wrench time is the only value adding activities and represents about 25% of the total downtime (Vaughn, 2009).

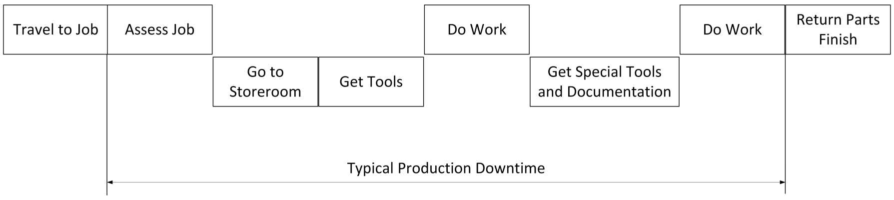


Figure 2.8: *Typical "as is" process (Vaughn, 2009).*

After SMED implementation completion it should be possible to only perform the static work while production is down i.e. perform only value adding work while machines are shut down. Figure 2.9 presents the SMED PM process.

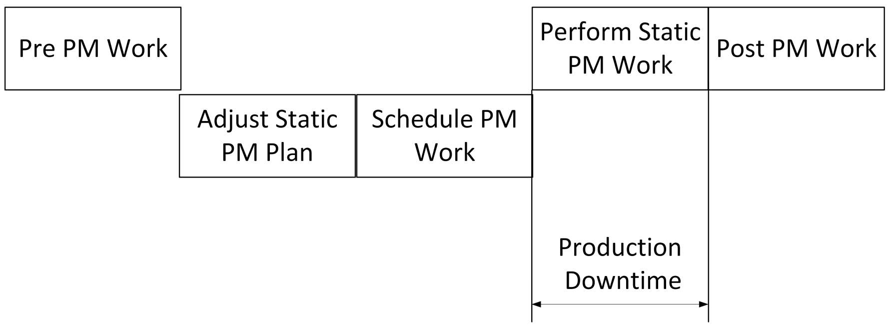


Figure 2.9: *The SMED PM process (Vaughn, 2009).*

2.4.3 5S

5S is a prerequisite for a successful TPM implementation. 5S does not only consider cleanliness and order at the work place but also the creation of a habit to continuously reduce waste and sustain the change, eliminating the risk of falling back into old, time-consuming routines. The 5S's are described in detail below:

Sort: The first step of the 5S procedure is to decide what to keep. Items seldom used should be red tagged and removed since it can disturb the work.

Straighten: Each equipment/tool should have an assigned storage place. This will reduce time wasted on searching for tools and will contribute to cleanliness and order at the work place.

Shine: The work place should be clean and the cleaning should be performed on regular intervals. Machine and equipment life will be prolonged and create a safer work place. Due to the fact that unnecessary equipment is removed and the work placed does "shine" will also aid troubleshooting.

Standardize: S 1-3 should be withheld and not be seen as a single effort. The cleaning, as for tool storage, should be standardized to maintain an organized work place.

Sustain: 5S should be an ongoing process and not only done when told to do a specific 5S activity from for example the first-line manager. A habit of wanting to change and improve the work situation should be striven to where total employee involvement is desirable (Fabrizio and Tapping, 2006).

Sustain or self-discipline is mostly seen as the most difficult S to achieve in the 5S process. Sort, Straighten and Shine are S:s initially easy to apply but hard to maintain. 5S can be seen as a continuous step-by-step process, illustrated in figure 2.10, where a wedge, a new standardization, is set to create a culture of continuous improvement (Liker, 2006).

Figure 2.10: *The 5S process (Liker, 2006).*

2.4.4 Operator maintenance

Operator maintenance is usually quick and effective maintenance activities performed by the operators at the production site. Activities performed by the operators can be both of a preventive nature such as lubrication and cleaning, as for CM when failure occurs depending on the severity of the breakdown and competence needed. 75% of all failures can according to Idhammar (2014c) be avoided or notified during the early stages through effective use of operator maintenance. By transferring suitable maintenance tasks to the operators, the knowledge level and the commitment among the operators will increase. The operators will manage to act more autonomous and through time increasingly contribute to higher technical availability. Operator maintenance can be summarized chronologically as (Makigami, 2014):

- Initial Cleaning
- Countermeasures to sources of contamination
- Cleaning and lubrication standards
- Overall inspection
- Independent inspection
- Organization of work
- Autonomous maintenance

The European Committee of Standardizations describes operator maintenance as: *Maintenance carried out by a user or operator* (SS EN 13306:2001).

2.4.5 Genchi Genbutsu

A central part of the Lean is Genchi Genbutsu that means go and see (Liker, 2006). This implies that one must go and see at the actual place at the actual part. The idea behind this is that problem solving and improvements cannot be done unless there is a comprehensive understanding of the situation. Lean also emphasize that higher level manager devote time to look at the source of any problem and not just established reports.

2.4.6 Visualization

Visualization is a part of the Toyota Way to manage information about the current status and deviations and exploit present problems (Liker, 2006). Post-it notes on boards for improvement projects or Kanban cards are used since it provides the workers with information concerning the actual workplace. Humans are visual creatures and need information to be visualized and problems displayed. Robots do not care about the workplace and can therefore use a computer, but humans tend to shift focus from the workplace to the computer screen that weakens the connection. A well-designed A3 poster gets the attention enabling information to be shared in efficient ways. Visual control is a way to detect deviations from desired state and standard. 5S is a part of visual control where all tools are designated a specific place, but visual control is more than cleanliness and order where amount or quantity could be grasped. It is not only time saving but also a quality assuring to have cognitive tools for easier and correct performance.

A3 report

An important part for documenting and sharing information is to determine what is actually essential for others to be aware of. Enabling more efficient reporting originates from Toyotas way of sharing information via fax (Liker, 2006). The information possible to fax had to fit on a piece of paper, the same size as an A3 and was often written by hand. The information available on one piece of paper was remarkable and evolved by experienced personnel. The poster is used for visualization that enables problem solving and decision-making without several pages of documentation. The poster follows the philosophy regarding waste elimination within all the functions at a company. Presentations and decision-making tends to take time spent on several unofficial and inefficient meeting. The information should be clear and concise and enable everyone to easily understand the complete content which might get lost if people are forced to read thorough reports. Each poster should include the beginning, middle and end process which in many cases is to determine the "as is", process for determine the future state and finally the future state. Three types of stories are determined: the status story, problem-solving story and key milestone stories. The content should be detailed and sufficient enough for decision-making, especially when investments are discussed. Without enough details and information the poster must be rewritten and additional time must be spent on adding or gathering information. Clear flows must be visual through the entire poster and always divided and presented in the same way for each story. Even if the poster should be used to share information there should be an additional report filed describing the poster more detailed. The A3 poster comes with some issues that must be considered. When transferring and sharing files as well as moving to presentations and printing, information might be lost due to the size and orientation (landscape/normal) which has made Toyota shift focus to A4 posters instead. The creator is forced to think one step further in designing the poster and higher demands are put on what information that is really vital. More important than the poster is the process creating the poster. This comes especially vigorous when team works are presented where everyone must agree on the outline. Everyone must fully understand the outline and the content before being published.

2.5 Standard and routines

Standardized work is a baseline for continuous improvement (Liker, 2006). Standardized work is what could be seen as the overall most effective course of action for a certain work procedure. It could be applied to the entire organization and could appear as a machine changeover procedure or specifically in the area of maintenance; how to prepare a maintenance work task or how to act in the case of a CM activity. Standardized work should not be seen as a monitoring technique of the operators' performance levels, but instead a tool for continuous improvements. Standardized work is an excellent tool to visualize and correct a problem in the process. It is also a valuable approach for involving the personnel in the improvement work procedure encourage to suggest improvements and create an iterative process towards best practice (Liker, 2006). However, one should not forget that improvements and establishing new more efficient standards must be fortified by an underlying reason. New standards may lead to freed up time and should be consider in the pre-phase of the improvement process to be occupied with value-adding activities avoiding wastes such as waiting time or unused creativity. As quoted by Liker (2006) *"If there is no need to sustain, any gains will not be maintained".*

Liker (2006) presents three prerequisites for standardized work that needs a degree of stability before standardized work should be considered:

- The work task must be repeatable. If the work is described in "If... then" terms, it will not be possible to standardize. For example, if the task is described by saying, "If A happens, then do B, but if C happens, do D," and so on, it is not possible to standardize unless these are just a few very simple rules.
- The line and equipment must be reliable, and downtime should be minimal. It is not possible to standardize if the work is constantly interrupted and the worker is sidetracked.
- Quality issues must be minimal. The product must have minimal defects and be consistent in its key parameters. If the worker is constantly correcting defects or struggling with the effects of poor product uniformity – such as size variation that affects the fit of the part, and thus the time required – it is not possible to see the true picture of the work.

2.5.1 Plan do study act

Plan do study act (PDSA) is a profound iterative process to systematically tackle difficulties that occur during production (Bergman and Klefsjö, 2010). In the occurrence of a problem there is of highest interest to localize the root cause. This is done during the plan phase by applying methods such as Failure Mode and Effect Analysis (FMEA) or Pareto charts together with a following action plan. When the plan is set, the do phase should be initiated. A team is established where involvement and commitment among the team members are stressed together with creating awareness and assure that everyone understand the stated problem and the planned improvement steps. When the do phase is closed, the steps taken and the outcome must be analyzed to verify that the result ended up as expected. In the case of a satisfactory result, new standard should be set during the act phase. Otherwise, the processes should be initiated once more learning from previous mistakes to assure that satisfactory results are achieved during the following cycle. Consequently, as the continuous improvement nature of the PDSA cycle as presented in figure 2.11, a new object should be decided as the primary improvement goal and planned as the initial step in PDSA-cycle.

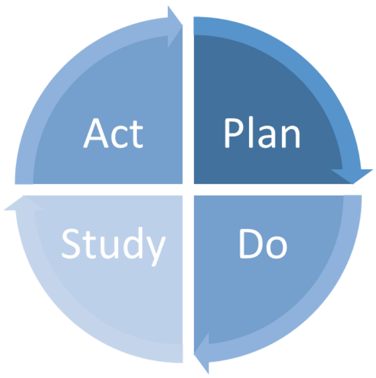


Figure 2.11: *PDSA cycle (Bergman and Klefsjö, 2010).*

2.6 Computerized maintenance management system

CMMS is in most cases an optional element in the TPM implementation (Smith and Hawkins, 2004). The idea behind the use of a CMMS is to achieve efficiency benefits that could never have been reach without. Management tasks could be automated where data processing and scheduling is performed efficiently. To fully reach the promised benefits of CMMS the system must be treated with respect to its purpose and everyone must be given instructions and standards on how to operate the system. The system cannot perform better than the information it has to process, i.e. the data quality must be of 100% (Smith and Hawkins, 2004).

"Organizations tend to be data rich but information poor" (Smith and Hawkins, 2004)

2.6.1 Data quality

To implement and use the system in an efficient way, everyone needs to trust the system, or rather the ones using the system. Meaning that information in the system must be reliable, only then it is possible to generate savings for more efficient work. To trust the system and the information within it, the data needs to be updated and have high enough quality for the purpose. One possible way to measure and secure data quality is to measure the reported time by technicians with the actual time spent on maintenance activities (Karlsson, 2010). In this way it is possible to track that all hours are reported but there must also be a standard for what and how to report for information to be of value for the receiver.

2.7 Daily planning

Maintenance as defined by the European standard (SS EN 13306, 2001) is; *"a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function"*. A maintenance plan is also defined as a structured set of tasks that includes the activities, procedures, resources and the time scale required to carry out maintenance (SS EN 13306, 2001). Maintenance can also be considered in a more holistic view as a system with a set of activities that should be coordinated and carried out in parallel with the production system (Duffuaa, 1998). In the work towards TPM and Lean maintenance it is important to coordinate the activities to decrease machine downtime working towards increased OEE.

Smith and Hawkins (2004) specify the day-to-day planning to be only a staff function and organizationally separated from the specific maintenance supervisor(s). The planner should coordinate the correct amount of human resources with the suitable skill level to the correct maintenance activity. The planner should support both maintenance managers and supervisors and not be a staff assistant for the manager. The most important part is that the planners have an independent position from supervisors and managers. If the organization is built around the fact that the planners should perform more than only staffing and also plan materials and instructions, they should be vertically integrated in the organization (a normal situation for larger organizations). Planning requires more craft knowledge than scheduling (Smith and Hawkins, 2004) for successful planning. Well-organized daily or weekly planning and scheduling meetings are key elements for operations and maintenance partnership. The purpose of these meetings should be to finalize scheduling and possibly minor planning (Idhammar, 2014a). Idhammar suggests following agenda:

- Review work from yesterday
- Update work for today
- Finalize work for tomorrow
- Finalize schedule for following week by 2 PM on Friday
- Track planning and scheduling of key metrics
- Schedule 100% of work force including contractors
- Resolve new work requests

Area representatives, maintenance supervisors and planner should be attending all of these meetings. Idhammar (2014a) further suggests that all maintenance functions should be represented. Meetings should be held short and efficient during mid-day for everyone's attendance. There are three essential requirements for efficient meetings:

- Having a priority chart. Planning for work in the backlog before the meeting
- Knowing the availability of people
- Realizing that all meeting agreements are final – any change is break in work.

Upper management must actively ensure that these meetings are being held correctly. Attendance must be controlled as well as the preparatory work. Indicators should be used at site to visualize the planning and scheduling activities (Idhammar, 2014a). By combining PdM with planning and scheduling it is possible to obtain several synergies as described by Idhammar (2014b):

- Reduced cost of spares and material
- Increased labor productivity (primary in maintenance but also for operators)
- Better job satisfaction
- Increased production yield
- Effective work practices
- Improved production quality

2.8 Daily maintenance report

Follow-up requires all data related to maintenance to be fully reported in a standardized way. If there are no data recorded it is difficult to detect disturbances and deviations. Maintenance reports must be compiled for making productivity follow-ups possible to perform and measure. Performance measures will serve no purpose if there are no data collected. As essential as reporting though is that data are reported in a standardized manner using comprehensible formats (Liker, 2006).

2.9 Driving the change

The need of change can be crucial to survive in the harsh competitive environment. Change management aims at reducing the costs and risks with change and usually involves activities in terms of cultural, organizational or environmental aspects (Hashim, 2013 and Murthy, 2007). A prerequisite for a successful change is to have support from the top management combined with the change being established and executed at grass root level with great involvement of the personnel. Coetzee (1999) states that the possible benefits generated from organizational change depend on how the employees' resistance to change is faced and how a climate of acceptance and support is maintained.

Hashim (2013) presents reasons for organizational change occurrences dividing it into external and internal factors. These factors, as presented in table 2.4, can indicate if the present state is not fulfilling the organizations vision and a need of change is required.

Table 2.4: European industry benchmarking performance measures (UTEK, 2004)

External factors	**Internal factors**
Technology development	Development and innovation in manufacturing process
Change in development in new materials	New ideas about the products that how to deliver customer value and satisfaction
Change in customer taste and requirements	Office and factory relocation closer to customer, supplier, and market
Change in new government policies and legislation	New product and service design innovation
Change in national and global economic condition and trade policies and regulation	The appointment of new and top management team
Social and culture value change	Inadequate knowledge and training programs
The innovation and activities of the rival or competitors	

There are several different paths to choose from during a change project triggered by abovementioned factors. Hashim (2013) presents four different styles of management change where two can be seen as each other's contraries; collaborative and consultative, and is consequently suitable during different change projects. Collaborative change focuses on the employee involvement and their participation during key decision due to their close relation to the object of change, increasing the commitment among the employees but with the risk of losing full control over a project. Consultative on the other hand is quite the opposite with limited employee involvement and limited influence during decision-making. Consultative allows the managers to control and manage the project more effectively, but where one is deprived of the creativity that exists among the employees. Idhammar (2014d) claims that whether the change will be a success story or not depends on the top management course of action. A change with focus on cutting costs can result in long-term losses. A mindset of increasing profit and optimizing the maintenance work leveling the process availability will much more likely improve the intended areas.

2.9.1 Lean implementation

Liker (2006) describes different techniques for implementing or reinforce Lean and which way to tackle Toyotas 4Ps; philosophy, process, people and problem solving. All 4Ps need to be covered for a complete Lean implementation, but in reality, an organization has to start somewhere. If resources for implementing Lean are small, the "Process" is seen as the most important part where locating and reducing waste in the transformation process is essential. Liker (2006) presents following approaches:

- Process improvement approach
- Hot projects approach
- Plantwide Lean tools approach
- Company X production system approach
- Value stream model line approach

Liker (2006) suggests applying a process improvement approach where each individual process has dedicated, clear goals to be fulfilled. These small projects for individual processes, kaizen event, should not be used as the main tool to obtain quick and effective solutions through the entire Lean process but instead as initiation of the Lean implementation. Hot projects focus on operations that have substantial impact on the process i.e. a bottleneck operation or something that causes quality issues within the process. This has proven to be successful when it comes to savings but should be considered in a broader perspective since it often lead to increased batch sizes and spare parts on stock. Plantwide Lean tools approach is where tools are used and managed one at a time, going across the whole plant during the implementation before moving to the next tool decided as implementation object. Any of the tools within Lean can be implemented in this way; standardized work, TPM, 5S, quick changeover, cells, Kanban, mistake proofing, Six Sigma, and even work groups.

Company X production system approach stresses the fact that company can build their production system on other already existing production systems that have been studied during benchmarking as Toyota builds on Fords production system. Ford uses metrics developed for all function where all employees are trained in how to use these metrics and the metrics are implemented in all parts for sharing between plants. A company must not copy another system; the new system must be developed with the knowledge of the existing system in mind. Learning by doing and exciting knowledge is important when developing the new system (Liker, 2006). Lean must be fully understood before the new system is developed; otherwise it will not become Lean. Everyone must have the required knowledge. An organization should consider the bureaucracy and theory but be aware of how it affects the real life actions. The value stream model line approach is suggested as the best practical start for most organizations. Since Lean is a value stream approach makes it easy to connect processes from customer to raw material, enabling the hot jobs and company X approach to make better sense. A VSM process is done by mapping the current state and the changes made accordingly to represent the desired future state.

Having the patience to do it right

It takes patience, commitment and understanding for each phase in the Lean implementation. A well-planned process must be applied where logical steps are taken. The usage of Lean tool has its purpose in leading to Lean systems and systems that leads to Lean value streams. By choosing a product family initially, it is possible to build strengths and have a process to learn from before tackling next process. Each level of implementation should follow the PDSA cycle and be handled by continuous improvement teams (Liker, 2006).

Leading the change

Transforming an organization to Lean is a political process. This is due to the fact that people have different understanding and agendas where only those who fully understand how Lean supports the daily work gains the benefits. Creating the common vision and goal for where Lean is supposed to bring the company in the future must be embraced by all employees. The interest can be created by the support from the organization as well as how strong the support is held. There must also be a balance between how hard to push the uncertain ones since a too hard agenda can create even larger blocks that has to be overcome. Leading the transformation is about power, the availability to call for favors and steer a group. "A leader needs to lead and is only a leader with followers" (Liker, 2006). The leader must share the organizational vision and steer the group to work towards that goal where power is about managing everyone to follow and not work against the goal. Successful Lean implementations can be seen in various companies but the level of successful implementation could still vary from plant to plant. In 90% of the cases it was noticed that the only reason why is due to lack of management commitment (Liker, 2006). Usually the plant manager was very enthusiastic and used the power in efficient ways while in small extent it was a middle manager that drove the change where the plant manager did not interfered. A leader's most important task is to develop people in the organization to advance through hierarchy. This is vital at Toyota where leaders very seldom are employed from outside the company walls due to the extensive amount of time it takes to learn the "Toyota Way" (Liker, 2006).

