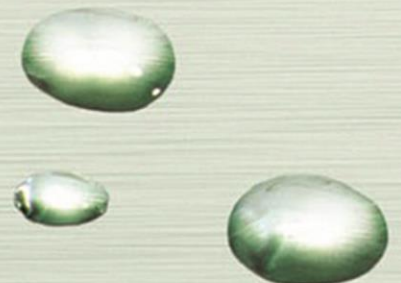


Improving Operational Efficiency of Discrete Production Processes in Large Manufacturing Organizations

*Real Life Case Study
at the Heineken Brewery in Zoeterwoude,
the Netherlands*



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Preface

The Master Thesis report in front of you is the final product of the master degree program Systems Engineering, Policy Analysis and Management, specialization Transport and Logistics at Delft, University of Technology. The aim of this program is teaching students the core concepts of challenging studies, including technical systems, management programs, economical behavior, and law. What makes the study unique is the analytical approach and tools that are taught to students to include all these aspects in analyzing complex environments. For me, this proved to be the perfect playing ground for my very broad interests. The only aspect lacking is the application of these skills in a business environment.

Therefore I want to thank all the people at the Heineken organization for giving me the opportunity to fill this personal gap with a research at the Zoeterwoude brewery and assisting me in doing so. In particular I want to thank my two supervisors at the company: Thijs Derksen for guiding me in day-to-day operations and Belinda de Winter for her process guidance of my internship. Both have helped me incredibly in providing contacts, brainstorming, and personal development.

Conducting a thorough academic research at a hands-on company as Heineken has proven to be a proper challenge for me. Without the supervision of Lori Tavasszy on this graduation project, I could not have been able to take the necessary extra step. I would also like to thank Ron van Duin for his personal and academic guidance during this entire project and who has kept me critical on my quantitative findings. Last, in a very practical and quantitative oriented committee, I would like to thank Haiko van der Voort for being a devil's advocate in numerous discussions and being a sparring partner on the different management theories.

Furthermore, I would like to thank Tim Markensteijn for very valuable reviews, Florence Theis for proof reading, Madelijn Vijfhuizen for designing the cover page and overall lay-out, and all for overall support. Lastly, my entire study career in Delft and in special the last 6 months, have been made entirely possible by my parents, Marlies and Hans Vijfhuizen. For this I am incredibly grateful and I am very proud on how we have overcome our own challenges.

Floris Vijfhuizen

Summary

In the present time large manufacturing organizations operate on a global scale and thereby form an extremely competitive market. Far going globalization makes markets highly competitive, putting the pressure on these organizations to be more innovative and improve the efficiency of its production processes in order to lower overall costs. These goals are aimed to be achieved by introducing elaborate continuous improvement strategies. Implementing such strategies however has far going implications on organizations, in terms of performance management, working culture, and organizational structure. Companies have often implemented one or more continuous improvement strategies. While these strategies promise to result in a perfect process, in practice this is not the case. Problems form when there is a significant gap between company goals and the actual operational performance. In that case a situation arises where not ideal operational performance can be caused by logistical malfunctions, a continuous improvement strategy that is not performing optimal, friction in the organizational structure, or even a combination of all. It is therefore difficult for organizations to identify what causes a non-optimal operational performance, given the complexity of the described environment. The objective of this research is to improve this operational performance by overcoming this knowledge gap. The following general research question is formulated to overcome this knowledge gap:

How can large manufacturing companies identify causes of discrete production processes not performing in line with company goals?

In this research a three step approach is used. The first step is to zoom out from the logistic process and analyze the characteristics of the organization and the used continuous improvement strategy. By comparing the organizational characteristics with academic literature, strengths and weaknesses of the organization can be identified, and also the corresponding opportunities and threats. The used continuous improvement strategy is analyzed, for it is never flawless. Methodologies keep evolving and improving, and new theories are being developed and tested every day. Looking critical at the used improvement strategy will provide insight in missed opportunities and the importance of certain focal points in the organization. The second step is linking these findings to an analysis of the logistical process. It is important to determine how the operational efficiency is defined and how it is measured. Step one might provide a different perspective for analysis or focal points. In this second step improvement projects can be selected and defined on an operational level. Step three consists of performing the selected improvement projects. It is important to incorporate the findings of step one into these projects. This way the findings in academic theory can be evaluated by testing in practice. This evaluation provides concrete feedback on the found causes of non-optimal performance of the production line. Combining these three steps will provide (i) a thorough analysis of the organization, (ii) identifications of barriers and enablers in the organization, and (iii) will present opportunities to improve the operational efficiency beyond the knowledge that is present in the organization. With the gained knowledge, step one can be repeated in order to create an iterative process for continuous improvement. This approach is conducted and tested at the Heineken brewery in Zoeterwoude, the Netherlands. During a six month period, a real life case study is performed at production line 81, a bottling line that packs beer into cases for export.

First it is shown that it is important to take into account the different perspectives between management and operators. In order to improve the production line in a structural way it is essential to communicate with operators in such a way it aligns with their goals. Next to this it is found that there are opportunities in using the tools presented in the Theory of Constraints. Based on a bottleneck analysis, it is shown that the losses with the biggest impact on the total production line are found downstream of the designed bottleneck, signaling a hidden bottleneck. It is shown that the output performance can be significantly improved by diminishing the amount of breakdown in the machines downstream of this hidden bottleneck. The performance indicator "Operational Performance Indicator No Order No Activity" has increased with 6.34 percentage points and the deviation of this indicator has diminished with 1.63 percentage points. If this major increase can be maintained in the future, this improvement could save the organization € 115,402 on a yearly basis in non-cash savings. This shows that using the Continuous Improvement strategy Total Productive Management is an effective tool for Heineken to structure its continuous improvement efforts.

The foremost general recommendation in respect to strengthening the findings in this research is performing more similar case studies. A case study at a comparable manufacturing organization is necessary to compare results and draw conclusions on the extent to which the findings can be generalized. The expectation is that the found principal-agent dynamic at Heineken is strongly comparable to other large manufacturing organizations. If that is the case, this can be a highly interesting addition to the theory on organizational structures.

For Heineken from a logistical point of view it is important to keep working on the newly identified bottlenecks, the Packer and Multipacker machines. Every minute won on these machines can directly benefit the operational efficiency of the entire line. These findings can also be applied at the other production lines in the brewery as well. This horizontal expansion can provide new insights into the general mechanisms of the entire brewery. For the long term it is recommended to involve the proposed rule of thumb in the monthly meeting between a rayon manager and the installation manager. Last, if Heineken wants to cope with the found principal-agent dilemma, a thorough behavioral change is required in the entire organization. It is recommended to implement a form of change management, for example the methodology founded by Kotter (1996).

Abbreviations

5S	Seiri, Seiton, Seiso, Seiketsu, Shitsuke (Sorting, Straightening, Shining, Standardize, Sustain)
AM	Autonomous Management
BDA	Break Down Analysis
BPS	Business Problem Solving
CI	Continuous Improvement
CILT	Cleaning, Inspection, Lubrication, Tightening
CS&L	Customer Service and logistics
DCS	Daily Control System
FI	Focused Improvement
FTE	Full Time Employee
FTR	First Time Right
HNS	Heineken Netherlands Supply
JIT	Just In Time
KPI	Key Performance Indicator
MCRS	Management Control & Reporting System
MES	Manufacturing Execution System
MTBA	Mean Time Between Assist
OEE	Overall Equipment Effectiveness
OPI NoNa	Operational Performance Indicator No order No Activity
OPI	Operational Performance Indicator
OTIF	On Time in Full
PM	Planned Maintenance
PQ	Progressive Quality
RCFA	Root Cause Failure Analysis
S&E	Safety & Environment
SMED	Single Minute Exchange of Dies
SOP	Standard Operating Procedure
T&E	Training & Education
ToC	Theory of Constraints
TPM	Total Productive Management
TQM	Total Quality Management
WCM	World Class Manufacturing
WPO	Workplace Organization

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1. Introduction

Aim of this chapter is to give an outline of the environment that this research is set in and the difficulties that arise. First the market of large manufacturing organizations will be introduced. Second, discrete production processes will be defined. Third, methods to improve operational efficiency are discussed. Fourth, Heineken as an organization and its brewery are introduced. Last, the report outline is presented.