2.9.2 The implementation of TPM

TPM is an effective and useful maintenance method if implemented correctly. First and foremost, leadership associated with responsibility and effectiveness is a prerequisite for a successful TPM implementation. Without any initiative and achievements fostered at top management level the TPM implementation will probably not be as successful as its fully potential. Emphasis should be out on creating knowledge about TPM throughout the organization to secure the awareness about the importance of mutual effort to evolve the maintenance function. A team should be assigned where each function within the company is present and will take on the role as communicator through the process and ensure that everyone working toward the same goals. The maintenance function and work procedure as its current state should be analyzed to be able to set goals that should be, as stated by Nakajima (1992), SMART: Specific, Measurable, Attainable, Realistic and Time-based.

The foundation is, by abovementioned statements, set to design a master plan for the implementation of TPM that should include information about resources needed, improvement areas and employee training. Consequently, programs for autonomous (for operators), planned and preventive maintenance should be designed. Lastly, in line with the Lean philosophy, a mind-set of continuous improvement should be fostered to sustain the TPM implementation. The steps to be taken chronologically to manage a successful TPM implementation can according to Nakajima (1992) be summarized as presented in figure 2.12.

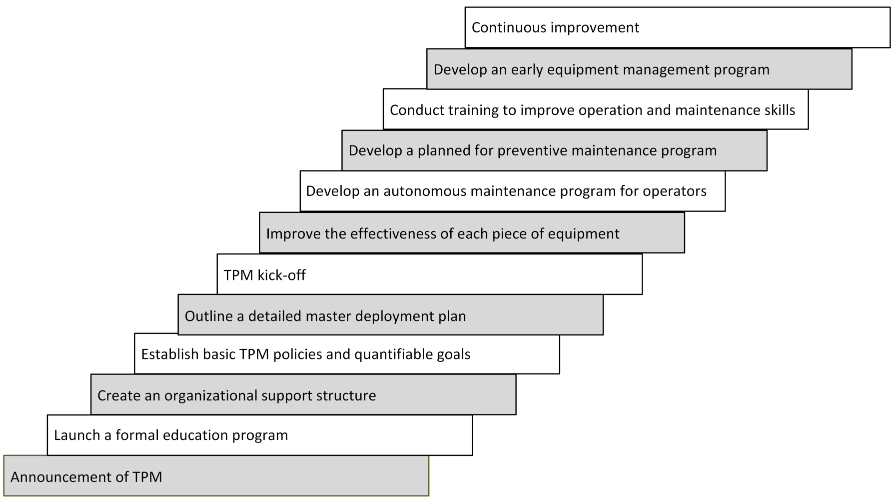


Figure 2.12: *TPM 12 step implementation (Nakajima, 1992).*

3 Method

This chapter will describe the techniques and methods used to conduct this master thesis. The approach has been chosen to fit the nature of this thesis where both qualitative and quantitative data has been reviewed.

3.1 Literature review

Maintenance, alike manufacturing processes, is constantly evolving to improve. New theories and elaborated existing theories abound which increase the importance of becoming familiar with current information and different theories contraries to find the procedures that best suit the modern industry where continuous improvements are central. The literature study will form the basis for fact finding and understanding to facilitate the creation of new solutions and ideas. Literature studies have been conducted to support assumptions and conclusions as well as learning during the project phase. Literature has been search for in following databases:

- Scopus
- Emerald
- Google Scholar

Following KEY words have been used separately and in combination with each other during search for relevant literature: Maintenance, TPM, Lean, KPI, Implementation, Visualization, Planning, Change management, CMMS, Sustainability.

3.2 Empirical data collection

Proper data collection where quantity and quality has to be considered is essential for a realistic reflection of reality (Klefsjö and Bergman, 2010). Data collection can be divided into qualitative and quantitative methods. Qualitative data collection incorporates the use of methods such as observations as for conducting interviews. Quantitative data collection on the other hand is the analysis of the process including data recording where numerical data collected results in statistics for further analysis. Quantitative and qualitative data collection methods can be used in combination to improve the quality of the data due to the fact that qualitative methods can fortify the data collected using a quantitative method.

Klefsjö and Bergman (2010) states that it is not possible to collect data before following questions are solved:

- What is the quality problem?
- What facts are required to elucidate the problem?

Empirical data was collected through provided documents as well as through ongoing discussions, visual inspections, unstructured- and semi structured interviews with relevant individuals at Borealis Stenungsund. The approach was chosen to initially gain general knowledge about the processes and create relevant questions for further interviews. Data were also collected externally on SKF, Parker Hannifin and Perstorp Oxo through company visits.

3.3 Observation

Observation is a qualitative data collection method referred to as the gathering of data by observing an event. Observations can appear as visible and hidden observation. Hidden observation is known as observations where the observed are unaware of the observation taking place where visible observations is the direct opposite (Zikmund et al., 2009).

3.3.1 Observations during F1-cleaning at L-302

Visible observations were primarily applied during a cleaning stop with the intention to reduce the downtime from 55 hours to 27 hours during one stop. The cleaning stop recurs approximately every 5th week. During previous cleaning stops the maintenance technicians have only been operating during the early shift. In the meantime the operators have been cleaning the line, following their provided task lists. To reach the goals set for the F1-cleaning, the production manager gathered the production stop coordinator and scheduled a feasible action plan. A week prior to the pilot stop a meeting was scheduled to coordinate the different departments and to verify what to be done to reach the goal of a 27 hours stop.

3.4 Maintenance value stream mapping

In the continuous work towards reducing non-value adding activities within Lean manufacturing, value stream mapping (VSM) has become one primary Lean tool for locating waste during a products lead-time. Sawhney, Kannan and Li (2009) has developed this tool to suit maintenance for assessing value adding and non-value adding activities in breakdown maintenance operations.

The creation of the maintenance value stream mapping (MVSM) during the F1-cleaning was drawn from the phase where the planning started until the work order was finished. The idea of the MVSM as suggested by Sawhney, Kannan and Li (2009) where the mapping should take place from equipment breakdown to finishing the work order was slightly reconstructed, since these kinds of cleaning stops usually are planned with set intervals. The planning phase in this study is then done while the process is running and does not affect the production. Instead the MVSM was created to know how long an unplanned stop could be if the same accurate planning should take place and visualize where the improvement areas are for both the non-value adding activities and the value adding ones.

3.5 Interviews

Interviewing is a qualitative method mainly used to gather information. The most common is face-to-face interviews. The questions can be of general nature such as a semi-structured interview that is usually based on a set of predetermined questions, which allows the interviewee to explore other areas of interest and express thoughts more freely. This enables a stimulating discussion where predetermined questions can assist the interviewer if the interviewee slips away from the focal area. The interview questionnaire can on the other hand be more strictly designed with specific focused areas and specified questions. This type of interview is advantageous for easier comparison between interview objects but at the loss of less fruitful discussions. In the lack of time and for example distance constraints, phone interview is a potential method to select.

Another advantage with a phone interview is the increased access to participants compared to face-to-face interviews (Opdenakker, 2006). On the contrary, the lack of body language identification and the understanding of the interviewee's situation are inhibited during phone interviews. E-mail interview is another possible substitute to the face-to-face methods. Except the drawbacks and advantages with phone interviews, e-mail interviews does give the interviewee more time to reflect over the questions which can be both an advantage as well as a disadvantage depending on the situation and how the questions are formulated.

Interviews were conducted internally at Borealis where production managers, maintenance managers as for safety, health and environment (SHE)-employed to create a holistic view of Borealis Stenungsund and to find the source of information described in figure 3.1. Production and maintenance managers were mainly interviewed to identify how well the production and maintenance follow up their processes and to see how well the internal communication between the respective parties appeared. The SHE-department was chosen as an interviewee object partly to see how great focus on SHE issues that appeared at the company, but also how independent this effort was or if decisions generally occurred from top management. Information was also gathered through interviews externally. A business excellence manager and a maintenance technician at SKF as for a maintenance manager at Parker Hannifin were interviewed to map the maintenance structure as for which tools applied within maintenance at each company. A maintenance manager at Perstorp Oxo with a process similar to Borealis Stenungsund was interviewed to map the performance level in the area of maintenance at other process industries. The interviews followed a semi-structured model with predesigned questions. The chosen approach facilitated an open discussion during the interview and allowed the interviewees to reflect and answer the questions more freely.

3.6 Benchmarking

Benchmarking is used to compare company's performance levels within several areas such as production, maintenance or service department. The benchmarking result will indicate if there is a need of improvement to become a competitive organization. Benchmarking can be applied internally as a comparison between different sites within the same organization or between production lines within the same factory. In the area of maintenance it can appear as a specific frequently performed work task or the overall performance of the maintenance function. External benchmarking can be divided into two methods. Competitive benchmarking does focus on the performance level of companies acting in the same type of business and does by that compete for the same clientele.

Best-in-class benchmarking does not consider the company type but instead focus on why the benchmarked company is performing at world-class level within the specific area and what methods used that could be appropriate to apply. Coers et al. (2001) states that factors such as size, industry, resources, and goals affects the type of benchmarking the organization choose to practice.

Benchmarking has been used to give a present state analysis of Borealis Stenungsund's current state in the area of maintenance and to identify other companies' performance levels in comparison with Borealis Stenungsund. Discrete industries as for process industries were studied using external benchmarking to see what techniques they have considered had the desired effect and consequently beneficial even after the implementation phase as for mistakes to avoid during the implementation.

3.7 Gap analysis

A gap analysis is used to examine the difference between current and goal state to create an improvement plan minimizing that gap. A gap-analysis should include information gathered both internally; operation and costs, as for externally; competitors (Rappaport and Mercer, 1998). A gap analysis can be valuable to clarify the organization's current state when a reluctant to change is present. Equally to other types of projects and improvement works the effort should preferably continue, creating new solutions approaching the desired future state after initiating a gap analysis (Rappaport and Mercer, 1998).

"The canyon a company's current situation and its projected goals can span miles. Effective gap analysis can identify problems and successfully bridge that canyon" (Rappaport and Mercer, 1998).

The gap analysis will be used to compare Borealis present state against the potential performance. The result will function as a guideline to improve Borealis current situation and achieve the fully potential within the chosen areas of study.

3.8 Computerized maintenance management system

SAP is the computerized maintenance management system (CMMS) used throughout the Borealis Group. SAP is a world leading Software Company best known for its enterprise resource planning application system and management, and software related services (SAP ERP, 2014). This application is installed at all divisions at Borealis and should be used for gathering and locating information. By using SAP in an efficient way it can facilitate management planning and scheduling as for improving the way of controlling production and maintenance operations.

The five chosen areas (see Appendix A for further details) has been studied and analyzed using the five steps procedure presented in figure 3.1. This approach allows for maximum utilization of SAP where information easily could be gathered anywhere at the site if properly used.

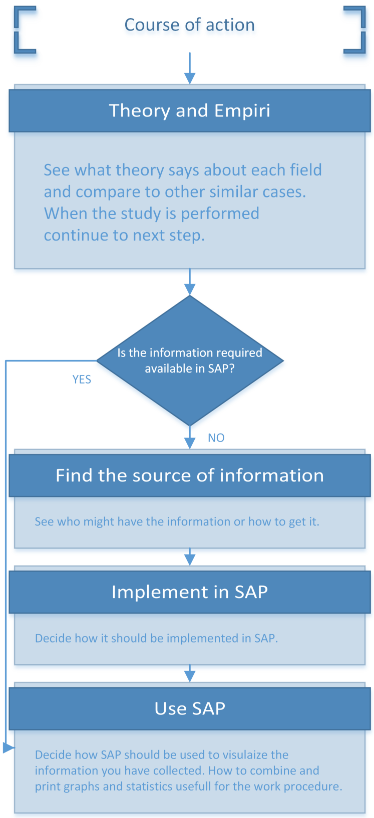


Figure 3.1: *Course of action.*

3.9 Analytic network process

Analytic network process (ANP) is a method used to assist decision-making with the ability to combine individual opinions to a common prioritization of the included elements. The method is based on individual judgment where two elements are compared regarding the impact those have on a specific criterion. The comparison is made by assigning a specific weight value from 1 to 9 of the importance one criterion has against another. 1 represents equal importance of the two elements and 9 extreme importance of the first element in relation to the latter one (see table 3.1). For example, by comparing the need of wheels to drive a car compared to having rear mirrors, given a score of 9 indicates an extreme importance of having wheels compared to rear mirrors to drive a car. All elements are inserted into a matrix, a super matrix, to calculate the overall priorities as presented by Van Horenbeek and Pintelon (2013). This is done to decide which elements to continue with and probably decide to use. One can also calculate the value of inconsistency, which presents whether the valuing of the elements is consistent to reduce the risk of interference and misleading results (Saaty, 1987). Saaty (1987) suggests that following question should be used when deciding the importance of an element compared to another:

- When considering two elements, i on the left side of the matrix and j on the top, which has the property more, or which one satisfies the criterion more, i.e. which one is considered more important under that criterion and how much more using the fundamental scale?

Table 3.1: The fundamental scale (Saaty and Vargas, 2006)

Intensity of importance on an absolute scale	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

ANP can be used specifically in the area of maintenance as a process to select maintenance performance indicators (MPI). Van Horenbeek and Pintelon (2013) presents a 5-step procedure describing how to develop a business specific maintenance performance measurement (MPM) system. The importance of linking the maintenance function with the manufacturing unit is highlighted to create a system useful throughout the entire organization:

1. Translate a generic MPM system to a customized MPM system considering all organizational levels (i.e. strategic, tactical and operational)

2. Prioritize maintenance objectives on all organizational levels (top-down approach) to derive business specific maintenance objectives based on the developed ANP methodology and model

3. Translate the business specific maintenance objectives into relevant MPI on each organizational level (bottom-up approach)

4. Measure, monitor and control maintenance performance based on defined MPI

5. Continuous improvement by redefining maintenance targets according to the business environment

To evaluate the suggested MPIs and the relative importance a software program developed only for assessing ANP calculations was used (Super Decisions, 2014). The input for the software is the judgment of each comparison against a criterion that will be presented as a matrix. The prioritization is then calculated by calculating each eigenvectors eigenvalue in the matrix and normalizing the value so that a prioritization is distributed between all the weighted elements. The highest prioritization achieved is the MPI that has the highest significant impact on the entire maintenance system where all connections are considered against each other and their independent weighing combined. The result builds mainly on own assumptions on each factor and criterion that might be easy to understand independently, but where the ANP method allows complex interactions to be calculated which is hard for the human brain to interpret (Van Horenbeek and Pintelon, 2013).

3.10 Maintenance terminology

The European standard EN 13306 (EN 13306, 2001) is a nomenclature present at Borealis Stenungsund and has been followed during the project to maintain a standardized terminology within the maintenance area. The interpretation of documents between personnel and other departments was simplified using the EN standard, following the directives from top management at Borealis Stenungsund to obtain a one-company approach.

4 Result

This chapter will give a present state analysis out of empirical findings at Borealis. External benchmarking is also presented where both discrete and process industries have been analyzed through interviews and observations. Data about the processes has mainly been collected through interviews, data collection and observations both through tours on site as for observed maintenance stops.

4.1 Borealis present state description

During interviews it has been evident that Borealis has, over the years, been forced to increase efficiency and productivity due to increased market demands. This has created a sometime stressful environment where changes are necessary for remaining competitive. The owners and management realizes the importance of availability and reliability that derives from well-conducted maintenance activities and new steps has been taken to become leader in plant reliability and availability. Borealis Stenungsund has the target to obtain its position as the leading plant within the Borealis group and has therefore decided to implement TPM. 5S has become the initial step in the TPM implementation at Borealis Stenungsund.

4.1.1 Organization

Borealis has a rigorous tree describing the organization and positions together with areas of responsibility. The maintenance department manager referred to as Plant Availability and Engineering (PA&E) Manager, is responsible for the communication with PA&E Managers at other sites within the Borealis group securing that they are working in the same direction and towards the same goals set by Borealis CEO. The PA Department has in its second line nine different areas of responsibility with subordinates at each division working as maintenance engineers, planners, and experts. The organization tree as an overview is presented in figure 4.1. The dark colored areas aim at highlighting functions that have been studied during this master thesis where both the mechanical as well as the outsourced maintenance has been reviewed.

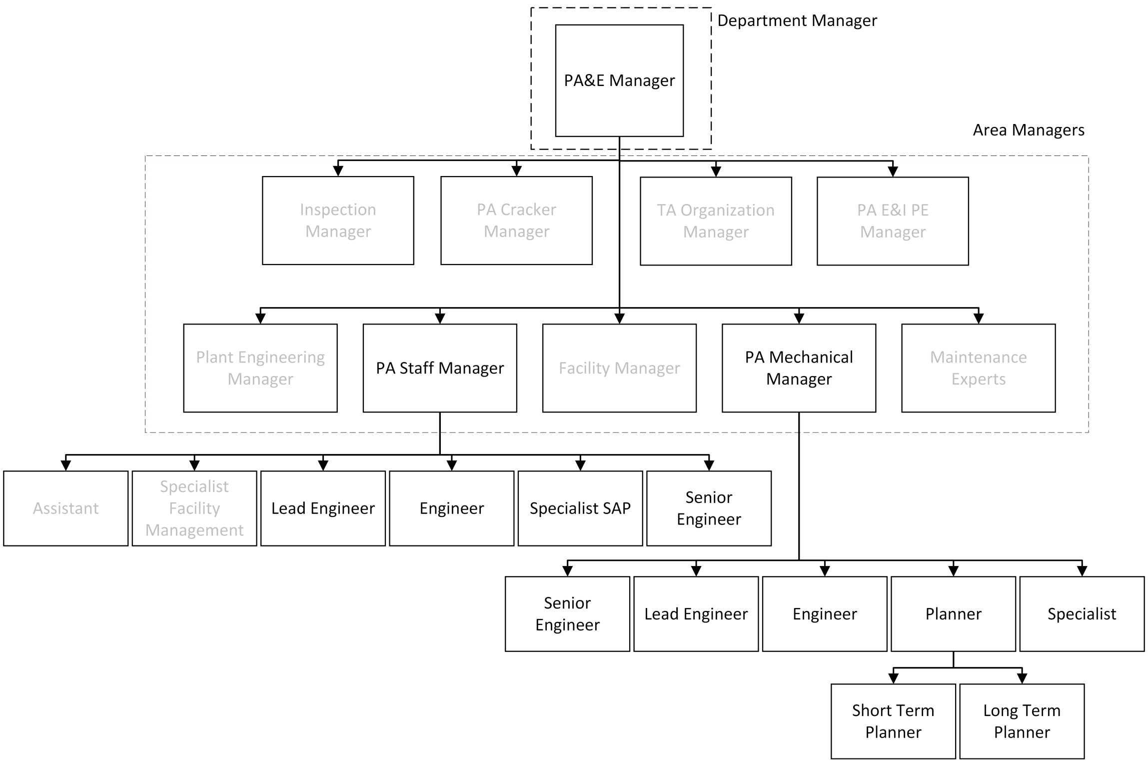


Figure 4.1: *Simplified organization chart over Borealis PA&E.*

4.1.2 Vision, mission and strategy

Borealis Group's vision is to be the leading provider of polyolefins, base chemicals and fertilizers that create value for society. The mission is to keep discovering by leading the way, grow successfully, create something truly innovative and secure sustainable growth. This is attained by following their values; responsibility, respect, exceed and nimblicity. They have responsibility for the health, safety and environment. Borealis Group believes in the one company approach and places great emphasis on the fact that everyone in the company staff collaborates. The company wants to exceed the customers' requirements, and as stated, *deliver what we promise- and a little bit more.* The final value, nimblicity, describes the fact the Borealis Group try to create smart and simple solutions by being fit, fast and flexible.