1.1. Large Manufacturing Organizations

In the present time large manufacturing organizations operate on a global scale and thereby form an extremely competitive market. Far going globalization makes markets highly competitive, putting the pressure on these organizations to be more innovative, improve the efficiency of its production processes in order to lower overall costs (Leitão, Cunha, Valente, & Marques, 2013; Mahalik & Nambiar, 2010; Scott, Wilcock, & Kanetkar, 2009). These goals are aimed to be achieved by introducing elaborate continuous improvement strategies. As will be introduced further in Paragraph 1.3, these strategies are complex on their own and implementing them is difficult. Often, companies are not even fully aware of the complexity of the required organizational change (McLean & Antony, 2014). The consequence can be that the implementation attempt fails, which causes the strategy to work suboptimal or even work counterproductive. Company characteristics play a major part in the success or failure of such an implementation. In this research the focus will be on manufacturing organizations, which are described by the OECD as organizations having a process where materials or components are transformed into new products (Organization for Economic Co-operations and Development, 2014). Next to that a distinction has to be made between Small and Medium sized Enterprises (SME's) and large organizations. The larger the organization, the more comparable type of suppliers and customers, a higher degree of automation, and different type of products and quality assurance requirements (Pool, Wijngaard, & Van Der Zee, 2011). Also, there is a difference between SMEs and large manufacturers with respect to structure, policy making procedures, resource utilizations, staff patterns, culture, and patronage (Antony, Kumar, & Madu, 2005).

1.2. Discrete Production Processes

The primary focus of improvement strategies at manufacturing organizations is on the production process. For this research a distinction is made between discrete and continuous production processes. Discrete production processes can be described by "following a set of time-consuming activities, performed according to a prescribed ordering. Events correspond to starting or ending some activity" (Cohen, Dubois, Quadrat, & Viot, 1985). The alternative is looking at the (semi-)processing industry, where production processes are (semi-)continuous. Unlike discrete processes, continuous processes involve long setup times, small batch sizes and complex resource characteristics (Abdulmalek, Rajgopal, & Needy, 2006; Pool et al., 2011). Most importantly, the continuous process obstructs a straightforward implementation of continuous improvement tools (Abdulmalek et al., 2006; Van Donk & Van Dam, 1996). For these reasons this research will focus on discrete production processes. A clear example of a discrete production process is the sequential process of assembling a car in a company like Toyota.

1.3. Improving Operational Efficiency

In order to continuously improve an organization's production process, numerous process improvement strategies have been developed over the years. Popular examples include are Total Quality Management (Cua, McKone, & Schroeder, 2001), Just in Time (Cua et al., 2001), Preventive Maintenance, 5S Workplace Management System (Moradi, Abdollahzadeh, & Vakili, 2011), Lean (Arbjørn & Freytag, 2013), Theory of Constraints (Rahman, 1998) and Six Sigma (de Mast & Lokkerbol, 2012; Schroeder, Linderman, Liedtke, & Choo, 2008). All these strategies aim to provide companies with the best tools for creating and maintaining a perfect process. In the basis these strategies have different underlying

theories, guidelines and focuses. Although different in the basis, the strategies do often overlap and are therefore sometimes hard to see apart from each other. On top of that, implementing such strategies has far going implications on organizations in terms of performance management, working culture, and organizational structure.

1.4. Report Outline

This thesis is built up in the following way. In Chapter 2 the research problem is formulated. Next to that, a literature study is done and the found knowledge gaps are presented, which all leads to the main research question. In Chapter 3 the research approach is presented and Chapter 4 introduces the case study performed at Heineken. In Chapter 5 an in-depth analysis is made of the presented environment, in order to compare it with existing theory. This will provide insight in the conditions that have to be taken into account when implementing improvement projects, and more importantly propositions are done that will be tested in Chapter 7. In Chapter 6 the current state of the production process is analyzed. A performance analysis is done and based on this solutions to improve the process are identified. Chapter 5 and 6 provide input for Chapter 7 in which the improvement projects are implemented. The result of these projects will be validated and the propositions from Chapter 5 will be reflected upon. Based on that conclusion, recommendations for future actions are identified. In Chapter 8 the conclusions are drawn and recommendations are made. In Chapter 9 the research and results are discussed and reflected upon.

2. Research Problem

In this chapter, the problems discussed in Chapter 1 are defined and translated into research questions. First, in Paragraph 2.1, the problems that arise within large manufacturing organizations are defined. By looking at the challenges organizations have to cope with and reviewing literature, knowledge gaps are identified. The societal and scientific relevance of overcoming these gaps is described after that in Paragraph 2.2. This leads to the research objective, deliverables that are described in Paragraph 2.3 and the corresponding research questions are formulated in Paragraph 2.4.

2.1. Problem exploration and Knowledge Gaps

Large manufacturing organizations and their need to improve operational efficiency is a topic that has been discussed thoroughly in the academic world (Ahuja & Khamba, 2008c; Antony et al., 2005; Bendell, 2006; Brady & Allen, 2006; Dora, Kumar, Van Goubergen, Molnar, & Gellynck, 2013). The research focuses on the underlying theory (Bhasin & Burcher, 2006), implementation (Ahuja & Khamba, 2008b), effect on performance (Brah & Chong, 2004; Cua et al., 2001), benefits (Melton, 2005) and downsides (Rodrigues & Hatakeyama, 2006) of the different continuous improvement strategies. In the current situation there has been written so much and researched so much that clear definitions and boundaries of the different strategies are vague (Arlbjørn & Freytag, 2013). On top of that, in practice the different strategies are being combined more and more (Pepper & Spedding, 2010). So, companies have often implemented one or more continuous improvement strategies. While these strategies promise to result in a perfect process, in practice this is often not the case. Each organization has different characteristics, circumstances, environments, and employees, which influences the overall performance. Problems arise when there is a significant gap between company goals and the actual operational performance. In that case a situation arises where not ideal operational performance can be caused by logistical malfunctions, a continuous improvement strategy that is not performing optimal, friction in the organizational structure, or even a combination of all. It is therefore difficult for organizations to identify what causes a non-optimal operational performance, given the complexity of the described environment. The following knowledge gap can be formulated for these large manufacturing organizations:

The steps large manufacturing companies can take to identify and resolve the issues that cause the non-optimal performance of their production process.

This is essentially the reason why large manufacturing organizations struggle with improving their operational efficiency. The threat is that an organization keeps trying to fix symptoms of an underlying cause. In other words, if an operational efficiency is lower than organization goals the solution is often sought in logistical solutions, instead of looking at the environment (the actual organization) that the problems are part of. However, if it is unclear what steps to take to analyze and identify root causes, a solution cannot be found.

2.2. Societal and Scientific relevance

Large manufacturing organizations and their continuous struggle to improve operational performance is an important research field in the academic world. The logistical challenges present at these organizations, the wide variety of continuous improvement strategies and their theories, and the implications of unique organizational characteristics are all important topics that are addressed in this research. The combination of these aspects is not thoroughly investigated before, nor is the required approach. This research will provide a very relevant contribution to these subjects, in terms of application, effect on an organization and potential to improve the overall organization.

The relevance from a societal point of view is even clearer. Each manufacturing organization has to cope with the pressure of lowering costs by improving operational efficiency, so this subject becomes ever more relevant. The potential for improving operational efficiency from a new point of view is very

interesting for organizations. The subject of analysis in this research is Heineken, which is a renowned company and can serve as a great example for the entire industry. All organizations in the manufacturing sector with discrete production processes can reflect upon this research which can help providing the discovery of new opportunities of improving the so desired operational efficiency.

2.3. Research Objective and Deliverables

It has to be clear that the objective of this research is to in fact improve the operational efficiency of large manufacturing organizations. This has to be done by overcoming the described knowledge gap, because you have to know what has to be changed in order to be able to change it. When this research is finished, this report will:

- provide insight in the general mechanics that influence operational efficiency in large manufacturing organizations
- show organizations how the critical mechanics can be identified that negatively influence operational efficiency
- show organizations how these issues can be addressed and changed

So, the aim of this research is not to develop a generally applicable stepwise approach for all manufacturing companies. However, by performing this research it can be shown what is possible and what works with this approach.

Achieving these research objectives will result in a number of deliverables. For the Technological University of Delft this document will serve as a MSc. thesis report. A part of the findings will be described in a scientific article, for academic purposes. Also, recommendations will be done on future research. For Heineken four improvement projects will be executed, resulting in an improved operational efficiency. Next to that, recommendations are done on how the efficiency can be further increased and which aspects should be taken into account in the short and long term.

2.4. Research question and sub questions

The problem exploration showed that large manufacturing organizations can struggle with non-optimal operational performances. The knowledge to identify the root causes for this non-optimal performance is lacking, which prevents organizations to improve their operational efficiency in a structural manner. The objective of this research is to improve this operational performance by overcoming this knowledge gap. The following general research question is formulated to overcome this knowledge gap:

How can large manufacturing companies identify causes of discrete production processes not performing in line with company goals?

In order to be able to answer this question, it is necessary to analyze the different aspects that might explain the gap between the current operational efficiency and the company goals, as described in the problem exploration. The following sub questions are formulated to analyze these aspects:

- How is the operational efficiency affected from a logistical point of view?
- How does the used continuous improvement strategy affect operational efficiency?
- How do organizational characteristics affect operational efficiency?

The questions are closely related, because the logistical approach follows the efforts made in the continuous improvement strategy, which all takes place in the organization in question. Figure 1 illustrates this relation. The questions will be answered by first analyzing the corresponding theory and distilling barriers and opportunities. Second, these findings are tested by performing improvement projects in practice. An elaborate research approach is needed in order to answer these questions. In Chapter 3 this approach is described, including the used research tools. Furthermore, the research questions will be repeated at the beginning of the chapter that aims to answer the respective question.

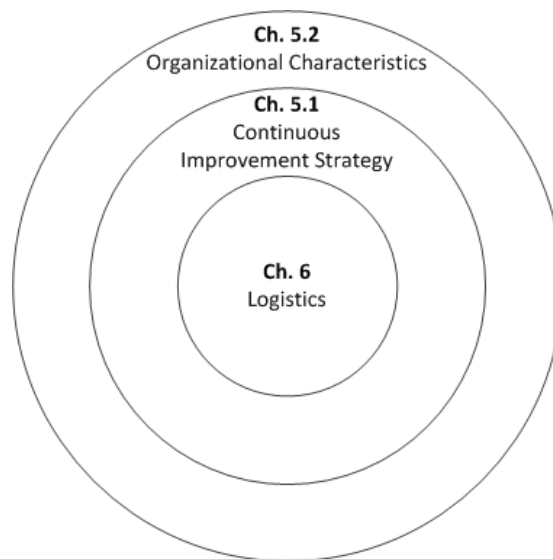


Figure 1 - Relationship of research subjects, linked to corresponding chapters

3. Research Approach

In Chapter 2 the knowledge gap has been identified that serves as the subject of this research. Based on this gap, research questions have been formulated. In order to answer these, a research approach is developed. In this chapter the used methodology, research tools, and data collection are described. First, in Paragraph 3.1 the overall methodology for this research is described. Second, in Paragraph 3.2 an overview of the used research tools is given and the tools are elaborated upon.

3.1. Research Overview

As described in the previous chapter, the goal of this research is to give insight into a complex environment, by analyzing the mechanisms that influence an organization's operational efficiency. When answering questions in environments where so many mechanisms influence each other, there is a need for a research approach that can cope with this complexity. The research approach in this thesis is built around a real life case study (Yin, 2003). The case study is performed at the Heineken brewery in Zoeterwoude during a six month period. Heineken and its production process will be introduced in detail in Chapter 4. There are a number of consequences that follow the chosen approach. The case study involves one case, so in the terminology of Yin this is a single-case design. The alternative, a multiple-case design requires extensive resources and time beyond the means of a single student, especially in the light of this thesis report. Multiple-case designs are considered more robust and better suited to develop or falsify new theory. The single-case design used in this study will serve the purpose of testing a set of propositions that will be formulated in Chapter 5. In this light, the case study will serve as a pilot study that aims to address broader theoretical issues. Next to being single-case, the study also has a single unit of analysis, making it a holistic design. A known threat is a lack of examining a phenomenon in operational detail. Therefore in this case study the operational unit of analysis will be examined into operational detail, before and after tests. The case study consists of multiple steps in which the research sub questions can be answered. In this case study, the business problem solving cycle of van Aken (2012) is followed (illustrated in Figure 2).

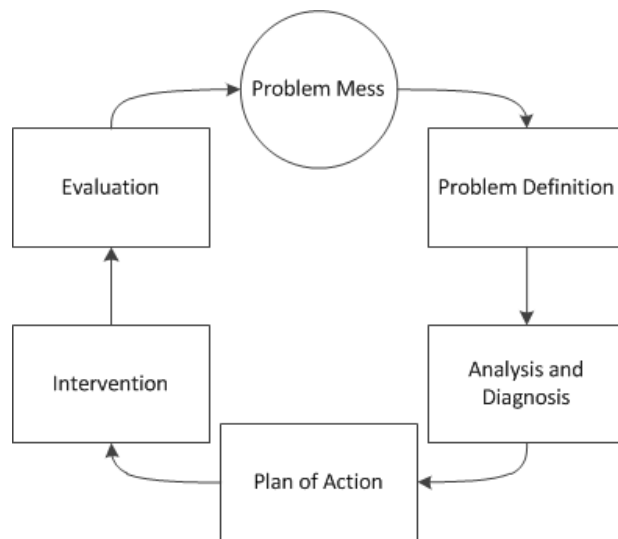


Figure 2 - Business problem solving Cycle (van Aken, 2012)

The steps are defined in the following way. The problem mess (i) and reason to perform this case study result from Chapters 1 and 2. The general phenomena are translated for Heineken into a problem definition (ii) in Chapter 4. Further in-depth analysis and diagnosis (iii) of the Heineken organization is done by comparing practice to theory. Based on this analysis a set of propositions is formulated that will be tested. Next to this, in Chapter 6 the current state of the operational performance is analyzed using a spreadsheet-based model in Microsoft Excel. Based on the gained insight intervention projects are

selected (iv) and executed (v) at the Heineken brewery. The operational effect of these interventions is evaluated by doing an ex post - ex ante comparison. Based on an evaluation of the process (vi), the propositions are tested and conclusions can be drawn.

3.2. Research Tools

During the case study, different types of research tools have been used because of the both qualitative and quantitative nature of the research. For each research question, different tools have been used. First, a thorough understanding of the organization has to be obtained to develop propositions that can answer the questions: How does the implementation of a continuous improvement strategy affect operational efficiency and how do organizational characteristics affect operational efficiency? This understanding is obtained by using a system analysis and a stakeholder analysis.

System analysis

Heineken as an organization is analyzed in four different ways: desk research, explorative field research, system diagram and fishbone diagram. In order to understand the production process, behavior of the different machines and the environment in general explorative field research is performed. During several weeks operators are shadowed in their day to day operations. Next to that, explorative field research is combined with desk research. Heineken as an organization is compared to what is written in academic literature. The organization in practice is explored and the findings are compared to what is discovered in the desk research. Furthermore, a system diagram is used to analyze the boundaries of the research area, its external influences, key performance indicators, and means to influence the process (Enserink et al., 2010). Last, the Ishikawa fishbone diagram is used to analyze the possible cause-effect relationship the system and the unit of analysis (Ishikawa, 1990). The fishbone diagram is composed using brainstorm sessions with two operators and two process technologists. After completion, the diagram is validated by the same group. The aim of the diagram is to give insight into the complexity of measuring operational efficiency and analyzing production losses.