Borealis PA's vision is to become a leader in plant reliability, availability, safety and process-safety and still obtaining competitive costs aiming of maximization of the Overall Asset Effectiveness. Borealis PA wants to make a decisive contribution to the OPEX-program. There is of great importance to achieve a ratio of 80% PM and 20% CM by year 2020 which will result in a great basis for high reliability and cost control at Borealis Stenungsund.

4.1.3 Operational excellence

OPEX was introduced at Borealis to achieve a balance between quality, cost, reliability and safety by being a learning organization. The OPEX program can be divided into work and supporting processes. The work processes consist of introducing changes; learning from incidents; prevention and risk management. Introducing change stresses the fact that there is a need of a clearly defined change process to reduce the risk of incidents and secure that the focus of the change processes is to improve the process performance. Learning from incidents focus on a systematic learning to avoid recurring incidents. The root cause should be identified by introducing a standardized investigation process at Borealis designing best practices to eliminate the risk of incidents. Prevention and Risk Management is a goal of turning reactive maintenance into a proactive and preventive work procedure in the area of risk handling reducing emergency breakdowns. The risks should be identified and ranked to allocate resources to the tasks with highest risks.

To support the abovementioned work processes Borealis aims at developing the organization by improved leadership, focus on competence development and introducing a work procedure that follows the Borealis way (TBW). The risks are analyzed using a risk assessment matrix and a bow-tie diagram. The risk assessment matrix includes weighting the probability of a failure to occur and the consequence that in such a case follows. A bow-tie diagram is introduced for the highest risk where how to reduce or eliminate the risk is defined. The implementation of OPEX is in need of cross-functional teams. Those teams consist of employees from production, maintenance and development department and are responsible of carrying the implementation of OPEX in the right direction. The future vision aims at further implementing OPEX within the entire organization. Everyone should be committed and elimination of waste should be a natural habit. Nimblicity – Borealis definition of being ready, fast and flexible to create smart and simple solutions – should be of equal importance as responsibility.

4.1.4 Critical success factors at Borealis

Following CSFs are stated at Borealis PA for reaching their vision and mission of 80% PM and 20% CM by year 2020:

- Obtain high standard within SHE and quality
- Working with reliability and continuous improvements
- Complete control of costs and cost control
- Systematically work towards improved availability on critical production units
- Common approach towards reporting and problem solving methodologies
- Harmonize follow up on technical availability
- Introduce Maintenance Performance Measures

- Continuously update PM routines

4.1.5 Performance indicators at Borealis

Borealis PA&E was analyzed out from their current state where a BSC was created to verify if the current KPIs were representative for all perspectives in the scorecard. The result is presented in figure 4.2. The KPIs created by and for PA&E has its focus on reflecting on the core values activities while other areas are not as highlighted such as customer perspective and employee satisfaction.

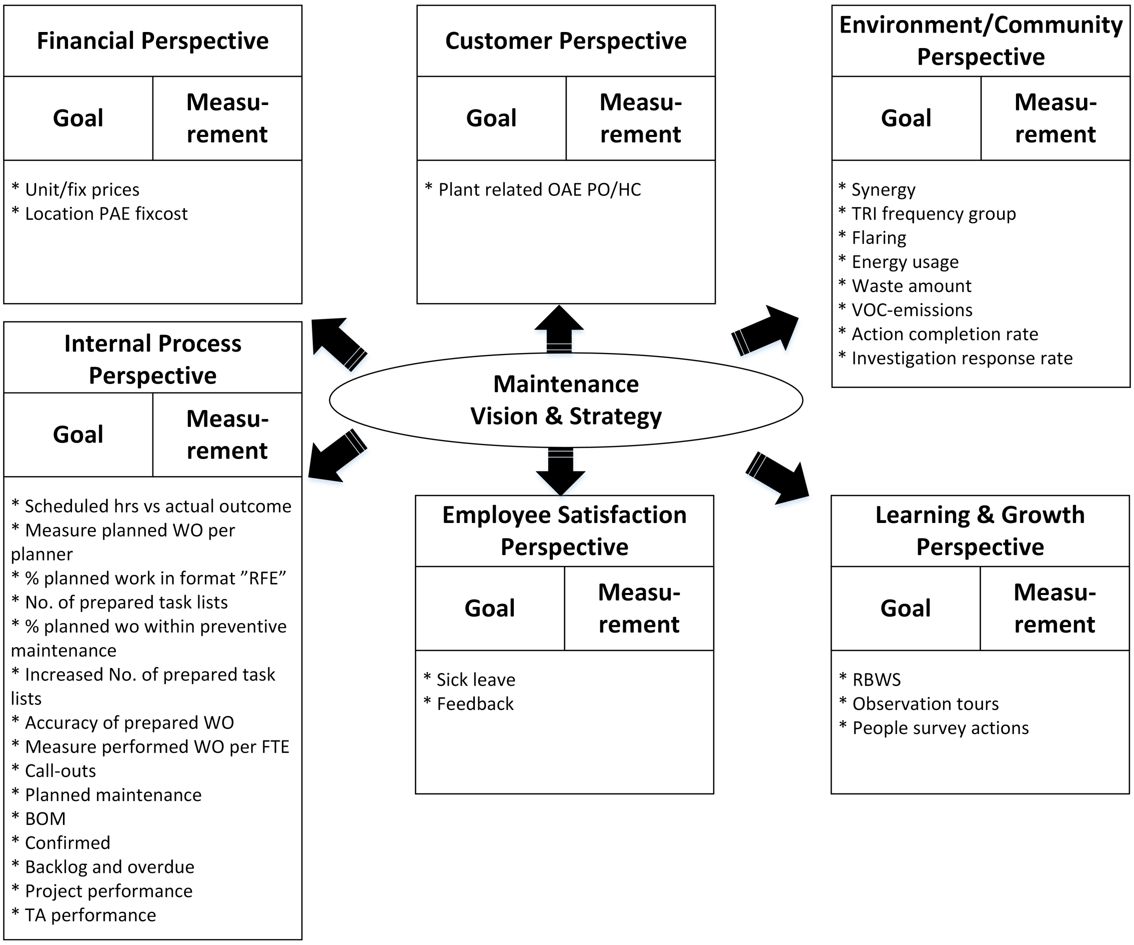


Figure 4.2: *Balanced scorecard of current state at Borealis.*

Performance indicators at Borealis PA today

The importance of using KPIs has increased at Borealis PA due to the understanding of the effect that maintenance has on cost, quality and safety. In 2003, Borealis hired a maintenance organization that delivered new inputs about how to measure the maintenance performance, mainly by introducing Risk Based Work Selection (RBWS). The idea behind RBWS is to classify maintenance work focusing on the risk, considering both the consequences and the probability for a failure to occur. RBWS is performed on all work orders to determine when they have to be performed. What would happen if you wait? What is the risk of failure? How long can you postpone the work before the risk becomes severe?

There are several KPIs used both internally and externally at Borealis PA. These KPIs are followed up on a monthly basis. The external KPIs are used to verify that the contractor that executes the outsourced maintenance work at PA, performs as expected. The main entrepreneur represents 75% of the total maintenance revenue. They are responsible for the daily planning which affects other entrepreneurs' work at Borealis. The external KPIs can be categorized into SHE, Planning, Execution and Unit/Fix prices. The focus areas are the number of performed observation tours per month, written synergies (near misses) per month and Total Recordable Injuries (TRI) per year. Synergies describe the result of unwanted events or events that could have occurred. TRI is real accidents where the exposed is incapable of performing the expected work and where medical treatment often is required. Borealis vision is to achieve a TRI record of zero injuries. Observation tours main purpose is to study how maintenance technicians act during different work situations and if it meets the set standards/requirements. The categories Planning Bilfinger Industrial Services AB (BIS) and Planning Borealis tracks executed planned work orders, accuracy and the increase of prepared task lists. Execution displays the amount of performed work order per full-time employee. The main contractor is compensated for each work instead of total hours spent. In other words, the efficiency is the contractor's responsibility to maintain. The final category, unit cost / fixed price, measure the contract cost in relation to the total adjust cost at PA.

Productivity follow up

Borealis has developed a system for measuring its contractor's performance level executing the maintenance activities, but internal KPIs are not used in the expressed extent. KPIs that exist today are categorized in the balance scorecard in figure 4.2. Even if the KPIs exist they are not followed up frequently which diminishes their importance. Personal development plans for the internal staff function is carried out once a year with the first-line manager where individual goals are settled and discussed which function as intended.

4.1.6 Visualization

At Borealis PA, TV screens are used to display information about general activities across the site, production performance, KPIs, ongoing projects and safety-related incidents. The slideshow usually consists of approximately 20 slides with various amount of information that complicate the possibility to interpret and process all information given. KPIs and more general information can be found on the mutual local network but are often KPIs presented on corporate level and not directly reflecting the maintenance department's performance.

4.1.7 Computerized maintenance management system

The CMMS system used at Borealis is SAP Plant Maintenance, the PM module within SAP R/3 system. By implementing PM, Borealis could use maintenance strategies such as risk-based management or TPM to:

- Increase the availability of objects
- Reduce the number of breakdowns through better use of PM
- Coordinating and employ human resources to fulfill specific maintenance orders
- Reduce cost of inspection, and preventive and planned maintenance

SAP Enterprise System has been present at Borealis since 1999 but never been fully utilized. The information about each maintenance activity reported varies. This was verified both through interviews as for data collection internally. The inconsistency in the reporting procedure complicates the interpretation of data and the possibility to evaluate and compare time periods and create action plans accordingly. Most commonly data reported is the cost for materials and personnel. The amount of work hours is usually reported as a total figure, leaving out information about the number of personnel performing each task. For example, 8 hours reported as a maintenance activity can be performed by one or several technician(s) during the 8 hour-period. There is often no such information available. This hinders data to be collected for following up on set KPIs or tracking historical events for root cause analyzes.

4.1.8 Scope of activities within plan maintenance at Borealis

The plant maintenance application is an integrated component within SAP R/3 system and is supposed to support Borealis in the way they are carrying out maintenance activities. The scope of plant maintenance activities stretches from representing organizational structure to supporting tool for planning maintenance activities. Cost planning, technical documentation and other important data recording could also be accomplished. Since Plant Maintenance is an integral component of the R/3 system it is directly linked to the logistics, optimized business accounting and human resources components. The continuous exchange of information enables different plants, departments and levels in an organization to share, get and collect information simultaneously.

4.1.9 Daily planning

Daily planning is performed by BIS who is responsible for the outsourced maintenance activities. The daily planning activities includes distributing work orders to maintenance technicians and trying to meet the planned schedule time. The daily planning also has to consider variation in manpower due to sick leaf etc. The planning follows the planned maintenance activities schedule as far as possible but a firefighting culture can still be distinguished where emergency orders receives higher priority than planned activities. Both Borealis and the contractors express the need of easier and faster ways to handle maintenance activities. This becomes evident during prolonged production down time and the available time slots are not filled with new maintenance activities because of the relative long duration from a written note until the start of a new maintenance activity. The daily planning has no official procedure and is up to each supervisor to handle.

4.1.10 Daily maintenance report

Maintenance reports after completed work orders have no standard regarding the content included. An estimated price for each work and the actual price is the only information available. Hours and comments on the work which is of importance for input to KPIs and follow up on root causes analysis can only be found in very small extent since it is not expressed from management nor standardized.

4.1.11 Standard and routines

Standards are present as handbooks available at several departments. These are seldom used nor updated. It is an issue when new projects are initiated, documents are created and old revisions are not removed. Evolving and revising old standards for continuous improvements are not standardized and new projects are often created before previous changes are sustained. Management is aware of the issue of standards and the importance of sustaining change.

4.1.12 Driving the change

Borealis does currently adopt the OPEX program to facilitate and coordinate activities within Borealis as presented in section 4.1.3. Besides OPEX, Borealis is a project driven organization where changes are performed in groups with a specified budget which gives total cost control but might not be as efficient since it takes time even for smaller changes to be implemented.

4.1.13 Improvement methodologies

The Borealis Way (TBW) is a methodology similar to the PDSA cycle to help ensure a consistent approach towards continuous improvement when new projects are generated. The projects where TBW is applied are rather extensive where no specific method for small scale-projects is present. Lessons should be learned from previous, completed TBW projects advocating collaboration throughout the organization without executing similar projects once more when not needed. In reality, the projects are not displayed for everyone to follow the mutual progress where each employee has their one fulfilment until the projects are finished and filed. This is also an issue for the acceptance for new standards since other functions are not aware of current activities. This is a sensitive subject for some since they want to keep the information to feel important instead of visualizing improvements and collaborate in a broader way. It is expressed that improved visualization and collaboration must be established to become a learning organization.

4.2 Maintenance value stream mapping

A MVSM was created out of the current state during the observed maintenance stop as seen in figure 4.3. The MVSM visualizes the process from the start of planning until completion of repair and the work order closure. Since the planning is made prior to the stop and the process is running simultaneously, the time buffers between each stage is not displayed since they does not affect the production. This will give an idea of how long time the planning phase could be if there is an unexpected breakdown, giving that there are no waiting times between the steps. The value-added time, MTTR, was proved to be 27 hours. MTTO represented 30% of the total time span from the start of planning until finishing the work order considering no delays in the planning.

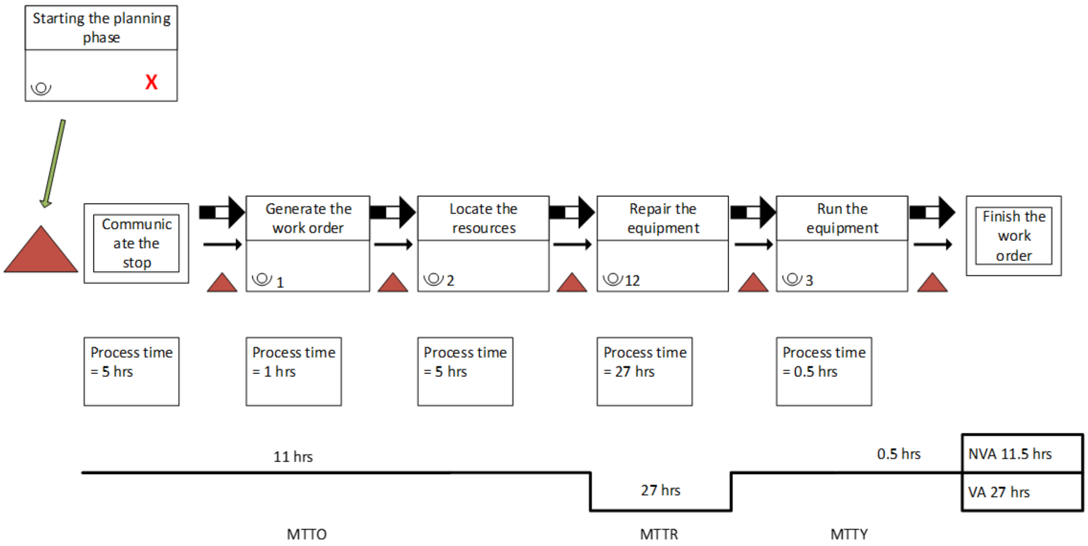


Figure 4.3: *Current state maintenance value stream mapping.*

4.3 Single minute exhange of die

The maintenance stop was observed focusing mainly on the maintenance staff, considering primary the execution phase and SHE aspects. The current state was mapped presenting value-adding and non-value-adding activities (see Appendix C). During the stop, several difficulties were identified. These were categorized into lack of communication, cleanliness and order, SHE, tools and equipment, and cleaning.

4.3.1 Communication

Lack of communication was evident throughout the entire maintenance shut down. The operation and maintenance function had for example two separate time schedules that led to production shut down 70 minutes earlier than necessary. The stop coordinator assumed that four technicians would appear during the maintenance shutdown and was surprised that only two technicians were scheduled per shift. The operation coordinator was forced to reassign two operators during the afternoon shift. The stop coordinator also noticed that maintenance activities were scheduled incorrectly and had without redistribution of tasks led to delayed production start. Additional maintenance technicians were also used during the early shift, which was not according to plan, but necessary to meet deadlines. A deformation that was discovered on a hot oil pipe during the shutdown was not passed on to the afternoon shift. There are several levels in the production facility where activities simultaneously appear. The absence of communication aids complicated the collaboration between the concerned parties.

4.3.2 Cleanliness and order

Tool trolleys lacked structure and led repeatedly to absence of tools, forcing the technicians to waste time on finding these. At one point, technicians were searching for fasteners where one technician expressed it as ”order, but in the wrong place.”

4.3.3 Safety, health and environmnet

The forklift was oversized and was the reason that the oil pipes were damaged. The forklift also functioned as a platform for assembly and disassembly due to the absence of other platform opportunities. Leftover plastics were removed from the zones during disassembly. The plastic was thrown on the floor and an obstacle during several occasions. Fasteners are placed in bins after the removal. These bins were dragged along the floor since they were too heavy to lift manually.

The technicians were repeatedly forced to use risky positions during the maintenance shutdown. This was mainly a problem when a pulley was disassembled to be used at another traverse. The mechanics were forced to climb on pipes and from a non-ergonomic position carry the pulley that is heavy and unwieldy.

Acrobatic positions during removal and the use of improper tools in the absence of others appear repeatedly. A large part of the maintenance consists of separating zones by mainly loosening/tightening bolts and transporting zones. Loosening these bolts often requires that one must use strength since the tools are mismatched. The technicians slipped on numerous occasions when loosening the bolts. During relocation of zones a spit in combination with strenuous work positions was used. Additional risks arise when tools must be transported between floor levels. This was recognized when the external cleaning company dropped a hose from the top floor and nearly hit an operator in the head with the nozzle.

4.3.4 Tools and equipment

The technicians had problems when a part was disassembled. Impact wrench and hydraulic tools were too "weak" to remove the bolts. The tool stay was not properly chosen and constituted a danger to the technicians since the stay during one occasion loosened and flew away. The cranes were slow, especially the one with the pulley, which took unnecessary time.

4.3.5 Cleaning

The cleaning of the line after the external cleaning company was flawed even though the need to clean the ceiling and the higher-lying parts was stressed to prevent particles from falling down during production, it was found that it was still dirt left that should have been removed after cleaning. In the production's list of maintenance tasks, it states that the filter holder bolt holes should be checked. However, this was not done and had to be cleaned afterwards by the technicians. Many parts must be sealed after cleaning to prevent ingress of contaminants. Nevertheless one component was stored outside without being covered in plastic.

4.4 External benchmarking

External benchmarking was conducted at different companies both within the process industry and discrete manufacturing for finding pros and cons discovered during their TPM implementation.

4.4.1 SKF AB, Gothenburg

SKF is a worldwide known manufacturing company that produces high quality bearings. The company is situated all over the world with a total of 132 sites in 32 countries. The site visited in Gothenburg produces mainly medium and large sized roller bearings (SKF, 2014). The maintenance department is an essential part of the organization since it contributes to increase the OEE by reducing the need of CM. SKF stresses the fact that the maintenance stops are investments that should result in increased availability. Nevertheless, one the interviewed maintenance technician clearly stated that the maintenance personnel are supposed to maintain the required function and not modify it. Those tasks should be delegated to departments such as construction or process development.

TPM is the core of the maintenance function at SKF and was first introduced in the early 90s. Initially, TPM was a scheduled activity on weekly basis and not integrated into the daily work as it is today. The company has during different periods faced problems during their TPM implementation. In the beginning, it was due to a lack of collaboration with the manufacturing unit. Instead, SKF started to act more as a company stressing the importance of collaboration and communication between the different units. SKF realized that trying to improve all the machines and processes simultaneously was time demanding. In 2005, a classification system was created focusing on the most critical machines and performing the improvement work in the correct order. The improvement work should be done as quick and effective as allowed, keeping the motivation high during the project. When failures occur, it is important to not only extinguish fires, but also finding the root cause, avoiding failures to recur. To connect the different units, meetings should be held where valuable information is exchanged. Meetings should have a clear purpose and clear guidelines on what to bring up and prepare before the meetings. SKF uses a method called management control reporting system (MCRS) where meetings during a one-year period are mapped and categorized into frequency and type and decide whether the meeting is needed or not. Meetings will be less time consuming and information will more effectively be spread and announced to concerned ones.

TPM can now be seen as a part of their work culture and a mindset among the employees. For further decreasing the number of emergency orders, SKF recognized the need to reorganize the maintenance department. The utmost change was to run stops in parallel according to a specific stop schedule. It resulted in quick and effective stops together with a better visualization of the stops. The maintenance department was also divided into a specific planning area and analysis area creating a much more concentrated focus. The planning and analysis group gather on a weekly basis and alternate the focus area between these departments during each meeting. Each Friday, there is also a meeting with the maintenance engineers to plan and delegate work tasks (considering each engineer's level of competence) for the following week and also greater stops executed at each production line at a four-week interval. During these stops all the maintenance engineers, regardless the contact line, can be summoned when not occupied to achieve the goal of quick and effective stops at the production lines. The service technician who is assigned the work task is responsible for the preparation. The meetings are held in a conference room that is shared with the quality, production and SHE department. Each group has its own whiteboard for information sharing. The whiteboard is updated daily and reviewed by each department's manager for discussing between specifically maintenance and production to study deviations finding correlations and creating solutions. The open displayed whiteboard enables everyone to speak the truth, by having the information available from maintenance and production hinders production to blame maintenance for bad performance and vice versa.

SKF puts great emphasis on employee safety. There is a coordination responsibility where each job should be risk analyzed which includes risks others are exposed to. The collaboration between the maintenance personnel and operator is extremely important at SKF. The fact is that the operator is the one who is in closest contact with the machine on a daily basis and can contribute with valuable information to the maintenance department and ease their maintenance planning. Since the service technicians are responsible for planning their own work it is important that everyone has proper competence. SKF has developed an education program where employees are educated in functions and areas, making it possible to perform more work tasks and implement work rotation. When distributing jobs between service technicians it is possible to give correct job task to the person with matching skills.

SKFs maintenance strategy is to support production in fulfilling their goals working towards complete planned and cost controlled maintenance. They are working according to the SS EN 13306 definition of maintenance: *Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.* KPIs at SKF are created to ease and support decision making of maintenance actions. Three main winning KPIs were identified; the OEE numbers were studied as well as its separate components such as availability to notice if machines are performing as required and in an efficient way. Backlog was also studied as indication on how well they are performing. Bottleneck availability was the most important KPI to measure. Buffers for other machines were kept to serve the bottleneck for smaller disturbances but D-time (downtime) as it is termed at SKF is the time that the bottleneck is down for any reason. Since the bottleneck controlled the profitability of the entire factory, it was seen as the most crucial KPI to study.

4.4.2 Parker Hannifin AB, Trollhättan

Parker Hannifin is a world leading company providing heavy automotive and aircraft industry with components within hydraulics, pneumatics, electro mechanics, filtration, process control, liquid- and gas control, sealing and shielding and climate control. The company has 58000 employees globally where 300 are situated at the visited site in Trollhättan. The site at Trollhättan business area is hydraulics (Parker Hannifin, 2014).

Parker Hannifin Trollhättan started working with Lean by introducing 5S in the late 90s. Structured equipment maintenance has through the implementation of Lean been focused on during the last five years. Parker early recognized the need to divide PM activities from emergency order. Great emphasis is put on performing PM when scheduled and should never be postponed. Otherwise there is a risk of losing the whole idea with PM and slowly turning preventive into emergency maintenance. PM is performed during specific weeks throughout the year for certain machine areas. Four weeks before these periods a meeting is held together with concerned personnel. Task lists are examined and discussed to confirm that each and every one understands what to be done and to assure that spare parts and the correct tools will be available when demanded. The company has not postponed a single PM week during the last two years. The interviewee claims that the most important aspect for a successful change or implementation is the support from the top management. A change can be suggested from the shop-floor level but has to be accepted from the topmost decision organ.

The strategy to divide the emergency team from the PM team is to reduce the workforce in the emergency team and increase the PM team. This is done by reviewing all the emergency work orders weekly and try to find a way to schedule them to fit the PM schedule. By doing so it is possible to find the causes and make proper planning and continuously decrease the number of emergency orders and move people to the PM team.

The operators should be active during the maintenance stops and collaborate with the maintenance personnel. The operators are the ones' running the machines and order the services and should be interested in highest quality work possible performed by the maintenance personnel. The techniques described by Genchi Genbutsu are used both in the maintenance area and the production area. Those are useful since you examine, for example, a maintenance stop and analyze the performance level according to a specific number of predetermined areas. If problems occur or any types of inconveniences, action plans are created to improve the current situation and secure accurate future routines. Each morning a meeting is held where maintenance quickly and effectively go through the maintenance prioritization. When problems occur with prioritized equipment, maintenance personnel should put aside other work tasks and attend at the required area. Pareto charts, one of the seven improvement tools (Bergman and Klefsjö, 2010), are used to prioritize equipment according to amount of stoppages per equipment which gives you the most unstable equipment where you stepwise examine the equipment to find the root causes to the high frequency stoppages.

4.4.3 Perstorp Oxo AB, Ödsmål

Perstorp is world leading in the area of specialty chemicals with around 1600 employees. The company is present in 22 countries around the world with production sites in nine of them. The Stenungsund/Nol site has around 200 employees. Perstorp Stenungsund is the largest user of natural gas in Sweden where 75% of the raw material used in the process comes from oil and natural gas. (Perstorp Oxo, 2014).

The maintenance department's vision is to secure the facilities in a cost efficient manner. To achieve such a goal great emphasis is put on effectively planning the maintenance stops both on an organizational level as for each individual maintenance technician. Perstorp Stenungsund reaches profitable growth by applying condition monitoring during operation, PM and ongoing observation of the equipment to ensure required equipment status. In 2009, Perstorp Stenungsund adapted the Toyota Production System during an improvement project with aid from an external company. The Perstorp Production System was created as a version that fits their unique industry. The maintenance department has a staff-level of five mechanics and employs entrepreneurs during large-scale maintenance stops. Each maintenance stop has one assigned technician who is responsible for the stop and by self-monitoring secure the status to eliminate the risk of same problem recurring. To follow up the maintenance quality KPIs are used. The KPIs such as the amount of emergency maintenance is measured in terms of hours instead of percentages or numbers. Percentages or numbers can vary due to several factors such as the different maintenance stops range and can lead to incorrect conclusions. Meetings are held every morning for a quick review on current work orders. Every Thursday larger meetings are held with the entire maintenance department to discuss all new work orders for the following weeks. Production has a similar meeting every Friday.

At Perstorp Stenungsund it is important to understand what investments gives in terms of benefits for the company. Supporting equipment should not be deprecated but instead question which equipment harms the productivity and create a succeeding action plan. The maintenance manager claims that outsourcing of the maintenance department can be fatal since you risk losing the entire ownership and control of the performed maintenance. When employing third party companies a report that presents the failures and not only that a failure has occurred should be provided to Perstorp to ease planning and prevention of future failures. At Perstorp, maintenance department is the cost owner of the equipment at the production areas. It is advantageous in terms of the maintenance department sense of ownership but with the downside that the operators do not feel the same responsibility and attitude against the equipment. The communication between the maintenance department and production is important and appears on a daily basis. Admiration and criticism is given and has created a strong collaboration between the two units. The equipment at the Stenungsund site is classified using RCM-classification. Each equipment is analyzed by a reliability group consisting of an engineer and a machine operator and classified as A, B or C. The maintenance department analyzes the result to give feedback on the classification and correct if needed. A is given when equipment failure results in breakdown, safety risks or environmental hazards. B is used when there is a possibility to run the process using for example another backup equipment and C when there is no risk of breakdown. The A-classified equipment is investigated to decide whether spare parts have to be on stock or not. Equipment with the largest downtime where most resources are allocated during a time period is focused on where large maintenance resources are concentrated to resolve these issues.

5 Discussion

Each research question studied during this project will be discussed separately. The discussion will also examine the possible implementation of TPM at Borealis Stenungsund.

5.1 Key performance indicators

KPIs should function as guidance in decision-making by proactively make decisions that will affect the organizational goals. If the KPIs are selected with the purpose of fulfilling the organizational goals i.e. affecting them will affect the overall goal.

5.1.1 Process choosing new key performance indicators

Finding the CSFs as described by Kaplan and Norton (1996) was the initial step in the process towards new KPIs at Borealis. Borealis objectives for PA&E are plant reliability, availability, safety and process-safety and still obtaining competitive cost aiming for maximization of the OAE (Wagner, 2008). These objectives could directly be connected to the six perspective scorecard described by Parmenter (2007) where some were interpreted and translated during interviews as important objectives especially for employee satisfaction; learning and growth was created in accordance with the structure presented by Parmenter (2007). The structure describes each KPI sufficient enough for everyone to fully understand each intendant meaning and as for who is responsible for data collection and presentation. The KPIs and KRIs suggested in table 5.1 are a combination of commonly used performance measures within industry as well as measures suggested by literature and Borealis standard (Wagner, 2008). The 10/80/10 rule was applied in the design of the performance measures as a guideline for the amount of measures obtained. The chosen KPIs and KRIs and the relation each has to Borealis success factors, strategic goals and the six perspectives presented by Parmenter (2007) is visualized in the suggested BSC (see figure 5.1). Bold performance measures in figure 5.1 represents KPIs while the others are chosen KRIs.

Table 5.1: Chosen KPIs and KRIs

KPI	**KRI**
Backlog	Achievements of individual targets
Data quality (reported data)	Availability
Immediate maintenance	Direct maintenance cost
Manpower efficiency on planned maintenance	Feedback
Near misses (synergy)	Maintenance cost as % of produced Ton
No. of failures	OEE
No. of observation tours	People survey
No. of TBW (improvements)	“Pulsen”
Preventive maintenance	Quality of planning
SMED execution	Quality rate
Training hours vs work hours	Rework
Updated PM-plans	Updated PM-plans
	Scrap rate
	TRI

Figure 5.2 give a visual representation on factors that could affect the production output and the sales income. By having this chart present at the company, it is possible for the maintenance organization to easier grasp what responsibilities and opportunities each area has. OEE is a combined measure on how well the plant is producing products by combining quality, speed and availability (Makigami, 2014). This is excellent to verify if the plant is performing at optimal conditions or if any of the six losses are present. The OEE figure does depend on production as well as the maintenance department that allows for an enhanced collaboration between the functions. Figure 5.2 visualizes how the OEE affects the output and what could possible cause losses regarding availability, performance and utilization. The counter-measure square presents what could be done to prevent these losses from occurring. The right-most square decides how each of these counter-measures should be controlled to gain the potential benefits. This representation of the output provides an overview on both

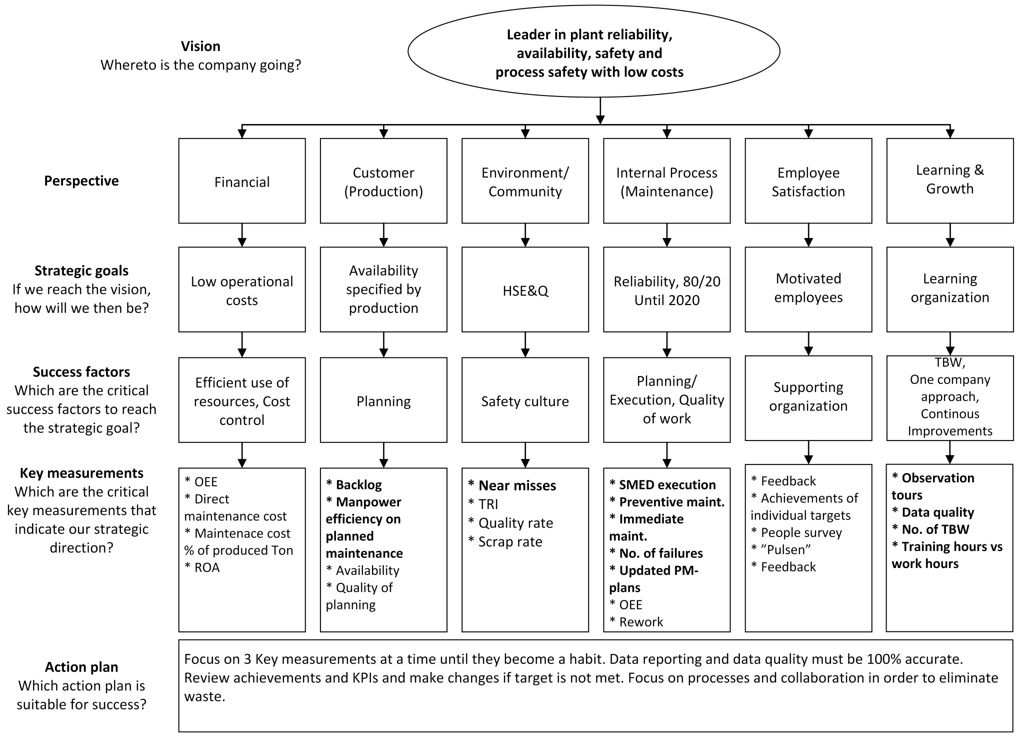


Figure 5.1: *Suggested balanced scorecard.*

different responsibilities and how each function could affect the output. On the contrary, this representation only give direct feedback on what parts that contributes directly to the OEE figure and should not be a measure for running an organization. By combining the factors contributing to the production output with the theories behind the BSC and all the perspectives a company need such as learning and growth as well as environmental and the employee perspective, it is possible to create a complete set of KPIs used to control the processes and measure success in all areas. The OEE target should be measured on the bottleneck and not all machines since the bottleneck controls the output for the entire plant (Makigami, 2014). Measuring one too many could be confusing providing different figures and wrong focus on where to put the efforts for improvements. Planned maintenance should be included as an availability loss if and only if the plant cannot meet the demand. This means that availability of 100% should be that it is producing all the time that there is a demand. Table 5.2 displays hours of outage allowed (downtime) for meeting specified availability target. This brings an idea into what challenges that derive from highly set goals and the importance of a sustainable change and continuous improvements for obtaining production availability at desired level in the future.

Table 5.2: Continuous availability target

Continuous availability target	Hours of outage allowed per month
99.99%	0.07 hours
99.99%	0.7 hours
99.5%	3.6 hours
99.0%	7.2 hours
98.6%	10.0 hours
98.0%	14.4 hours

Figure 5.2, presenting the factors affecting the production output, was created trying to combine the top down with a bottom up approach where the DuPont model displays the connection from ROA to the actual production output. The Du Pont model for ROA described by Soliman (2008) was modified creating the model presented in figure 5.2 to obtain an improved understanding on how to affect and control the parameters affecting the output from a shop floor level perspective up to top management, establishing a KPI pathway as described in section 2.3.3.

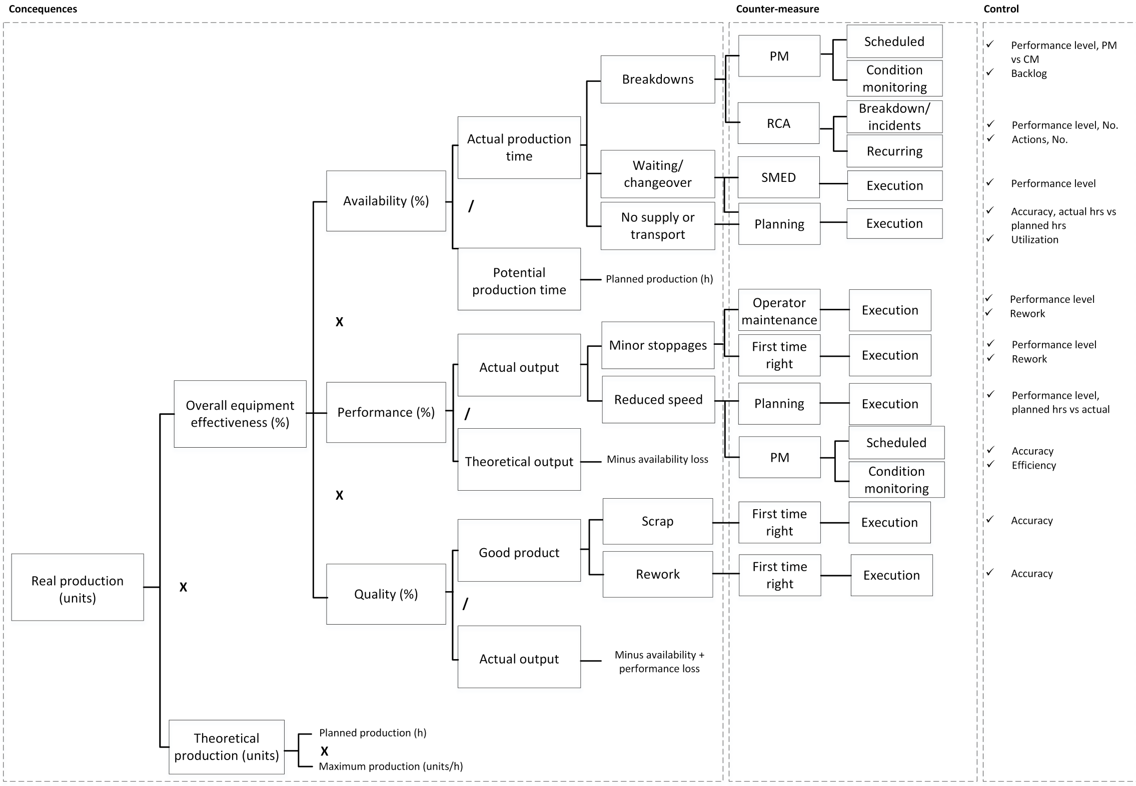


Figure 5.2: *Factors affecting the production output.*

KPIs are currently distorted since a mismatch between the dimensions that should be measured is present. An excessive focus, initiated by top management, is on the internal process and is strongly linked to the financial perspective. KPIs must tentatively be balanced where customer and employee focus must be increased (Kaplan and Norton, 1996). The KPIs that are present at the maintenance department is of a too broad nature and do not trigger the interest and recognition the staff should have to the measured KPIs. KPIs should be designated to directly influence the staff's performance. Another problem that is recurrent is the fact that focus is often on too many KPIs simultaneously. The proposed KPI scorecard (see figure 5.3) simplifies the interpretation on how they are affected which allows employees to understand how to influence these. For the KPIs to have an impact and lead to progress, is as mentioned in the standards and procedures, qualitative reported data required. It does consequently forces the direct management to provide information about why correct data is required and that its purpose is to jointly improve organization performance and not single out individuals' lack of productivity. By closely monitoring the measured KPIs and the outcome, one can simpler verify that correct ratios are measured or if the focus is misleading and must be revised.