Stakeholder analysis

Next to analyzing the system, the people in the organization are analyzed as well. Using a stakeholder analysis an overview of the current situation is provided. The analysis consists of six steps: problem formulation, inventory of involved stakeholders, describing formal relations, determining goals and interests, mapping interdependencies and drawing conclusions (Enserink et al., 2010). In order to get insight information on the philosophy and history behind Total Productive Management as it is developed at Heineken, a semi-structured interview is held with Fons Jacobs. Jacobs is TPM manager at Heineken Netherlands Supply and therefore expert on this subject.

The second step is to answer the question 'how is the operational efficiency affected from a logistical point of view?' This is done by using a spreadsheet-based model, developed in Microsoft Excel.

Excel model

In order to analyze the current state of the operational performance, relevant data is needed. This data is obtained from the Heineken reporting system MES (Manufacturing Execution System). This central computer system is linked to all the sensors and control systems that are situated on and between all

machinery of the packaging line. MES consists of a database that is able to store and show all relevant output of these control systems in (almost) real-time. For this research a data analysis is done using a spreadsheet-based model, developed in Microsoft Excel. This model is linked to the described database (MES) and is able to visualize and filter the great amount of data. The information gained is on production volumes, duration of production, and losses per shift (eight hours), per machine. The model retrieves actual data from the MES database on production volume and the time the machines are in different statuses. In the model there are options to filter the data on: shifts in certain periods, shifts per product package (six-pack, 12-pack or 24-pack), and shifts with or without production. Data is retrieved from the 1st of January 2011 until the 28th of May 2014. The used calculations, formulas and variables are explained in the corresponding chapters and in Appendix E1 – Bottleneck analysis model formulas.

Real life testing

Last, the propositions developed for answering the three research questions are tested by applying the Heineken approach in real life. This means performing four intervention projects, based on the Heineken methodology. This way it can be seen how the propositions hold up in practice. The impact of these projects is evaluated both qualitatively and quantitatively.

4. Heineken Case Study

This chapter will give an introduction to the case study at the Heineken brewery in Zoeterwoude, the Netherlands. Heineken Netherlands Supply and the organization of its packaging department will be introduced in Paragraph 4.1 and 4.2 respectively. In the next paragraph, the discrete production process of the packaging department will be explained in detail. Fourth, in Paragraph 4.4 the unit of analysis is defined. Improving this performance indicator will be the focus of this case study. Last, in Paragraph 4.5 the challenges at the packaging department are explained.

4.1. Heineken Netherlands Supply

As described, in order to analyze the process of improving operational efficiency of discrete production process in a large manufacturing company, one case is selected. Representing the described environment, the globally active manufacturing organization Heineken N.V. will serve as research subject in this thesis. The research is performed at Heineken’s brewery in Zoeterwoude, the Netherlands. As part of Heineken N.V. (Appendix A1 – Heineken N.V. overview), Heineken Netherlands Supply (HNS) is responsible for producing, packing and distributing Heineken products in the Netherlands and numerous foreign markets. HNS produces its beer in three breweries: Zoeterwoude, Den Bosch and Wijlre. The Zoeterwoude brewery produces the larger part of the group volume with 60% of the total volume. In 2010 HNS formulated their “HNS Vision 2015”, in which they aim to be the number one in costs, be the number one in delivery reliability, and produce at world quality, while using Total Productive Management (Everts, 2011). HNS is especially important for the production of the Heineken brand. In 2012 HNS produced around 15.9 million hectoliters of beer, of which around 5 million was destined for the domestic market. Heineken N.V. can be classified as a large manufacturing company in the food producing sector. With 190 breweries worldwide, Heineken has an elaborate production chain and a network of many suppliers and buyers. Next to that, beer has a relatively short shelf-life and uses heterogeneous raw materials. This affects storage, conditioning, processing, packaging and quality control (Gellynck & Molnár, 2009). Because of the sheer size of the organization, the impact of seasonality and varied harvesting conditions can be kept low (Luning & Marcelis, 2006). The discrete production process that is the focus of this research is located in the packaging department of the Zoeterwoude brewery of Heineken. This department covers the entire process from obtaining beer from the brewing department to delivering packed units to the logistics department. Divided in five divisions (rayons), the packaging department consists of 14 production lines (Appendix A2 - Figure 38). This research will focus on rayon 5, and more specifically production line 81. This bottling line produces Heineken, Heineken Light, and Amstel Light for export. The process starts at the moment beer and empty bottles are received from the brewery and the logistics department respectively. The process ends at the moment pallets packed with beer are delivered to the Customer Service & Logistics department. Figure 3 illustrates the bottling process of production line 81 at the Heineken brewery in Zoeterwoude. The production process goes from left to right, and is explained in detail in Paragraph 4.3.

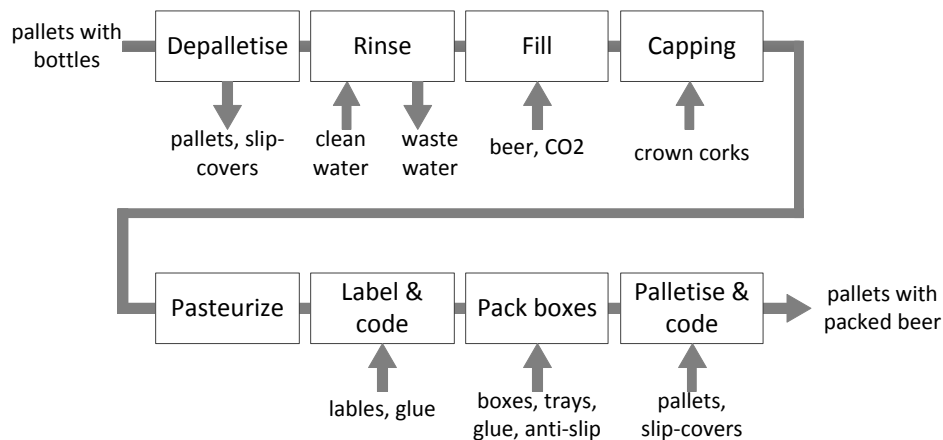


Figure 3 - Simplified Production Process Heineken Zoeterwoude line 81

In short, the linear process goes as follows: the depalletizer takes empty bottles from a pallet and places them on a bottle lane. This will bring the bottles to the Filler, where bottles are cleaned, filled with beer and sealed off with a bottle cap. From there the pasteurizer will pasteurize the bottles and after being dried, the labelers will put labels on the bottles. From there the bottles are transported to the so-called dry area where the bottles are packed into boxes. At line 81 a choice can be made to either operate the 6/24-pack area, or the Multipacker area. Once packed, the bottles are transferred on to pallets and delivered to the Customer Service & Logistics department (CS&L).

Lastly, in order to make the production process perform at its optimum, Heineken introduced Total Productive Management (TPM). In 2003, Heineken has started the implementation phase as part of a global strategic program. The aim is to implement one language for running operations and improvement of processes. TPM at Heineken is the methodology for achieving: World Class Operations Management (WCOM). The three pillars of WCOM at Heineken consist of Lean Management, Total Productive Maintenance and Six Sigma. TPM is designed in such a way that all layers of the organization, both horizontally and vertically are involved.