Borealis vision to achieve a ratio of 80% PM and 20% CM is based on previous studies performed by Borealis where they have benchmarked other Swedish industries for finding a suitable distribution. However, is this the optimal distribution for the process industry and Borealis in particular? Why have companies chosen a specific distribution and how could this suit Borealis? Are the benchmarking performed against companies similar to Borealis (Coers et al., 2001)? The distribution may prove to have to vary between the different functions within the company, preferably kept in mind when determining the allocation and the long-term plan of action to be followed to achieve this goal. Such a mindset is useful for Borealis that requires cooperation among various entities within the organization and a thorough analysis to truly understand its process and its requirements. Choosing the PM and CM distribution has a strong connection to the approach to be used when implementing Lean, i.e., the adjustment that might be needed to suit the unique organization based on functional and useful tools and methods that Lean offers.

5.1.2 Analytic network process

The ANP method has been used to evaluate and prioritize the chosen KPIs as presented in the BSC (figure 5.1). The result of the ANP method is presented in Table 5.3 where all chosen KPIs have been prioritized against each other. Safety and improvement work has been highest ranked out of the individual judgment that has been made. OEE could be recognized as the highest process related ranked KPI. The individual judgments have been made by the authors during the project and builds on their own perception and knowledge within the field of maintenance. However, it can still function as a guideline in the decision making at Borealis Stenungsund.

Table 5.3: Prioritized KPIs as a result from the ANP method

Name	Importance	Ideals	Normals	Raw
Achievements of individual targets		10.6%	2.0%	0.00
Actual quality produced vs planned quality		5.4%	1.0%	0.00
Backlog		6.1%	1.1%	0.00
Data quality/ SAP		16.1%	3.0%	0.00
Direct maintenance cost		2.4%	0.5%	0.00
Feedback		59.1%	11.2%	0.02
IM		5.0%	1.0%	0.00
Maintenance cost % of sales		2.2%	0.4%	0.00
Manpower efficiency on planned maintenance		9.5%	1.8%	0.00
No. of TBW		55.3%	10.5%	0.02
Number of failures		6.2%	1.2%	0.00
Observation tours		82.8%	15.7%	0.03
OEE		38.2%	7.2%	0.01
People survey		5.3%	1.0%	0.00
PM		13.8%	2.6%	0.00
Pulsen		2.6%	0.5%	0.00
Quality of planning		24.9%	4.7%	0.01
Rework		12.2%	2.3%	0.00
ROA		0.8%	0.1%	0.00
Scrap rate		8.9%	1.7%	0.00
SMED execution		14.6%	2.8%	0.00
Synergy		100.0%	18.9%	0.03
Training hours vs work hours		23.2%	4.4%	0.01
TRI		7.4%	1.4%	0.00
Updated PM plans		16.1%	3.0%	0.00

ANP is an effective tool for jointly determine which KPIs that are currently relevant to measure and monitor (van Horenbeek and Pintelon, 2013). The ANP method can be used at group level, where common KPIs are weighted against each other and together present a result that reflects the group's shared values (Saaty and Vargas, 2006). Such a basis provides security and enhances the understanding of why certain KPIs should be measured. This opens up for discussion and enables greater collaboration among individuals in the organization.

5.2 Productivity follow up

During the daily meetings there should be time allocated for reviewing previous achievements and update everyone of the status on their work. By doing this on both the daily, weekly and monthly meetings everyone gets a chance to notice how each and everyone's work effort has contributed to the mutual goals at Borealis.

Productivity follow up shall be done by presenting results. This is done in standard and color-coded templates for each team/area/discipline. The scorecards covering currently measured and followed-up KPIs, see figure 5.3, are individual at team level and general for the maintenance function on group level. Everyone should be able to interpret the presented KPIs knowing how to personally influence the outcome (Parmenter, 2007). The maintenance and production unit should have daily updates at the respective production area while each team/discipline gets weekly KPI reports. The group meetings should consist of overall KPIs for the entire maintenance function once a month to get a more comprehensive understanding and notice if the goal has reflected what everyone shall endeavor. During these meetings, uncertain KPIs that do not seem to produce results should be evaluated and revised. It is then of importance to find out if the data for measuring new or updated KPIs are available in SAP. The measured KPIs do also have to simultaneously contribute to the organizations mutual goals. A connection between non-financial and financial goals, presented in the company's BSC, has to be present accordingly (Kaplan and Norton, 1996).

5.2.1 Key performance indicator scorecard

Visual presentation of currently most important KPIs should be done on a weekly basis where a suggested design is presented in figure 5.3. The scorecard should be presented during group meetings as well as weekly meetings with the planners and supervisors. The scorecard consists of the current target in relation to the actual result using a color-coding rating. Depending on the result, three different categories are possible. Green represents a result in relation to or above the target, yellow is a result slightly below target, and red represents a severe result where actions urgently need to be addressed. The scale to decide upon the color-coding should be decided by a group representing concerned personnel for each individual KPI (Parmenter, 2007). The weekly report of KPIs include the most recent four weeks results to present a trend and indicate if actions taken has an impact on the result. Current issues and actions to be taken should be stated for each currently Top five-measured KPI.

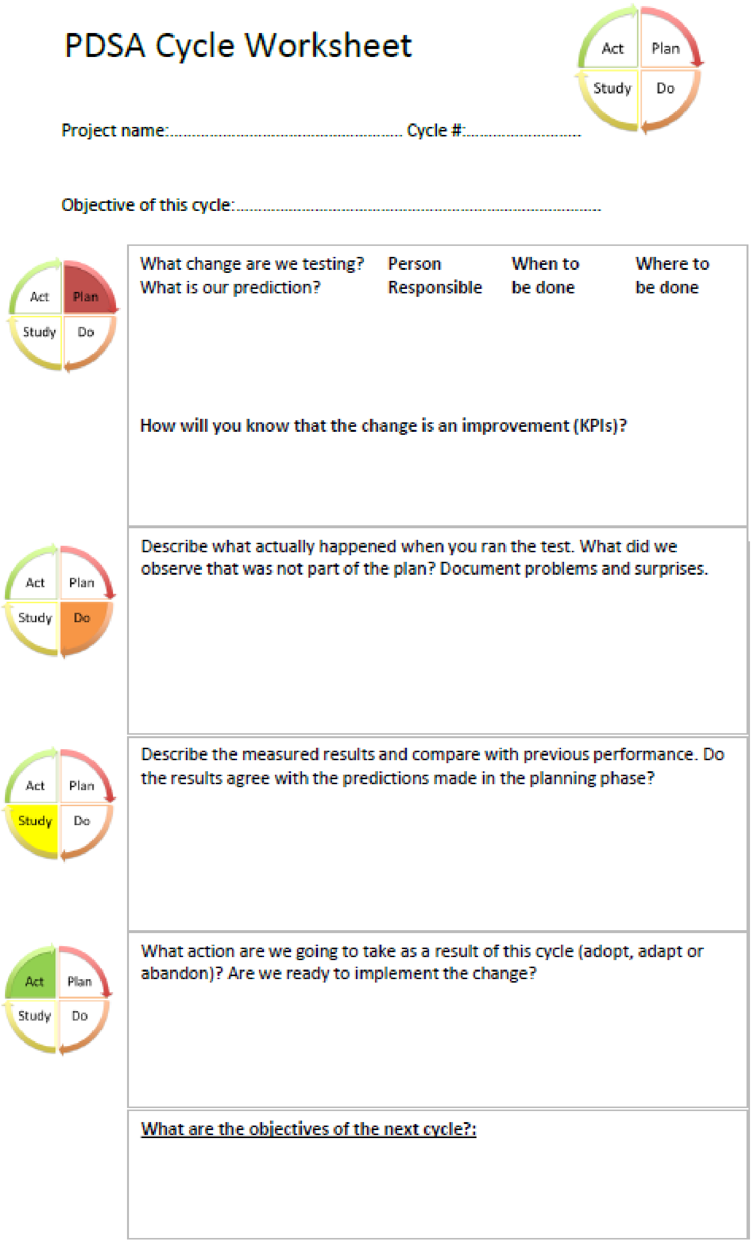
Top five KPIs Weekly report W.5

Top 5 indicators	Target	Result	Rating
Availability (see graph below)	> 95%	97	
Backlog (see graph below)	0	1	
Preventive (see graph below)	> 80%	80	
No. of prepared task lists	2	1	
Quality of planning	> 80%	60	

Figure 5.3: *Example of visualization of KPI result using an excel sheet.*

5.3 Improvement methodologies

A supplement to TBW was created for managing minor projects and continuous improvements. The PDSA cycle worksheet in figure 5.4 follows the structure described by Bergman and Klefsjö (2010) where each step needs to be revised and closed before next step in the cycle can begin. The worksheet should be a standard that allows improvements to be understood by everyone in the organization. Each step should be reviewed and confirmed during the improvement meetings before next step is initiated. This allows everyone to comment on changes and contribute with new ideas and solutions. It will also facilitate that improvements are carried out in proper manner where everyone is aware of the status so that new standards can be transferred and communicated. The PDSA cycle worksheets will be placed on the improvement board in figure 5.5 for everyone to see and be used as a visual tool for transferring information to others.


PDSA Cycle Worksheet

Act Plan Study Do

Project name:.. Cycle #:..........................

Objective of this cycle:..

Act Plan Study Do

What change are we testing? What is our prediction? | Person Responsible | When to be done | Where to be done

How will you know that the change is an improvement (KPIs)?

Act Plan Study Do

Describe what actually happened when you ran the test. What did we observe that was not part of the plan? Document problems and surprises.

Act Plan Study Do

Describe the measured results and compare with previous performance. Do the results agree with the predictions made in the planning phase?

Act Plan Study Do

What action are we going to take as a result of this cycle (adopt, adapt or abandon)? Are we ready to implement the change?

What are the objectives of the next cycle?:

Figure 5.4: *PDSA cycle worksheet.*

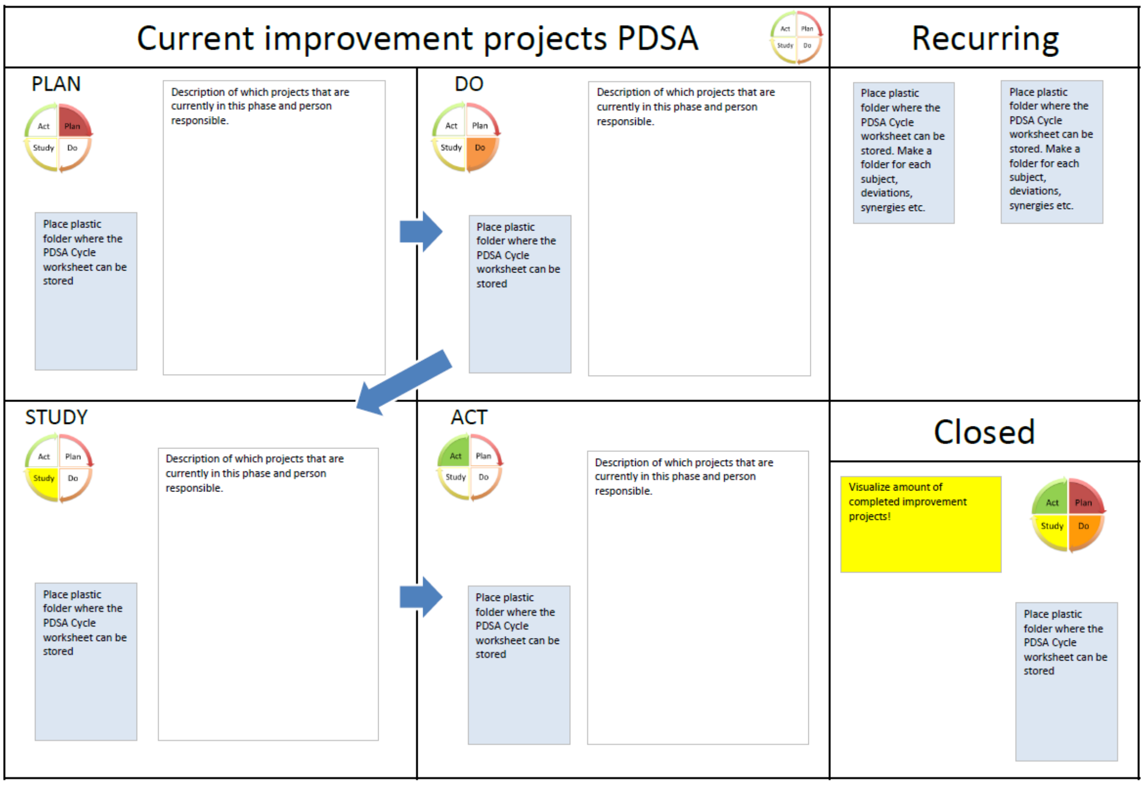


Figure 5.5: *PDSA improvement board.*

For a visual representation of all ongoing PDSAs an improvement board (whiteboard) has been proposed as visualized in figure 5.5. All concerned parts review each project before being approved and initializing the next step in the PDSA cycle. This has showed to be a successful strategy at SKF and enables new standards to be accepted. Space has been assigned for frequently recurring subjects for further analysis. All closed and finished projects are displayed in the down right corner as a KPI where everyone is informed about the improvements implemented. At SKF a similar model has been applied referred to as "Finna-Fixa-Försvinna" (Find-Solve-Close) where group discussions are held to create acceptance among the participants when closing a project phase; find, solve, close and proceed.

5.4 Computerized maintenance management system

Lack of data hinders the possibility of follow up the maintenance process, locating problem areas and improve it continuously. The activities reported in SAP should follow a specific guideline regarding the type of maintenance activity executed as presented in figure 5.6. This supports the work towards reaching a distribution of 80% PM and 20% CM at Borealis Stenungsund. It is important that the data quality is as intended since the goal of 20% CM activities consists of "2s-6s" and not "0-1s". "0s-1s" are CM activities that are stated as immediate CM with restricted planning possibilities and may require extra emergency staff, also known as "call-outs". A striving for eliminate "0s-1s" should therefore be a goal in itself. Maintenance activities are given a value of 0-6 depending on the time frame the activities has to be completed avoiding breakdown. There is consequently an absence of a rigorous reporting structure at Borealis Stenungsund. A standardized structure does not exist more than informally. There are insufficient data for all KPIs to be measured. Consequently, data presented in table 5.4 needs to be recorded for all the KPIs and KRIs to be possible to measure.

By gathering all of the above stated information it is possible to calculate all KPIs suggested in the BSC as seen in figure 5.1 and described in Appendix E. Since data collection could be time consuming it is possible, by various suppliers, to implement additional applications to SAP for automatically creating reports. This will further decrease the resistance that comes from further responsibilities and work tasks for middle management. Before initiating a process of installing an automatic reporting system one must consider the pros and cons by

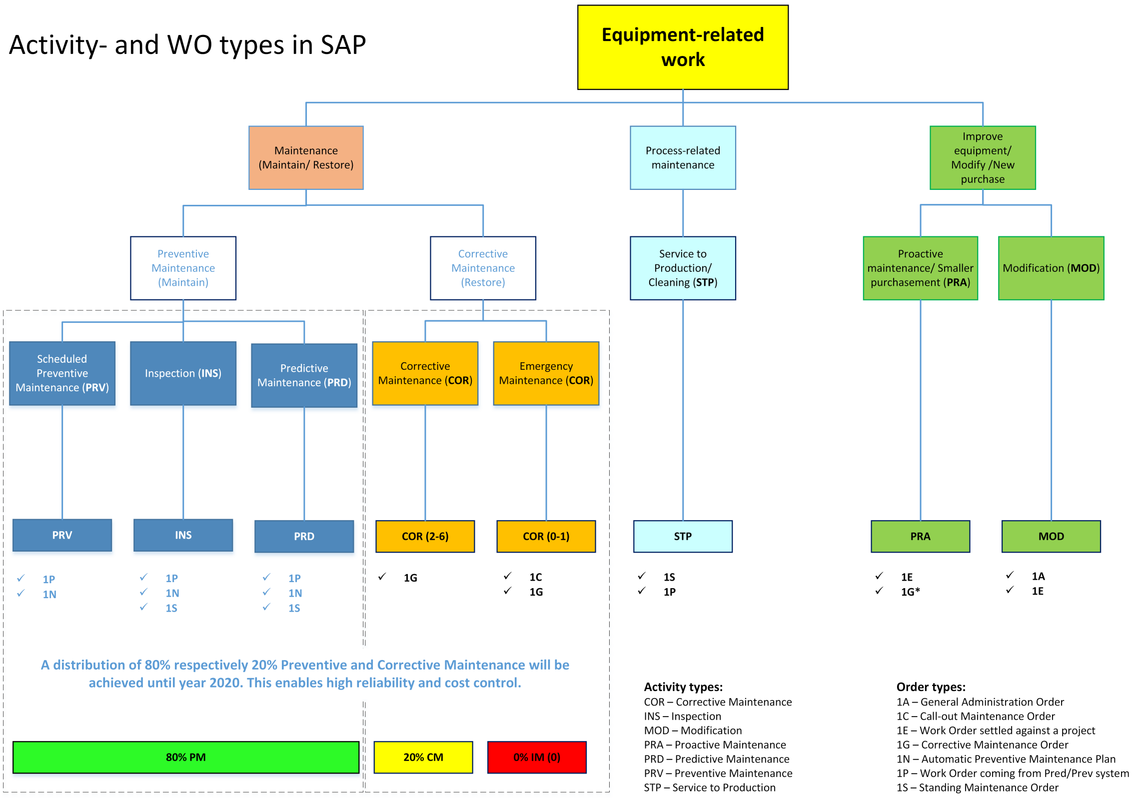


Figure 5.6: *Activity- and WO types in SAP.*

Table 5.4: Needed measurements for tracking KPIs and KRIs

Time	**Production data**
Planned maintenance hours (time plus staffing)	Planned production time
Actual maintenance hours	Actual production time (planned minus breakdowns)
Total reported maintenance hours (actual work) + total paid maintenance hours	Produced quality (%) compared to plan
Stop hours due to failures	Production speed (%)
Emergency maintenance hours	
Mean time between failures (MTBF)	
Mean time to repair (MTTR)	
Maintenance data	**Employee data**
Maintenance cost per production line	No. of reported “synergies”
No. of failures in total	No. of TRIs
No. of failures resulting in shutdown	No. of observation tours
No. of breakdowns	No. of PDSAs, improvement projects
No. of planned maintenance activities	Training hours
Preventive vs. corrective maintenance	Feedback, number of PDSAs compared to no. of improvement suggestions
No. of emergency maintenance orders	Achievements on individual targets
Backlog	Status from “Pulsen”
No. of updated task lists (PM-plans)	
Reported hours in SAP compared to actual hours	

developing an own system or buying from a system vendor. The external benchmarking revealed that there are a deeper understanding and flexibility of the system by developing an own but then one must be responsible and having the right knowledge for doing so. If decision is made to purchase such a system it is important to specify the need and demand on the system. Olofsson (2014) presents a requirement specification suitable for any attempt to adopt an advanced automatic reporting system.

Following seven questions needs to be considered (Olofsson, 2014):

1. How long going is the Lean/TPM implementation? Does the work today focus on bigger losses or is there a need for high accuracy in the measures?
2. Is there a strategy for working with improvements? Should these be generated from the system?
3. Is there a need for decision support enabling increased production? In case of, which has the most need for this system? Operators, maintenance department, planning, supervisors, engineers or higher managers?
4. Are there defined bottlenecks or are they shifting?
5. Are good locking reports essential or is it more important to be able to dig deep into statistics and numbers for finding root causes?
6. Is there actually a demand for the increased capacity that derives from increased OEE or other factors affecting the capacity?
7. Is there a need for further functionalities such as process data?

5.5 Daily planning

A structure for the daily planning meetings has been created where the suggested subjects by Idhammar (2014a) and Idhammar (2014d) has been evaluated to suit Borealis process for handling work orders. The meetings have been assigned a designated area where punctuality must be focused on for higher efficiency and time saving. Assigning the maintenance crew with the daily work tasks and addressing new issues that has arisen should be done according to the suggested structure. A plan for assigning extra maintenance orders in case of available time has been constructed as a suggestion for faster decision paths.

5.5.1 Daily planning suggestion

Preparation prior to the planning meeting:

- Having a priority chart. Planning for work in the backlog before the meeting
- Knowing the availability of people
- Realizing that all meeting agreements are final – any change is break in work.

Following should be brought up during quick and effective daily meetings as present by Idhammar (2014a) with all concerned parties (Technicians, Electrical and instrument technicians, planners, supervisors, area responsible (engineers, specialists), production coordinator):

- Review work from yesterday
- Update work for today
- Finalize work for tomorrow
- Finalize schedule for following week by 2 PM on Friday
- Track planning and scheduling of key metrics
- Schedule 100% of work force including contractors

- Resolve new work requests

These meetings should not only be supported from the manager, but should consequently be followed-up to confirm that concerned parties attend the meetings and that preparatory work is done prior to the meetings to obtain increased effectiveness. The whiteboard (see figure 5.7) has to be updated with previous day's planned activities to be visualized for the attendants.

All stops should be visualized on the whiteboard together with daily (updated) KPIs. The production has to participate and fill in updated production and process data to visualize the connection between maintenance and the production unit.

Coordination between production and maintenance are currently lacking and differs qualitatively between different production areas. Maintenance and production can mostly be seen as two different internal "businesses" at Borealis that jeopardizes the possibility to see common goals such as productivity, instead of having individual financial goals as a base. The visual planning presented in the report is a tool to get closer to exactly what Borealis refer to as a one company approach. These aids promote short, efficient meetings and enable each function to get an overview of the process and what is occurring at the relevant production area. Interaction between production and maintenance simplifies monitoring of KPIs and the source of the problems that arise. That functions largely work separately will complicate a common visualization of the process, since this gives rise to a resistance to change. An open attitude from the maintenance aspect which introduces the proposed visualization tools in their daily work and present the benefits of these for the production unit will facilitate closer future cooperation between the units.

5.5.2 Visual planning

Daily planning for both maintenance and production were suggested to be visualized through whiteboards. Figure 5.7 presents the result where the white boards' function as a tool both for enhanced understanding and as a mutual area for discussion and collaboration between maintenance and production. For each production area maintenance stops should daily be visualized using red-tagged magnets. Small magnets represent detected equipment failures where large magnets are used when the maintenance stop is of a more extensive nature and results in equipment breakdown. Green magnets visualize CM free workdays. The whiteboard should also consist of planned maintenance activities for each production area to ease the collaboration and planning between the maintenance and production unit. Together with the maintenance and production whiteboard (figure 5.7) the currently most important KPIs should be present.

Maintenance		Current events for maintenance										Planned / Preventive maintenance					Backlog per line
Week	Line	Mon	Thu	Wed	Thu	Fri	Sat	Sun	< 1h	1-8h	> 8h	Mon	Thu	Wed	Thu	Fri	
33	Raw																
33	L-1																
33	L-2																
33	MH																

Production		Production (Ton)														Result	
		Mon		Thu		Wed		Thu		Fri		Sat		Sun		Week	
Week	Line	Quantity (Ton)	Qualilty (%)	Quantity (Ton)	Qualilty (%)	Quantity (Ton)	Qualilty (%)	Quantity (Ton)	Qualilty (%)	Quantity (Ton)	Qualilty (%)	Quantity (Ton)	Qualilty (%)	Quantity (Ton)	Qualilty (%)	Quantity (Ton)	Qualilty (%)
33	Raw																
33	L-1																
33	L-2																
33	MH																

Figure 5.7: *Maintenance and production planning.*

5.6 Maintenance report

A standard for writing maintenance reports must be established for enabling data recording for KPIs, analyzes of maintenance activities and possible root causes. Data should not be overwhelming or insufficient (Smith and Hawkins, 2004). That organization tends to be data rich but information poor does not apply at Borealis. Data for analyzes are insufficient and must be recorded for future analyzes. All reports written must contain the data required for the KPIs to be presented. Data must always be filled in for each job where all the hours and number of technicians per task are presented. If decisions towards changing existing KPIs are settled, the report template must be updated accordingly. Information shall go out to all concerned that a review of the current template is implemented to obtain as high data quality as possible for future maintenance reporting. Without sufficient and qualitative data, correct conclusions cannot be stated (Smith and Hawkins, 2004).

There is no former evident strategy on how to act to improve maintenance at Borealis. Sub-optimizations have occurred on each individual work without a holistic perspective. This probably explains why the reporting of maintenance activities do not occur in a uniform manner and have led to that information in some cases is scarce, while the information that may be sufficient in some cases constitute little importance as the overall picture cannot be visualized. The fact that Borealis is developing a strategy makes reporting more important to analyze and further work with the classification equipment should have. To immerse themselves in reports to a greater extent to find frequent recurrence faults and the faults that cause the most downtime will be more and more interesting where the emphasis should be just at getting into a functioning and unified reporting system.

Through the KPIs that have been developed during this project, we have tied necessary data for each KPI respectively. It requires, however, that the one reporting the data has been properly instructed about how accurate the data should be and when and where to report. A recurring problem that has emerged, probably as a result of an organization where the primary goal is to pass a budget has resulted in maintenance activities that should be reported as acute or remediation has been posted and reported as planned maintenance. This allows the maintenance department to meet its targets for each budget and appear representative outward to the rest of the organization. This way of working is to fool oneself and only hampers analyzes since inaccurate data will be retrieved from the system. A similar scenario arises when the external firm that performs maintenance activities only reports the time to be compensated for and not the actual stop time. This may be due to lack of understanding of what the difference in compensated hours and downtime means or that one avoids reporting correct time with the risk of being questioned if the deviation is too noticeable from the planned maintenance time.

5.7 Standard and routines

Management in accordance with supervisors and maintenance crew defines and implement new standards together with the other departments during the rotating team meetings where production and maintenance agrees on new routines together and if initiated projects are carried out in a pleasing manner. The PDSA cycle worksheet will function as a method to create standards where completed activities should be reviewed and agreed upon before implemented. The standards must be supervised and continuously updated and not being left behind where old routines tend to be used instead. Standard and routines will consequently be introduced when reporting proposed KPIs following provided solutions as for visualization of the current most important KPIs as presented in section 5.2.1. Meetings should, as presented in figure 5.8, follow a standardized meeting agenda to obtain quick and effective meetings and to eliminate empty, time-consuming meetings without clear intentions. SKF has successfully implemented similar meeting agendas together with their MCRS to settle necessary meetings that in combination has proven to result in more qualitative and productive meetings.

Working methods and operating procedures are too often ingrained in individuals' behavior. It is often rehearsed methods that one considers as the best and most efficient ways to perform tasks on. This creates a resistance to change among several individuals. Consequently, the introduction of standards and routines and the ability to maintain those generally seen as best practices is hampered. In Borealis Stenungsund does this manifest itself through the reporting done to SAP. The reported objects and times to SAP differs widely among staff and hinder the collection and reporting of data, for example in the form of KPIs that require reliable data to enable accurate and worthwhile follow up to improve the outcome and help achieve the company's common goals. Great emphasis must be placed on informing and training staff in how data should be reported to obtain enhanced data quality and how this benefits the person in question. At Borealis, one-point lessons are applied in some areas, which is a standard in how to proceed in the execution of tasks. One-point lesson is an excellent tool available to enable wider distribution and use of standards and procedures, and understanding of how and why to report accurate and reliable data, short and informative featured on a one-point lesson-sheet.

5.8 Implementation strategy

Implementing TPM puts great emphasis on managers to get everyone committed during the TPM implementation (Nakajima, 1992). A plan that is fully understood throughout the organization should be made to ease and facilitate the implementation where the time factor carefully has to be considered. Having the patience to do it right and not get ahead of the plan is a management task that is essential. Educating people in TPM is also important since the focus to work together striving for a common goal is a rather diverging approach to what is today standard where people have their own areas to consider without feedback from the actual output.

The first step is the master plan where everyone gets a holistic view of the steps in the implementation. When that is established, a set of KPIs should be created so improvements can be measured. It is important to evaluate these KPIs in the beginning so that KPIs actually have the intended purpose and if not they should be evaluated and reviewed for suiting the purpose. Management commitment has been seen during several occasions as the one common factor that determined whether the change is going to be successful or not. While management is committed they must also give responsibilities to the staff for a grass root approach towards the change. This enables everyone to be engaged and feel a sense of ownership.

The 12 step approach developed by Nakajima (1992) is strictly followed in Japan and has proven to be successful. However, it has showed not to be the case in many other western countries where the discipline fostered in the Japanese culture is not as evident. Another approach would be the one Liker (2004) suggests for general Lean implementations where focus should be on creating and visualizing value flows. This gives everyone an idea of where the waste is located and what activities that actually produce value. Only improving equipment efficiency might not be the optimal solution since some equipment does not produce as much value as others do which will be visualized creating value flows.

Overcoming resistance from employees regarding the aspect that people notice increased workload, it is important to inform everyone about the suggested meeting agendas and standardized planning meeting which gives freed up time that should directly be set of for TPM work. Additionally they must be informed of the positive effects that TPM has when it comes to having control of the situation and putting out fires belongs to the past.

The collaboration between maintenance and production needs to be improved both economically, administrative and vision wise where everyone should works together towards the same target. This is a work that is currently ongoing at higher management level but still nothing that the maintenance technicians get to be a part of. The maintenance technicians are the ones performing the actual tasks and are used to work with old routines and habits as management that implies they must be as involved and infirmed as management. Without this perspective there is a risk of TPM being just another project that does not get to be implemented. This perspective further increases the importance of collaboration since Borealis has outsourced the execution of maintenance tasks. One can argue that if you pay for a service they should deliver what has been promised. This argument does not reflect reality and should instead be changed to an approach where Borealis production partner should be further integrated in the daily work and resources must be given for them to be integrated in the TPM implementation. Costs will initially rise as education and investments needs to be made but is essential for a TPM implementation to be sustained. Financial benefits will follow in the long run (Liker, 2006).

Andreas Veje[1] , one of the production managers at Borealis, was interviewed discussing the collaboration between the maintenance department and production. He was positive and understood that the collaboration needed to improve and he also suggested that his staff could do a lot more during periods when the machines are running and perform operator maintenance as well. He stated, however, that tasks that needed focus to get

[1] Andreas Veje (Production manager, Borealis) interviewed by the authurs the 19th of Feb 2014.

finished at a certain time might be difficult since the operator staff needs to respond to different events that might occur occasionally forcing them to put aside the maintenance activity.

Projects have a tendency to be initiated without changes being sustained at Borealis. Such behavior must be changed for long-term goals to be met. By providing education and information about TPM as a way of thinking and acting, ensuring that everyone believes in it will create a more positive attitude towards projects and the ability to sustaining change. Relevant information must be easy accessible for creating a better communication between departments and build in the collaboration that is necessary for TPM to succeed.

5.9 Single minute exchange of die

The mapping of the current F1-cleaning state in Appendix C was the starting point for the establishment of a possible future state with reduced non-value-adding time, presented in Appendix D. By improving the communication and coordinate the work tasks performed by the maintenance and production function a time reduction by 30% can be reached. Following suggestions regarding the areas presented in section 4.3 are advocated:

Lack of communication

- Enhanced planning and use of maintenance technicians to a greater extent had enabled a shorter maintenance shutdown since this was evident repeatedly during the stop.
- The lack of a thought out overlap approach has to be overlooked to avoid increased safety hazards as for non-value adding activities such as searching for tools and equipment
- Use of means of communication will save time during the stops. One suggestion was to use a walkie-talkie pool for stops of this type of maintenance stop. It would ease the communication at L-302 between all parties active during the stop.

Cleanliness and order

- Checklists reviewed prior to the stop and a natural approach of where tools and equipment shall be would certainly streamline maintenance.

Safety, health and environment

- Safety needs to be reviewed. Using forklifts, especially diesel forklifts indoor are not acceptable and expose operators to unnecessary risks.
- As a suggestion, removed plastics should be placed directly in a bin to keep a clean and tidy workplace, avoiding obstacles to the operators themselves and encourage a 5S-mindset.
- The use of wheeled bins would have facilitated the work of the technicians and decreased the physical strain.
- The damage hot oil pipe could not only lead to absenteeism and lack of staff but also a financial burden and should be given higher priority than it currently seems to do.
- Proposal submitted by the mechanics of either having an extra pulley or an extra lifting beam between the existing lifting beams. This would also reduce the need for a forklift indoors since an added lifting beam would make it possible to reach components at the line previously transported with the fork lift.
- One must fulfill the requirements that is put on the facility and presented at corporate level. The technicians suggested, among other things, the use of a ratchet that would allow tighter tightening before hydraulic tools are used, thus avoiding the need for manual effort and the risks associated.

Tools and equipment

- The tools should be checked as a part of the preparatory work to eliminate problems with inoperative tools.
- Replacing the slow cranes using cranes that are wireless controlled saves time and increases safety since technicians do not need to be in direct contact with the zones throughout the assembly and disassembly of the zones.

Cleaning

- New, improved nozzles were suggested to be used when cleaning the area above the line improving the cleanliness and avoiding particles to fall down during production up time and contaminate the products.
- The production team should have been present more frequently during the stop for following up the maintenance shutdown ensuring that everything functioned as it should and for closer cooperation between maintenance and operation. The production is, after all, the customer who wants a properly performed maintenance work within the specified time frame.

It is vital to follow up each stop and examine the result, finding both pros and cons with the executed F1-cleaning. The meeting before and directly after the stop should as a suggestion follow succeeding meeting procedure:

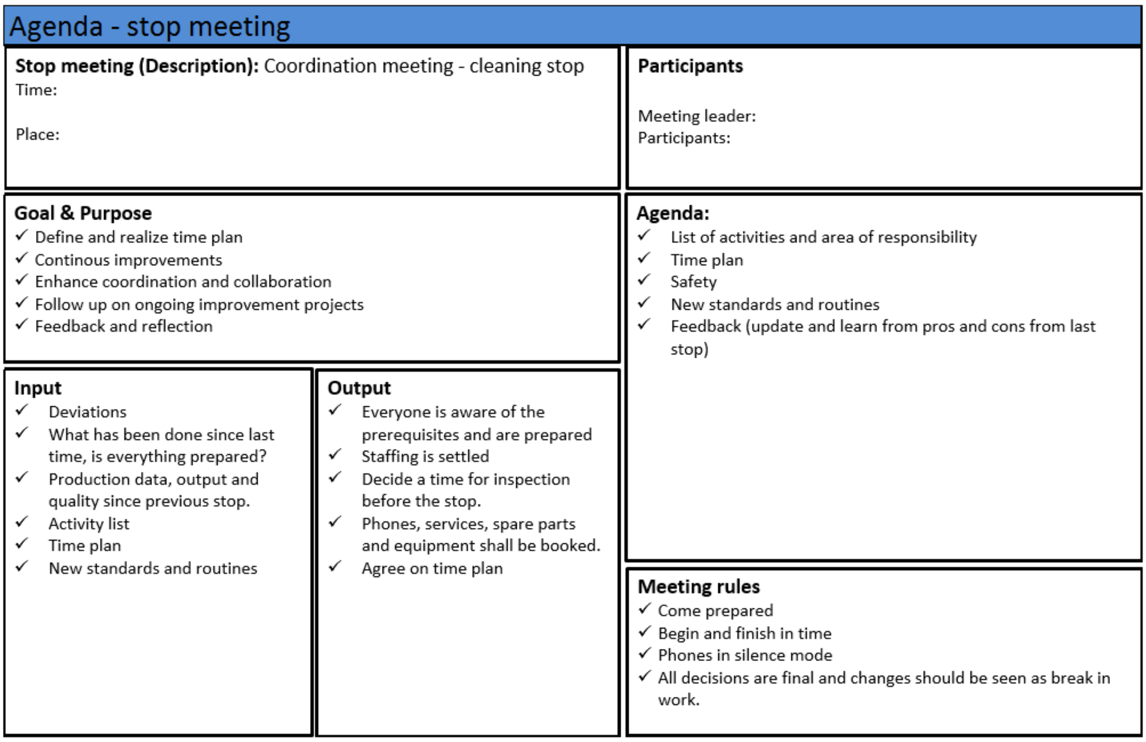
Two weeks prior to the F1-cleaning a meeting should be held where material is secured and services should be booked.

One week prior to the F1-cleaning:

- Arrange staffing and book up staff
- Review the tools and apply 5S
- Arrange phones/radios and number list
- Arrange fork lifts to concerned personnel and breakfast/lunch/dinner
- Inspect the line!