4.2. Heineken Zoeterwoude packaging department

As described in the introduction, the packaging department of the Zoeterwoude brewery in the Netherlands will serve as subject for this case study. The department will represent large manufacturing organizations with a discrete production process. The organizational structure of the packaging department is briefly described in the introduction. In Appendix A2 - Heineken brewery Zoeterwoude, an overview is given of how the departments are organized (in rayons) in cooperation with the supporting staff, consisting of a Quality department, a TPM department and a Maintenance department. Each rayon has a Rayon Manager (RM), three Team leaders (TL) and three or five teams of operators. As Figure 4 shows, there is a clear hierarchy in the organization. Operators manage the core operations, running the production line. Team leaders manage, support and assess the operators. The rayon manager does the same for the team leaders. Rayon managers on their turn get supported, managed and assessed by the department director. The maintenance staff supports operators in specialized maintenance work (specialized lubrication for example). TPM facilitators support operators and team leaders in performing TPM-based projects. The finance department controls operations on financial performance and validity of investments. The quality department monitors the quality of the delivered product.

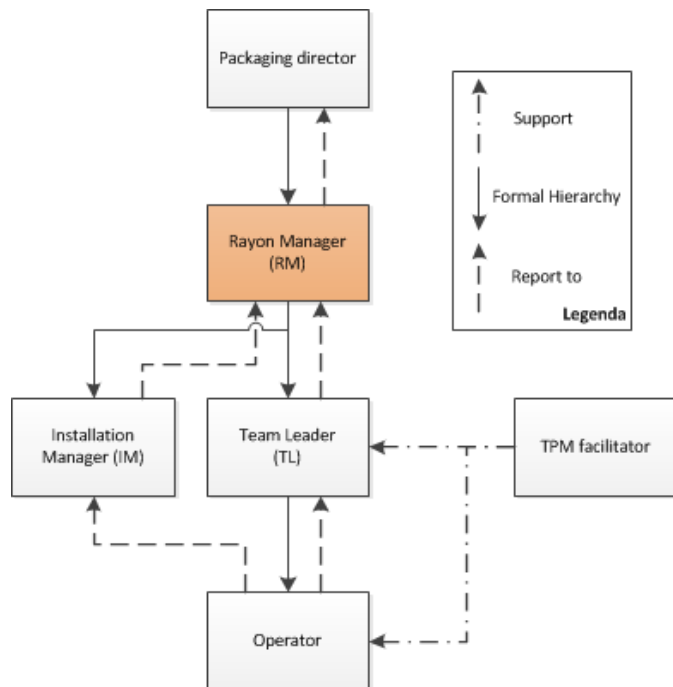


Figure 4 – Formal Organization Chart Heineken Production line

4.3. Heineken Production Line 81

As explained in the introduction of this report, the case study is focused on the bottling process that is used within the Heineken organization. Bottling line 81 produces Amstel Light, Heineken and Heineken Light for export. Figure 5 illustrates the production process in detail and Figure 6 (on the next page) illustrates the corresponding machines. The numbers of the processes correspond to the numbers of the machines, as do the colors of the processing area. The focus of this study will be on the internal process, so Out of scope will be: the logistical process of delivering materials, handling finished products, demand forecasting and production planning processes.

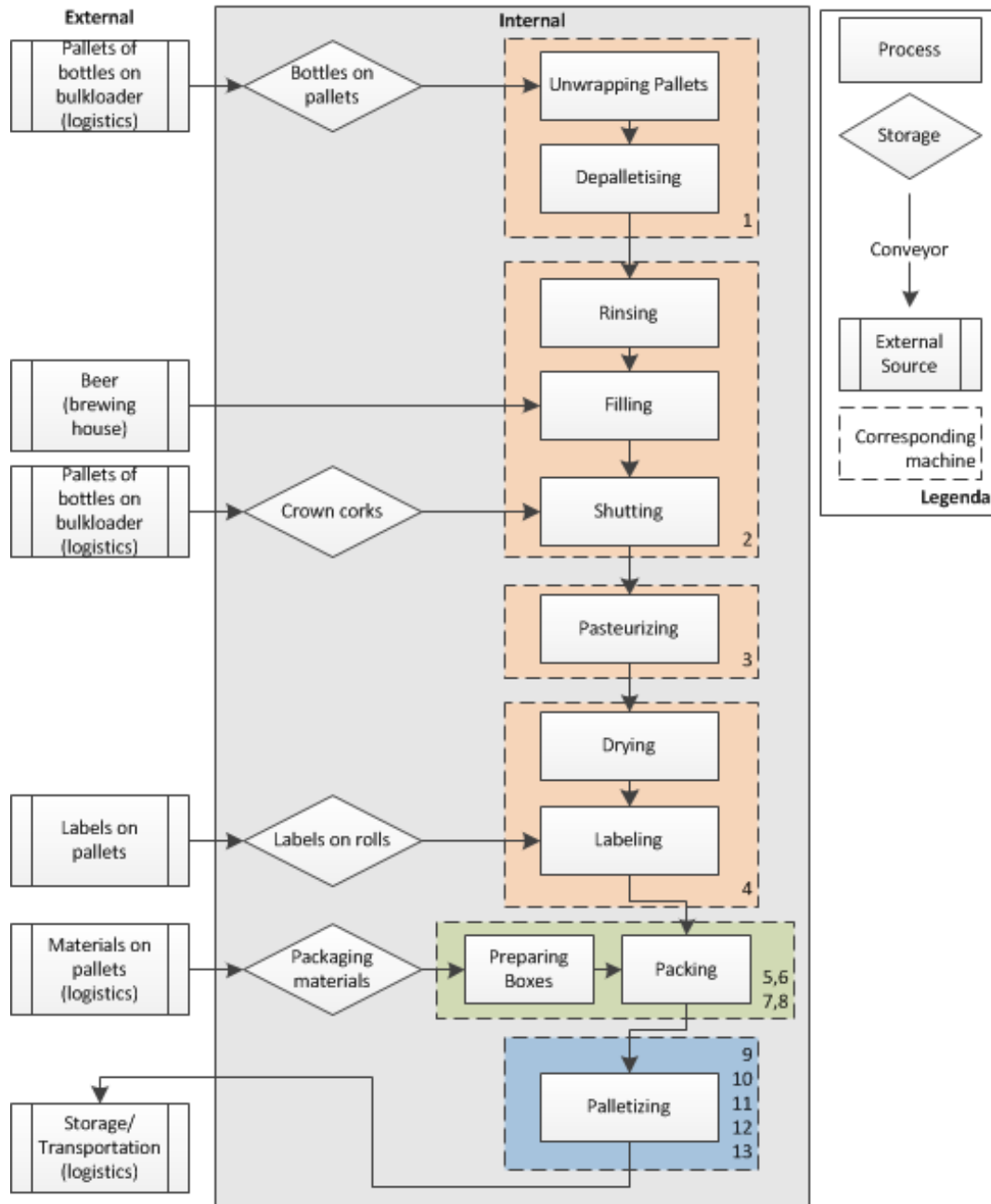


Figure 5 - Heineken Zoeterwoude line 81 Functional overview

The illustrated processing areas: wet, dry and palletizer are physically different areas on the shop floor. Wet and dry correspond to the state of the product at the time it is produced (beer bottles are wet when they come out of the pasteurizer and are dry when they are put in boxes).