During planning and follow up a meeting agenda must consequently be present (see figure 5.8). Suggestions should be examined to determine what to be done. Update work procedure after each stop to create a new standard to follow. Before and during each meeting following shall clearly be stated:

- Relevant persons to attend meeting
- Which ones will appear, and reason if they do not. The meeting minutes are excellent if someone cannot participate for a quick overview of what is raised
- A secretary shall be determined. The position shall be rotating
- Information should be provided about what to be done before the meeting
- An agenda over what should be included
- A maximum time should be set for a rapid and efficient meeting
- No late entries should be accepted!
- Great emphasis should be put on establishing a common time schedule that everyone has access to. This avoids confusion and provide an overall picture of what other units work with during the stop
- It must be clear that the stop coordinator (maintenance and operation) are the first to be contacted if there are any confusions during the maintenance shutdown



Agenda - stop meeting

Stop meeting (Description): Coordination meeting - cleaning stop
Time:
Place:

Participants
Meeting leader:
Participants:

Goal & Purpose
- ✓ Define and realize time plan
- ✓ Continous improvements
- ✓ Enhance coordination and collaboration
- ✓ Follow up on ongoing improvement projects
- ✓ Feedback and reflection

Agenda:
- ✓ List of activities and area of responsibility
- ✓ Time plan
- ✓ Safety
- ✓ New standards and routines
- ✓ Feedback (update and learn from pros and cons from last stop)

Input
- ✓ Deviations
- ✓ What has been done since last time, is everything prepared?
- ✓ Production data, output and quality since previous stop.
- ✓ Activity list
- ✓ Time plan
- ✓ New standards and routines

Output
- ✓ Everyone is aware of the prerequisites and are prepared
- ✓ Staffing is settled
- ✓ Decide a time for inspection before the stop.
- ✓ Phones, services, spare parts and equipment shall be booked.
- ✓ Agree on time plan

Meeting rules
- ✓ Come prepared
- ✓ Begin and finish in time
- ✓ Phones in silence mode
- ✓ All decisions are final and changes should be seen as break in work.

Figure 5.8: *Suggested meeting agenda.*

Follow up meeting will take place immediately after the stop where everyone can participate. During the meeting are positive aspects as well as constructive criticism to further improve the work process to the next stop discussed.

It is important to provide and receive feedback both during and after the process. Responsible personnel have to inspect the line to recognize the problems that may be present (Liker, 2006). The purpose of controlling and discuss on site is not to act as a strict supervisor, but to assist the operating personnel and gain insight in what to improve. Solving a problem behind a desk that has not been perceived in reality is no effective method since the underlying causes that can be discovered by being at site where it all take place is lost. Operators possess most knowledge about the work and must have a leading role in the daily improvement process. A close relationship between managers and personnel is critical to bring problems to the surface and actively make a change. By involving the personnel you built a trust that goes beyond the typical role of managers in which control and monitor creates inharmoniousness and distance leading to lower confidence and lower quality of work. Increased teamwork and creativity is achieved by letting the operators participate, a prerequisite for continuous improvement.

5.10 Maintenance value stream mapping

The MVSM created of the current state in section 4.2 shows a quite equal distribution of value adding and non-value adding activities and a total maintenance lead-time of 38.5 hours (including planning). This though is already a reduction from 55 hours (excluding planning) as the stops took before as a result of an efficient improvement work previously done at Borealis. However, hours were the process is not producing is a loss of income and especially important in process industries with capital extensive equipment and products. The focus was then to reduce the complete maintenance lead-time where a SMED analysis as presented by Vaughn (2009) was performed on the value-adding time (MTTR) in the MVSM. However, improvements can further be achieved prior to and after the MTTR stage. Mean time to organize (MTTO), i.e. activities prior to the execution phase, can be reduced through the use of suggested planning tools such as the meeting agenda in figure 5.8 as for a clearer communication between the functions. MTTY can also be decreased through self-checking routines and higher quality of work. MVSM can facilitate as unpredicted stops occurs that for example requires similar actions to be taken with the absence of the possibility to plan prior to the stop.

The SMED analysis itself revealed that a reduction of 30% should be possible through better planning and preparation while the MTTO and MTTY was estimated in the future state map also to have a positive effect on the maintenance lead-time. A new future state map was then created as seen in figure 5.9 where discussions and individual judgments has been considered regarding the effect it has on MTTO and the MTTY and the observed improvement potentials during the SMED-analysis that has been carried out. The future state map indicates that a total reduction of the maintenance lead-time of approximately 35% should be possible to reach.

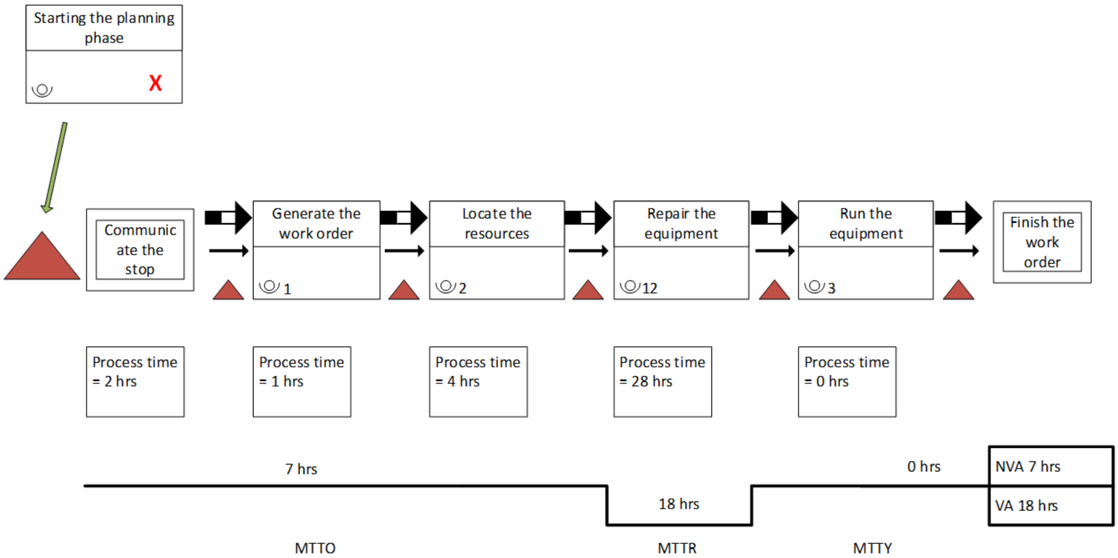


Figure 5.9: *Future state maintenance value stream mapping.*

6 Validity of results and recommendations

The results build on both theoretical and empirical studies that have allowed the subject to be understood in a valuable manner. The study has had its main focus on the maintenance organization and should gain from further and deeper understanding from the production perspective. The proposed solutions could be implemented successfully at Borealis PA, but the result of an implementation depends partly on the communication and collaboration between maintenance and production. However, top management commitment will be of greatest importance and must be considered carefully before starting the work towards implementing TPM. We recommend that this part is fully overlooked and established at the highest top at Borealis Stenungsund. However if they have that support we believe they will succeed since the commitment and knowledge of the internal processes is present and will contribute to a good and solid implementation.

The weighing of the MPIs using the ANP method in this master thesis builds on the authors' own judgments and should not be considered as the final rating to follow. The ANP method itself builds on individual judgments by the authors. A better representation of the actual weighting must be done by concerned parties at Borealis with the right knowledge. However, using the ANP software Super Decisions it calculates the inconsistency which presents if the judgments are consistent to reduce the risk of interference and misleading results.

There are always new researches and theories and ways to proceed where effort has been made on finding the most updated and essential information. This has built a credible framework for our study but there are probably still many unexplored theories that has not been reviewed.

The observation that was made during the maintenance stop could unintentionally have affected the performance of the technicians. Our presence could have influenced both the speed of work but also created stress that may have resulted in some of the hazardous behaviors observed. Besides that we believe we had a good connection with the technicians since we clearly stated from the beginning that we would not consider their performance in our evaluation. They were involved and engaged in our work since they realized the potential of getting their voice strengthen against their managers.

Doing this study once again we recommend interviewing several managers, especially from the production area which would strengthen the results and its credibility since it is quite a large gap between the two functions. Prejudices between the functions were observed and seeing both sides of the coin equally would clearly gain the result. A more comprehensive study on how the SHE factors further could contribute to better maintenance performance would also be of interest for further studies at Borealis.

7 Conclusion

For Borealis to manage the implementation of TPM they must shift focus from an organization driven by a budget and start to focus on the customer perspective. Set budgets and cost control should not be neglected since they still meet an important purpose from a financial perspective, but should be settled in relation to the customer perspective. Maintenance activities are expenses that are a necessary part of the organization but awareness of where maintenance can contribute to higher profit should be the target. This focus must be considered when the financial assets (budget) are spent. Enabling everyone to fully realize the benefits that derive from maintenance can only be done through improved communication and transferring of information. This applies between maintenance and production as well as between different maintenance function. Visual tools are excellent to apply for obtaining enhanced communication and sharing of information. However, the visual tools are easily misrepresented. Effort should be put on determine information of interest for the concerned parts. The presented information should be responsive to the receiver and reflect the quality of the recipient's job performance. MPIs has been constructed to reflect all parts of the organization from top management down to shop floor level, reflecting how maintenance could contribute to achieve the overall targets set by top management. A structured reporting system must be established for enhanced data quality and reporting. This allows for better analysis of the processes while making the presentation of performance indicators both reflect reality as well as ease the time spent for data collection. The CMMS installed at Borealis is not fully utilized and harms all necessary data from being collected. A table was constructed where all necessary data is presented for each MPI to be followed up. Persons must be assigned specific areas where they are responsible for the reporting in tidy manners.

Documenting projects and improvement works, such as the F1-cleaning, was lacking structure and must be established in the entire organization for avoiding unnecessary work that derives from hidden information and inefficient data collection. Structures for how planning and meetings should be held allows for important information to be shared where unprepared meetings left vital information out and require longer time than necessary. Projects tend to take long time to perform due to complex structures. A PDSA worksheet where developed for better facilitating smaller projects. By combining the worksheets with an improvement board also allows for new standards to be implemented without as much resistance as well as enabling a sustainable change.

The gap-analysis of the cleaning stop at L-302 indicates that there are significant time to spare (30%) by having a better collaboration and planning between departments. Creating a common schedule where times are standardized allows for better understanding and efficient maintenance activities. The methods used during the observation such as SMED and MVSM allows for a good understanding and interpretation of the complete stop. A visual representation of the entire stop where both maintenance, production and supporting function is displayed revealed the improvement potential and the importance of better collaboration. Other tools such as 5S and operator maintenance was shown to significant reduce production downtime during maintenance activities. Most important part of the observation was how clear it become why SHE factors should have higher priority, not only due to safety reasons but it also showed the significance it has on decreasing production downtime.

TPM as a work method will most definitely be suitable for reaching Borealis vision and strategy by being leader in plant reliability, availability, safety and process safety and still obtaining competitive costs. Reaching 80/20 relation between preventive and corrective maintenance will also be possible through deep root cause analyses.

By implementing TPM, Borealis will most certainly contribute to the overall goals in the OPEX PA program but might not do so in the short term. TPM tends to increase the cost initially due to investments in education and safety but will pay back in the long run by creating reliable and stable production at the same time as being responsive and flexible meeting variations in customer demands.

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Appendix A TPM pyramid

Below is the TPM pyramid developed by the consultancy firm JMAC in collaboration with Borealis (figure A.1). The circled areas are described below.

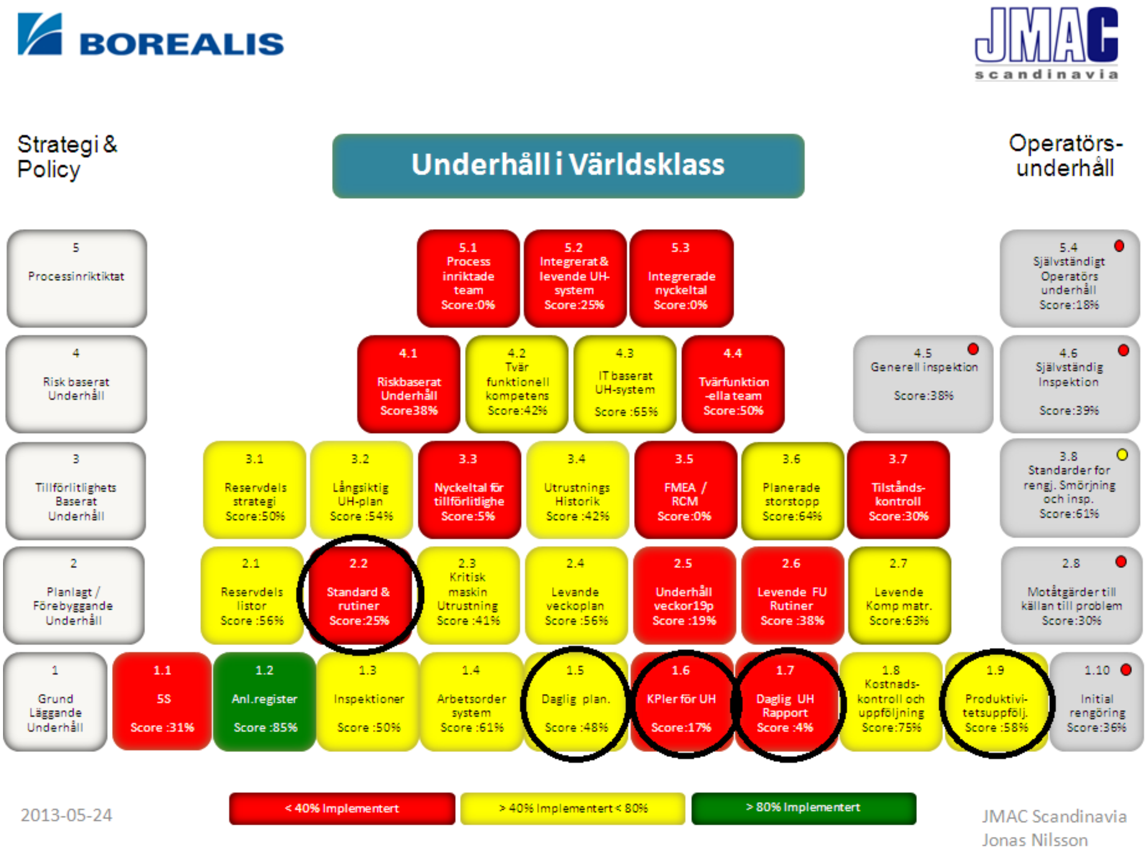

Figure A.1: *Borealis TPM pyramid (Nilsson, 2012). Circled areas are studied during this project.*

Daily planning

Structured set of tasks that include the activities, procedures, resources and the timescale required carrying out maintenance.

KPIs for maintenance

Economical and technical indicators for maintenance and production serving as metrics to see how well maintenance achieves the goals. Using KPIs can visualize the progress towards the target in a good way for both management and operators. It is though important that the chosen KPIs reflect the goals for both the maintenance department and the company. The KPIs should be set to reflect the production outcome direct.

Daily maintenance report

Reporting should be done via SAP and may consist of technical, managerial and administrative documents. The reported data must have 100% quality and be inserted in SAP in a standardized way. The reported data may be failures, faults and maintenance information related to an item. This data may also be maintenance costs, item availability, up time and any other data that are relevant for the measured KPIs.

Productivity follow up

Measure and visualize the OEE for separate production units. The OEE could be measured in several ways, it is therefore important to state what the OEE will measure. Here is the definition used during this project:

*OEE=equipment availability*performance efficiency*rate of quality*

An OEE figure above 85% is generally defined as world class.

Equipment availability: time which an item (production unit) is performing its required function as a percentage of the total planned production time.
Performance efficiency: the speed that a unit runs at in percentage of its designed speed.

Rate of quality: Percentage of 100% quality products produced by a unit. Lower quality products and scrap are to be included in this equation.

Standard and routines

A set of "best practices" that should work as instructions for everyone enabling a task to be performed in the same way each time. The standard and routines should continously be revised and improved to create the new set of "best practises". In this project will the standard and routines focus on Routine maintenance instruction using SAP.

Appendix B Present state analysis by JMAC

JMAC:s present state analysis describing the five chosen areas for this study.

B.1 Daily planning

Strengths

- Daily planning of PM: Borealis presents works weekly to BIS. BPP creates a 2-week detail plan

Areas of improvement

- To higher extent detail plan the maintenance work linked to existing resources
- Visualize manpower on a board and hold daily repeatedly, short/effective meetings in the workshop
- Visualize and plan maintenance activities

B.2 KPIs for maintenance

Strengths

- Backlog work orders are measured and followed up

Areas of improvement

- Define KPIs within the maintenance function that are daily, support the value flow and to high extent can be influenced
- Visualize, set targets, request these KPIs and identify deviations
- Use measures that directly affect the production result: Technical Availability, Reoccurring failures, MTBF, MTTR
- Use these KPIs to focus on methods that creates the required result

B.3 Daily maintenance report

Strengths

- All the daily (Emergency/Preventive) maintenance is reported back to the system through the work orders
- Production does report errors and uses SAP for that purpose

Areas of improvement

- Report all KPIs/line with focus on production
- Use KPIs to identify deviations and generate action plans
- Create reports where the team goes through the last day's events
- Divide responsibility down to maintenance technicians and demand support
- Create formal morning meetings with reports from maintenance technicians

B.4 Productivity follow up

Strengths

- External costs are connected to specific plants

Areas of improvement

- Connect all costs that are linked to a specific plant such as internal spare parts, man hours etc.
- Visualize/distribute and revise reports
- Use follow ups during renovations and investments
- By recording costs against a specific equipment it will be easier to calculate the Life Cycle Cost and plan the outcome in a better way

B.5 Standard and routines

Strengths

- PM instructions can be found for the equipment

Areas of improvement

- Complement with more comprehensive process descriptions. The demand should control the scope and prioritization
- Complement with SOB on specific missions, both reoccurring as for long time between execution
- Regularly revise and look through instructions and process descriptions
- Involve maintenance technicians since they are the one who performs the maintenance work.

Appendix C Current state SMED analysis

Figure C.1 presents the current state analysis. The red areas corresponds to work tasks performed by the operators, blue for maintenance technicians, green for the contracted company and the orange the special cleaning workshop.

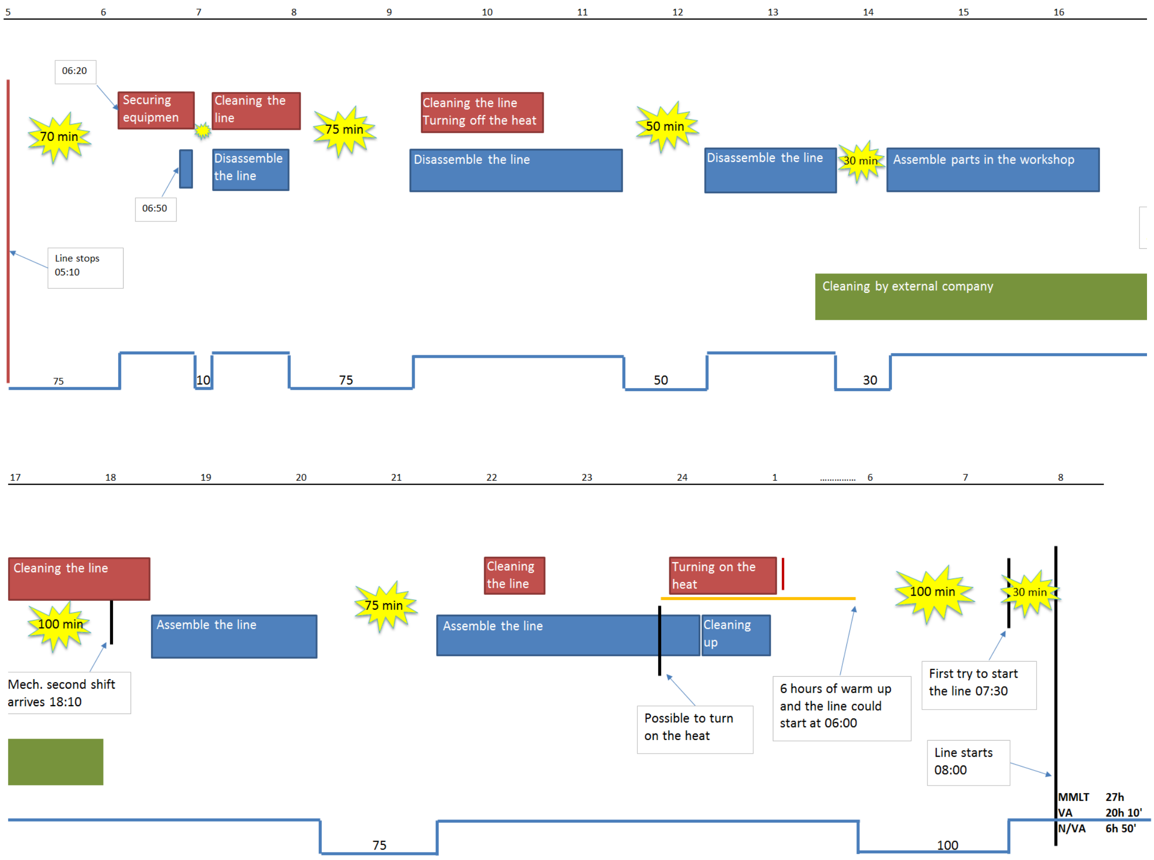

Figure C.1: *Current state F1-cleaning.*

Appendix D Future state SMED analysis

Figure D.1 represents the suggested future state. The red areas corresponds to work tasks performed by the operators, blue for maintenance technicians, green for the contracted company and the orange the special cleaning workshop.

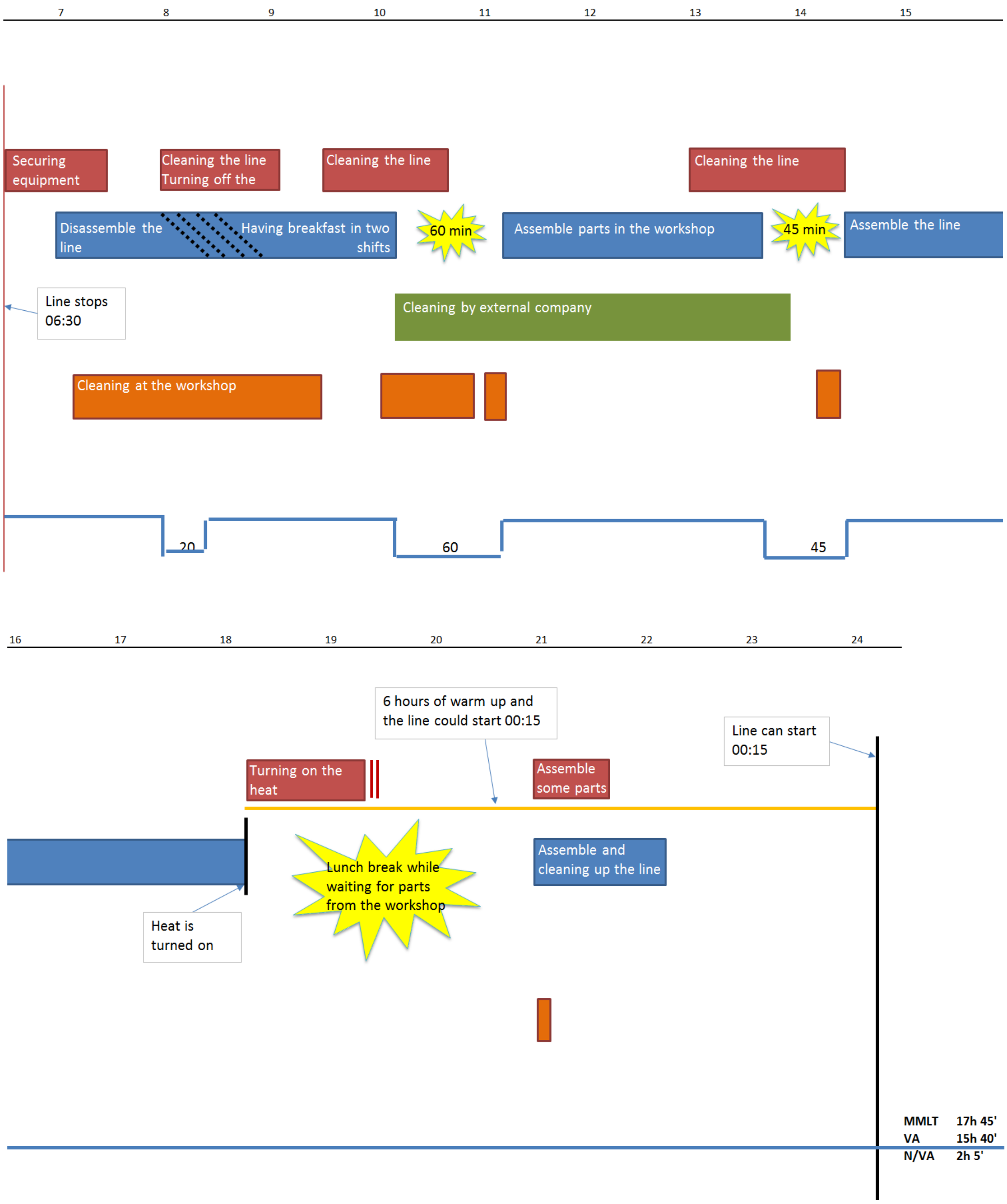

Figure D.1: *Future state F1-cleaning.*

Appendix E Performance measures description

All suggested KPIs and KRIs are detailed described alphabetically.

E.1 Key performance indicators

BACKLOG

Deviation from planned maintenance activities. All maintenance activities that have passed due date from planning.

Calculation: Number of maintenance activities not performed with past due date.

Why Borealis should use this indicator: Planned maintenance activities serves a purpose, whether if it is to get a machine running again or prevent accidents from occur, it should be of highest interest to keep the backlog size as low as possible to prevent loss of capital or injuries. Resource and capacity planning must be improved if the backlog size increases. Other ways to prevent backlog from occurring is to minimize the number of errors i.e. improve the existing tools and machines, create standards for component replacement, increase the replacement time by determine when it is necessary to change by using condition monitoring and RCM for the actual component condition and possible consequences.

DATA QUALITY

A KRI designed to track if the technicians use SAP since every single performed work should be reported.

Calculation: Total reported hours in SAP/total time spent

Why Borealis should use this indicator: A higher amount of correctly reported works will facilitate the analysis of the situation at the company and function as an aid when aiming at improving the company performance. An analysis that is useful and has high contribution factor and is dependent on high quality data, e.g. correctly reported hours in SAP kept as high as possible.

IMMEDIATE MAINTENANCE

Maintenance that is carried out without delay after a fault has been detected to avoid unacceptable consequences (SS EN 13306:2001). Immediate maintenance should be seen as maintenance work classified as a 0 or 1 at Borealis.

Calculation: hours spend on IM/total hours reported as maintenance work, not 8 hours per full time employee

Why Borealis should use this indicator: IM is costly and creates unnecessary chaos in a capital extensive business such as Borealis. IM could result in poor planning with succeeding quality issues. The expenses will increase and the risk of planning rework is significantly higher. The time aspect might also be affected since the planning might be insufficient. Risk assessment and condition monitoring are potential actions that could decrease the percentage of IM.

MANPOWER EFFICIENCY ON PLANNED MAINTENANCE

To verify that the work is performed within planned hours. This indicator serves to identify if standards are obtained. Slightly variation is accepted due to the nature of maintenance (various condition from time to time), but a greater variation must be investigated in order to create better standard and routines for certain activities. Other reasons for deviation could be poor planning.

Calculation: Time spent on maintenance / time planned for maintenance

Why Borealis should use this indicator: This indicator, as mentioned before, is useful only for maintenance activities that are planned with good accuracy and quality where standard times are either recorded on site or collected from historical data. If good planning and standards are obtained it should be possible to fit more work into one 8-hour shift and keep the backlog size down.

NEAR MISS (SYNERGY)

Borealis has a developed system for reporting near misses and create action plans for correcting them referred to as Synergy. Synergies is one of the most important numbers to keep track on since injuries and accidents are the far most costly expense a company can have economically but also how it could affect the good will and trust which takes years to build and can be destroyed in an instant. The reason why synergies should be measured could be reviewed by the accident triangle presenting that 600 near misses (synergies) leads to one major injury (Jones, Kirchsteiger and Bjerke, 1999). The numbers presented in different accident triangles varies from study to study but the essence is that the amount of near misses is connected to the fatal outcomes.

Calculation: Keeping track on the amount of synergies and take actions to prevent risk and hazard.

Why Borealis should use this indicator: This should be used for all the reasons described above. "If you think safety is expensive you should try having an accident"

NO. OF FAILURES

This indicator should be used to track trends in maintenance, for example, are the failure rates going up as a result of certain actions taken or due to seasonal changes? If the failure rates increase below limits, they must be investigated in order to be prevented.

Calculation: Total numbers of failures reported

Why Borealis should use this indicator: Amount of failures increases the amount of work and the time machines are down. By measuring the amount of failures it is possible to locate their sources since they are traceable and prevent them from occurring again or at least in the same frequency.

NO. OF OBSERVATION TOURS

Observation tours are performed by personnel at Borealis whom inspect another employee during a work task. They ask questions and analyze the execution of the work task to verify that the personnel are performing the work task in a correct and secure way.

Calculation: No. of observation tours/employee

Why Borealis should use this indicator: Observation tours will guide the company in achieving higher level of knowledge within the company and create a safe work environment for the employees.

NO. TBW (IMPROVEMENTS)

Number of performed TBWs (improvements) is one step in the right direction for standard and routines and should be a significant indicator as long as there still are many left to do. This indicator should however be reviewed when the target is reach and another indicator might be more appropriate.

Calculation: Number of performed TBWs for a given period until target is reached

Why Borealis should use this indicator: This indicator should be used in the step towards an improved standardization and increase the efficiency during the planning process. This will also enable the planner to perform better in his/her planning accuracy.

PREVENTIVE MAINTENANCE

All adjustments and fault corrections that are performed against found failures (discrepancies) before loss of production, quality or resulting effects have occurred (SS EN 13306:2001). This indicator will increase due to well-conducted planned maintenance and by reducing the amount of CM.

Calculation: PM hours/total time spent on maintenance

Why Borealis should use this indicator: The amount of PM performed at Borealis is important to measure to verify that the goal to be achieved by 2020, 80% PM, is reached.

SMED EXECUTION

Amount of maintenance performed while machines are running. This indicator was created as a direction towards the Lean philosophy and the tool SMED in mind. The idea is to indicate the amount of preparation done by the service technicians. Preparation of materials and equipment during uptime and before execution of planned maintenance work reduces the downtime of the process.

Calculation: (maintenance hours – hours the machines are shut down) / hours the machines are shut down

Why Borealis should use this indicator: This indicator should be used to prepare equipment before machine shut down. Maintenance activities should be planned, organized and performed fast for better utilization of machines.

TRAINING HOURS VS WORK HOURS

Employee training increases the knowledge within the organization and is an area highly stressed within the area of TPM.

Calculation: Training hours as percentage of performed work hours

Why Borealis should use this indicator: Increased knowledge level will improve the entire organization's performance, especially the maintenance unit. Focusing on training hours and educating the maintenance personnel will be a contributing factor to the goal of reaching 80% PM.

UPDATED PREVENTIVE MAINTENANCE-PLANS

Updated PM plans is one step in the right direction for standard and routines and should be a significant indicator as long as there still are many left to do. This indicator should however be reviewed when the target is reach and another indicator might be more appropriate.

Calculation: Number updated PM-plans for a given period until target is reached

Why Borealis should have this indicator: This indicator should be used in the step towards an improved standardization and increase the efficiency during the planning process. This will also enable the planner to perform better in his/her planning accuracy.

E.2 Key result indicators

KRIs should be used to visualize the outcome. KRIs are oppose to KPIs, not indicators that could be used to guide decisions towards a goal, but instead a way to verify if the goal was reached or not.

ACHIEVEMENTS OF INDIVIDUAL TARGETS

Achievements of individual targets set together with the manager are tracked to see the % of achieved personal goals.

Calculation: percentage achieved personal goals

Why Borealis should use this indicator: Continuous improvement is a philosophy within Lean not only to be implemented to improve the physical parts of an organization but also to leveling the knowledge among the employees, which of course results in an improved process further down the line. Tracking the % of achieved personal goals will guide the individual and clarify if precautions need to be taken in order to improve continuously.

AVAILABILITY

Ability of an item to be in state to perform a required function under given conditions at a given instant of time or during a given time interval, assuming that the required external resources are provided (SS EN 13306:2001).

Calculation: MTBF/(MTBF+MTTR)

Why Borealis should use this indicator: A good overall measure on how maintenance fulfills its intended purpose. It is also an indicator the maintenance function directly could effect and simultaneously contribute to increase the OEE figure.

DIRECT MAINTENANCE COST

For this parameter to be interesting it should be measured in correlation to something. It is suggested that it should be measured as a percentage of turnover.

Calculation: Total maintenance cost

Why Borealis should use this indicator: Cost is an essential part of the OPEX program and should be measured accordingly. It is though important that cost figures does not only end up as figures with no meaning and that they reflect something of value. If however cost is measured against turnover, it could be used as an indicator to benchmark against other industries. Total maintenance costs must though be recorded, but not necessary as a KRI.

FEEDBACK

It is extremely hard to know if one is performing their work tasks accurately without any constructive feedback. The feedback should be received from the direct manager in order to aid the employee to achieve higher knowledge and avoid any missteps during assigned work tasks. Feedback can most certainly also be to highlight excellent work performed by the employees.

Calculation: Follow up meetings with employees

Why Borealis should use this indicator: Feedback is a great tool to realize the need of improvements among the employees and together build up a strategy to do so. It is a useful complement to the competence matrix to efficiently develop each and every individual's knowledge base.

MAINTENANCE COST AS PERCENTAGE OF PRODUCED TON

Maintenance cost displayed as a percentage of sales. It could be the average price per produced unit for a quarter multiplied by the actual production. This is a good way to indicate if investments in maintenance pay off by giving back availability to production. Helps everyone to see maintenance as a contributor to the increased sales and not just an expense.

Calculation: Maintenance cost / amount produced (Ton)

Why Borealis should use this indicator: This indicator should be used to profile maintenance as an important function that could provide results to top management. Spending money on maintenance should be seen as investments where the delivered service is increased availability.

OVERALL EQUIPMENT EFFECTIVENESS

OEE)is used to see how well a function or a site is performing. This indicator should be displayed at a higher level in the organization to reflect both the work done by maintenance and operation. This number could be used to visualize for top management that maintenance and operation must collaborate and both be seen as resources in the work towards plant efficiency.

Calculation: OEE = Availability * rate of speed * rate of quality

Why Borealis should use this indicator: OEE is a commonly used figure that could be used for highlighting the actual status on the plant efficiency and how different departments are equally important. It could also be used to benchmark between other sites within the Borealis group.

PEOPLE SURVEY

Questions formulated to collect information among the employees and create awareness about the employees' situation.

Calculation: Yearly people survey with follow up documents on which actions that have been taken that should be handed out to the employees within the organization

Why Borealis should use this indicator: The personnel should be handled with respect. Conducting surveys among the employees will collect information about how the company performs according to the employees and what problems that are faced among the organization. In fact, the employees are the ones that majority of the workday appear where the process takes place and face problems and deviations daily.

PULSEN

"Pulsen" is a health check performed every fourth year for each employee.

Calculation: % of healthy checks performed within a time frame of four years for each individual at the company

Why Borealis should use this indicator: The health among the employees is extremely important. Absenteeism should to the highest extent be avoided and a primary goal should be to maintain a healthy climate and healthy employees that enjoy being at work. The healthy checks create awareness among the employees that the company is concerned about their health state and value each employee equally.

QUALITY OF PLANNING

Quality of planning tracks the accuracy of planning. It can also indicate that other factors are imperfect such as the competence among the maintenance personnel (both technicians as for planners) or the preparation work, ordering of spare parts etc.

Calculation: Planned work/actual outcome

Why Borealis should use this indicator: Inaccurate quality of planning can be a good indicator on the need of revising the documents and updating them according to current situation. Overall, Quality of planning presents a result that visualize the need of improvement and the need of scrutinizing parts related to planned work in relation to actual outcome.

QUALITY RATE

This indicator measures if the quality produced ends up as requested as presented in the production schedule. Even if the quality is approved, it does not mean it turns out as expected due to the different products produced at Borealis Stenungsund that allows some sort of deviations from planned outcome.

Calculation: Actual quality (quantity) / Planned quality (quantity)

Why Borealis should use this indicator: It is important that Borealis always aims at improving continuously. One should not always accept that products may be approved but not of the planned quality. It is dangerous to do so and does not go in line with TPM referring to the fact that one should produce what customer demands, not more or less, otherwise it is waste.

REWORK (QUALITY OF EXECUTION)

Quality of execution describes if the performed maintenance tasks where correctly done the first time, without any need of rework.

Calculation: (Total working hours – amount of rework in hours)/total working hours

Why Borealis should use this indicator: Measures should be done to assure that the customer is satisfied. Unsatisfactory results indicate that precautions need to be taken. It could be a result of inaccurate planning, lack of competence or insufficient quality of the machinery in the process.

RETURN ON ASSETS

The DuPont-model can be applied to analyze a company's performance as the product of net profit margin and total asset turnover, i.e. ROA.

Calculation: Net profit margin * total asset turnover

Why Borealis should use this indicator: Each factor can be divided into smaller, more specific elements to manage to optimize the outcome on each level depending on how well a company uses its resources, reaching as high ROA as possible. The ROA can function as a benchmarking tool between competing companies, pinpointing areas of improvement. Borealis can apply ROA in the area of maintenance to locate causes related to maintenance such as breakdowns or insufficient planning. ROA should be the financial target for maintenance since the OEE number directly affects the ROA.

SCRAP RATE

The goal is to produce maximum output of the demanded quality. Scrap rate present the amount of scrap produced in relation to the total amount produced.

Calculation: (Produced amount – Defect amount) / Produced amount

Why Borealis should use this indicator: As the Lean philosophy advocates, the waste should be eliminated to the highest extent possible. Pellet loss is for example a focus area at Borealis Stenungsund where the entire organization should contribute to reduce the pellet loss. Reducing the scrap rate requires efforts toward a stabilize process and well-conducted maintenance, a prerequisite to meet 80/20 distribution between PM and CM by year 2020.

TRI

TRI presents Total recordable injuries per year.

Calculation: (No. of injuries*1.000.000)/No. of hours worked

Why Borealis should use this indicator: TRI is important to measure to verify that the work environment is safe and precautions are taken for every possible risks that the employees are exposed to. A TRI outside the target indicates that the site does not reach the organization's standard known as a safe work environment and measures must be taken.