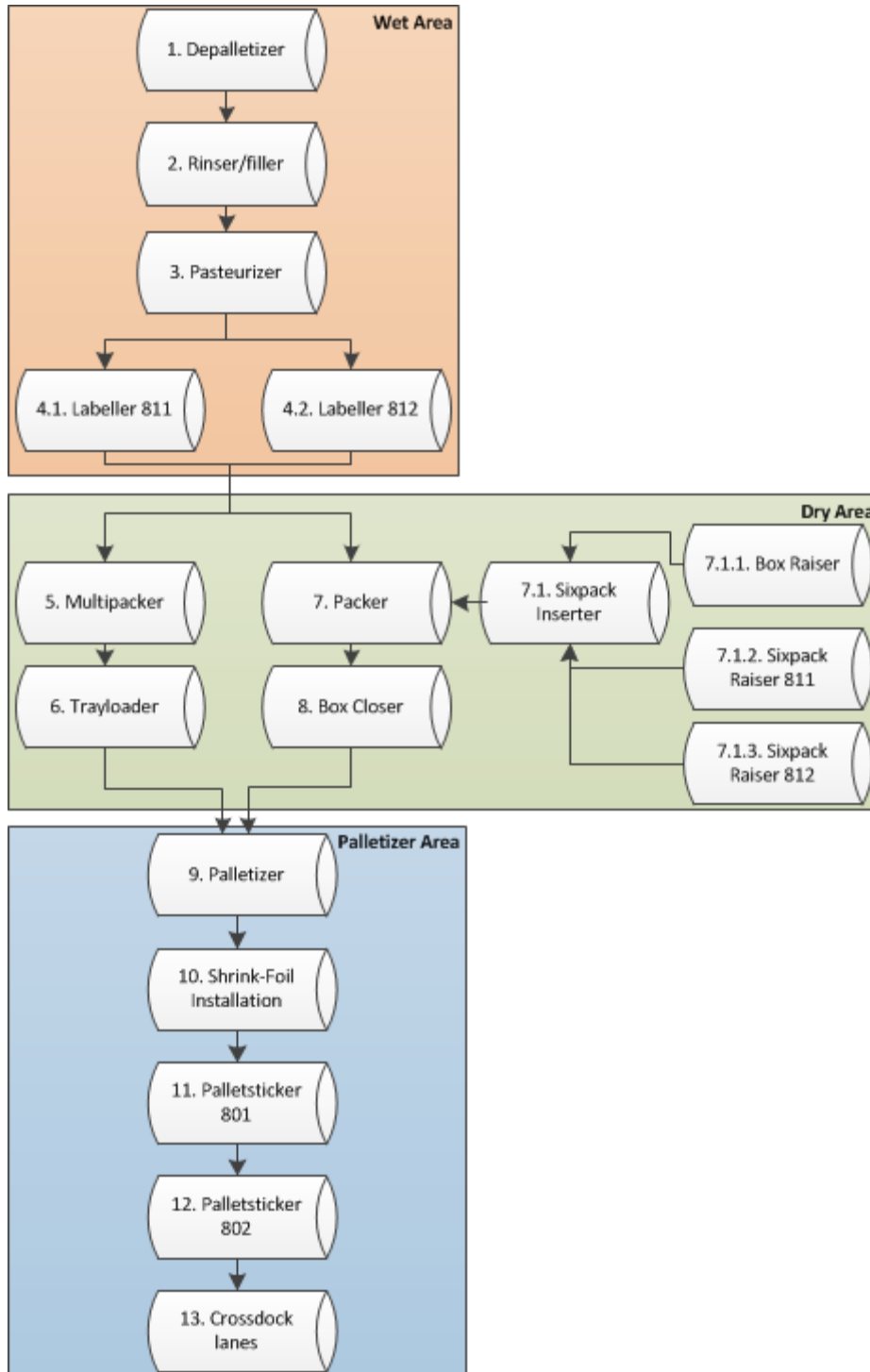


Figure 6 - Heineken Zoeterwoude line 81 Machine overview

4.4. Unit of analysis – Operational Efficiency

When performing a case study it is important to define the unit of analysis, in order to properly interpret possible findings. In this case study the aim is to improve the efficiency of a production line. Heineken has an own performance indicator system with which they measure their performance, which will also be used in this research. Within the Heineken brewery the performance is measured based on an extensive set of key performance indicators (KPI's). In Appendix C1 - Overview the elaborate list of KPI's can be found as formulated within Heineken Netherlands Supply. Using KPI's is Heineken's way of incorporating the measurement of both intangible and tangible assets into their management system (Kaplan, 2008). The main performance indicator for operational efficiency is the Operational Performance Indicator (OPI). The indicator OPI is derived from the Overall Equipment Effectiveness (OEE) theory. Looking at OEE, a number of papers have been written on its effectiveness, usability and its impact on performance (Braglia, Frosolini, & Zammori, 2009; Garza-Reyes, Eldridge, Barber, & Soriano-Meier, 2010; Zuashkiani, Rahmandad, & Jardine, 2011). All agree that OEE is capable of providing a good measurable insight in the performance of a company. Figure 7 provides an overview of how OEE is defined and where the biggest losses are according to the theory.

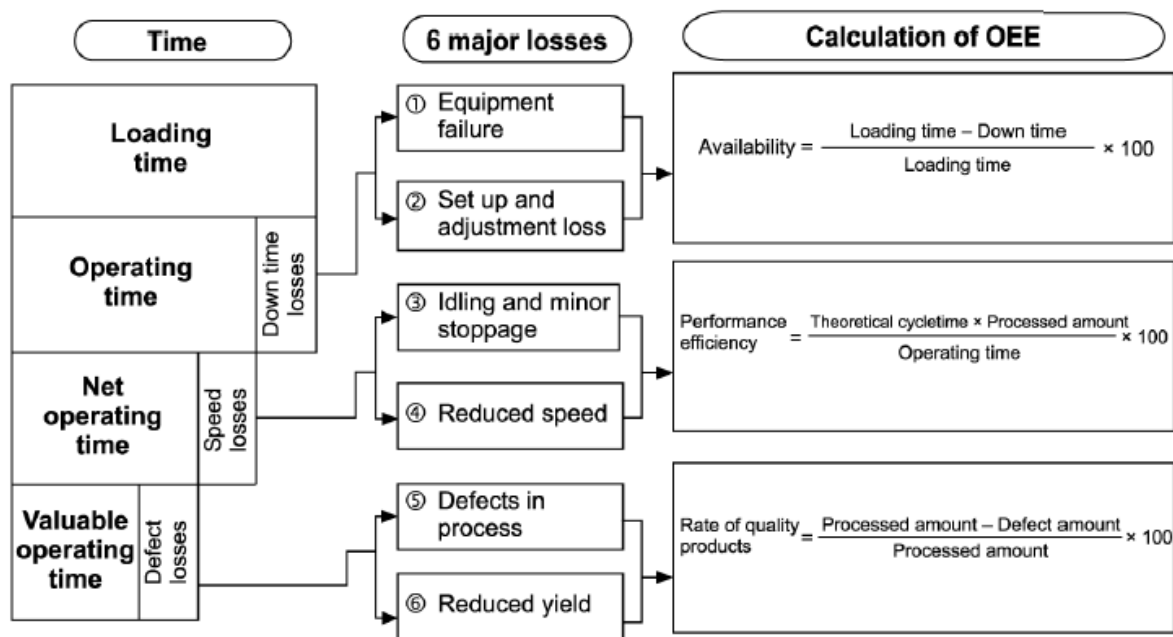


Figure 7 - The OEE formulation and the six losses (Batumalay, and Santhapparaj, 2009)

With OEE, an organization looks at the total time that is available, down time losses, speed losses and defect losses. These three types of losses are translated into Availability, Performance and Quality. When the efficiency on these aspects is measured and combined, the Overall Equipment Effectiveness can be calculated.

Equation 1

$$OEE (\%) = Performance (\%) \times Quality (\%) \times Availability (\%)$$

On a shopfloor level Heineken uses the Operational Performance Indicator No order No activity (OPI NoNa) to measure the performance of its production lines. An illustration of this KPI can be found in Figure 8, which shows what aspects are taken into account and what aspects are left out, when calculating the performance indicator. OPI NoNa calculates the performance based on the production time where operators are present and there is actually an order for production. That means production time loss due to the following is also not taken into account: 3rd party and non-operator maintenance, operator training, and operator-based meetings.

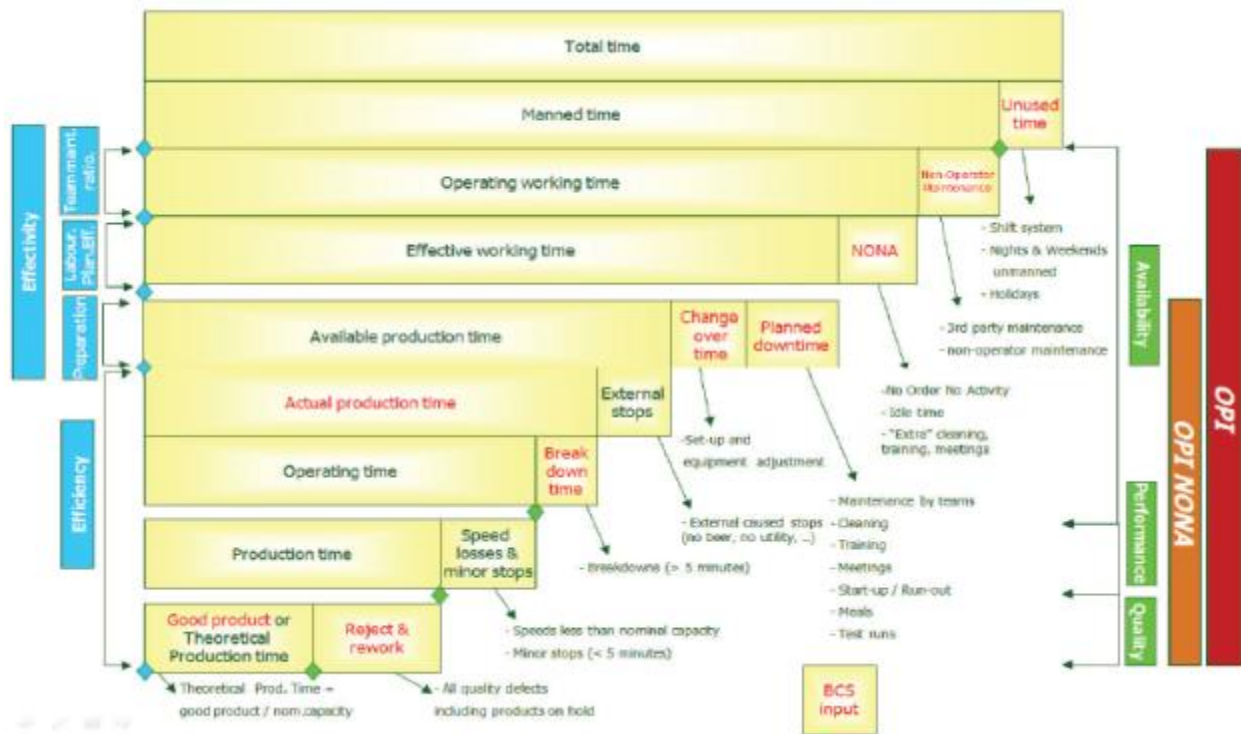


Figure 8 - Description of OPI NoNa (Efeso, 2008)

So, a lower OPI NoNa may indicate machine breakdowns, speed losses, no material inflow or quality-based rejections of products. The KPI is reported in the Manufacturing Execution System (MES), which can also provide overview reports (including Pareto analyses). The performance is measured with the output of the designed bottleneck, calculated from the performance of the filler. Losses are defined as planned downtime (time for maintenance for example), change-over time (shifting from producing one product to the other), external stops (not enough material for example), breakdown time (a machine broke down and needs to be fixed), speed losses and minor stops, and reject and rework (bottles not filled high enough for example).

In order to analyze OPI NoNa it is necessary to investigate the downtime of the different machines, the volumes produced per time unit, the utilization of the machines, their isolated production rates, the calculated speed loss, the variation of the performance and the average performance. Table 1 gives an overview of these variables. The variables utilization and isolated production rate will be explained in Chapter 6.

The downtime of each machine is divided in six different statuses, which machines can be only one at a time:

- Blockage* Machine m_i is **blocked** during a time slot if buffer b_i is full at the beginning of this time slot, and m_{i+1} fails to take a part from b_i at the beginning of this time slot
- Starvation* Machine m_i is said to be **starved** during a time slot if buffer b_{i-1} is empty at the beginning of this time slot
- Breakdown* Machine m_i is said to be **broken down** during a time slot if m_i is not able to produce parts due to internal malfunction
- Unknown* Machine m_i has status **unknown** if m_i is not able to produce parts due to unknown reasons
- Production* Machine m_i is in **production** when m_i is producing parts and is not starved, blocked or broken down
- Production Stop* Machine m_i is in **production stop** when m_i is not producing parts because of planned downtime

Variable	Unit	Equation
Operational Performance Indicator	%	$Performance (\%) \times Quality (\%) \times Availability (\%)$
Utilization	% (bottles/(bottles))	$\frac{Arrival Rate (bottle)}{Production time (hour) * Maximum Capacity (\frac{bottle}{hour})}$
Isolated Production Rate	Bottle	$(Production time + Starvation time + Blockage time (hour)) * Maximum Capacity (\frac{bottle}{hour})$
Speed loss	Minute	$(1 - Utilization) * Production time (minute)$
Downtime	Minute	(production line; overall time period; downtime; shift; machine status)
Volume	Bottle	(production line; overall time period; counter; shift; machine status)
Standard deviation	Bottle or Minute	$\sqrt{\frac{\sum(x - \bar{x})^2}{(n - 1)}}$
Average	Bottle or Minute	$\frac{1}{n} \times \sum x$

Table 1 - Units of analysis

4.5. Problem Exploration and Knowledge Gap for Heineken

In Chapter 2 a general knowledge gap is formulated, on which the general research question is based. To make the transfer to this case study, the knowledge gap is translated to the specific challenges that are perceived at the Heineken organization. For Heineken, there are clear goals for increasing the company's efficiency: overall production costs (€/hectoliter) have to decrease, productivity (hectoliter/Full Time Employee) has to increase, while maintaining high quality (First Time Right (FTR)) and a reliable service (On Time in Full (OTIF)). Looking at the operational efficiency indicator Heineken uses itself, 'Operational Performance Indicator No Order No Activity' (OPI NoNa), it can be seen that the production process of production line 81 is not performing as good as the company wants. Figure 9 illustrates the output performance of production line 81 over the years 2011, 2012 and 2013 per week. The red line depicts the goal management has set on beforehand. The plotted linear trend line indicates an overall continuous decline of the output performance of 3% per year. With an average of 62%, 60%, and 56% for the years 2011, 2012, and 2013 respectively, the overall performance indicator is not near the ideal situation of a constant 80% (Derksen, 2013).

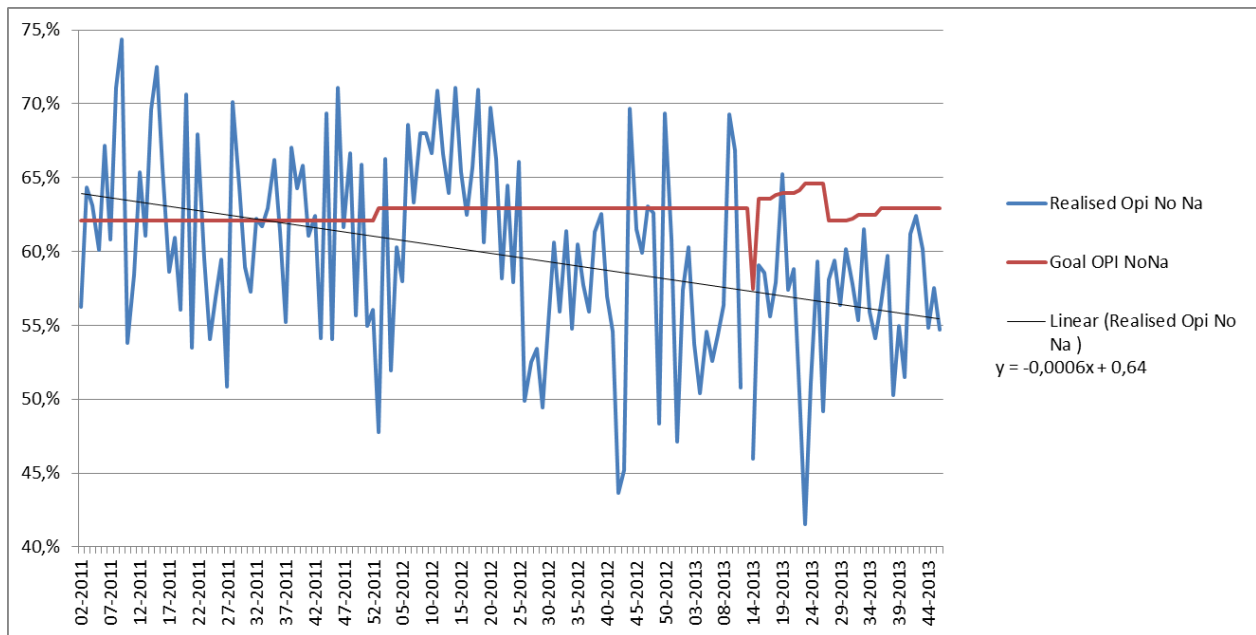


Figure 9 - Realized OPI NoNa Heineken Line 81 Zoeterwoude 2011-2013

Looking at the given situation in terms of organization and continuous improvement strategy, Heineken is looking for ways to structurally improve its operational efficiency. The following knowledge gap can therefore be formulated for Heineken:

The steps Heineken can take to identify and resolve the issues that cause the non-optimal performance of production line 81.

Looking at the presented environment, a number of aspects can be identified that all have an impact on the performance of Heineken: a linear and discrete manufacturing process, the aim to optimize the efficiency of this process, a complex performance measurement system, and the implementation of

TPM. Figure 10 illustrates the environment on a strongly aggregated level. As can be seen, the production process is affected by external factors, while the performance of the system is measured with specified KPI's. The available means of Heineken to affect the environment are bundled in the TPM methodology. Looking at the internal process, the skill level of operators is an important aspect since it has an impact on both planned and unplanned downtime. Availability, quality and performance can be recognized from the OEE theory, as explained in Paragraph 4.3. Underlying in the OPI KPI is of course the goal to reduce overall costs.

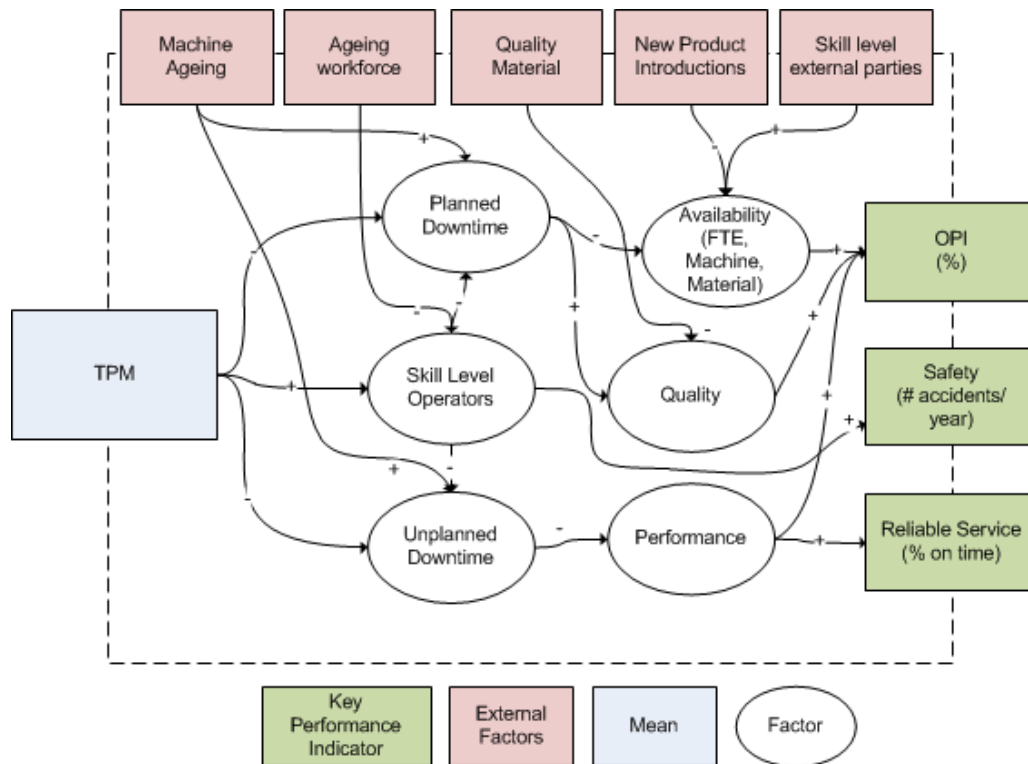


Figure 10 – Strongly aggregated system diagram of the Heineken packaging department

The packaging department has a straightforward linear production process, where the function of each machine is clear and there is data available to gain insight in production volumes and times, general causes of loss of production time, quality of product, and the time between necessary actions of operating staff (Mean Time Between Assists, MTBA). However, as mentioned in the problem exploration of this research an overall continuous decline of the output performance of 3% per year can be seen. The overall performance indicator is not near the ideal situation of a constant 80%. From a management point of view this means that the production process is not in control (Colledani & Tolio, 2011).

The current performance measurement system is data driven. The performance indicators are focused on: costs, production time, volume and efficiency, loss of material, product and energy, and quality of product and service (Appendix C1 - Overview). These indicators are influenced by six major aspects: Man, Material, Machine, Method, Management and Environment (Everts, 2011). Due to the number of possible causes for an increase or decline in performance, interpreting these performance indicators is difficult. This complexity is illustrated in Figure 11 (page 34) in a fishbone-diagram. For example, if a

machine repetitively stops in a certain week, this can have numerous causes that interact with each other. A new type of box (Material) can be smoother than normal which causes the machine (Machine) to stop, but only if the operator (Man) places the boxes too tight on the feeding table. Due to an incorrect use of tools (Method) this is not reported and therefore management does not assist in solving the problem (Management). To find a solution for the machine stopping, all these issues have to be analyzed and addressed.

So, analyzing the root cause of certain behavior can prove to be difficult. This is increased because information can be scarce or hard to interpret. In the described environment “information is often inaccurate, unavailable, or obsolete” (K. M. Eisenhardt & Bourgeois, 1988). This brings forward a number of complications for the organization. First of all, personnel at Heineken have to deal with the mentioned uncertainty on a day-to-day basis. Data is abundant, time-sensitive or obsolete, which sets high pressure on decision making. Next to that, as a link between several departments numerous stakeholders are involved, which increases uncertainty. Fortunately, a large part of the required information is present with the shopfloor operators. The operating workforce has tacit and expertise knowledge of the production system, known issues and solutions. Data is hard to interpret, but operators see what happens continuously. When switching to another product (from Heineken to Amstel for example), operators manually tweak machine settings to let the machine perform optimally. When problems arise, they know from experience which steps to take to find a solution quickly. The operators are an essential part of the organization, but they are collectively on a critical point in the ageing process. The expertise and tacit knowledge makes operators valuable and costly to replace by temporary employees for example. Operators are expected to work autonomously, which requires a lot of experience. When two of four operators get replaced by temporary employees (due to sickness for example), the work pressure for Heineken operators increases significantly. The desire for operators to work autonomously is driven by the implementation of TPM. TPM at Heineken is aimed to: gain control of the production process, improve its efficiency and improve communication between employees. This brings forward a number of changes that these operators have to comply with.

To summarize, there are four aspects with a number of implications on Heineken’s performance. There is a gap between company goals and performance, a hard to interpret performance measurement system, shopfloor operators have expertise knowledge that is not fully used, and there are challenges to overcome while implementing TPM.

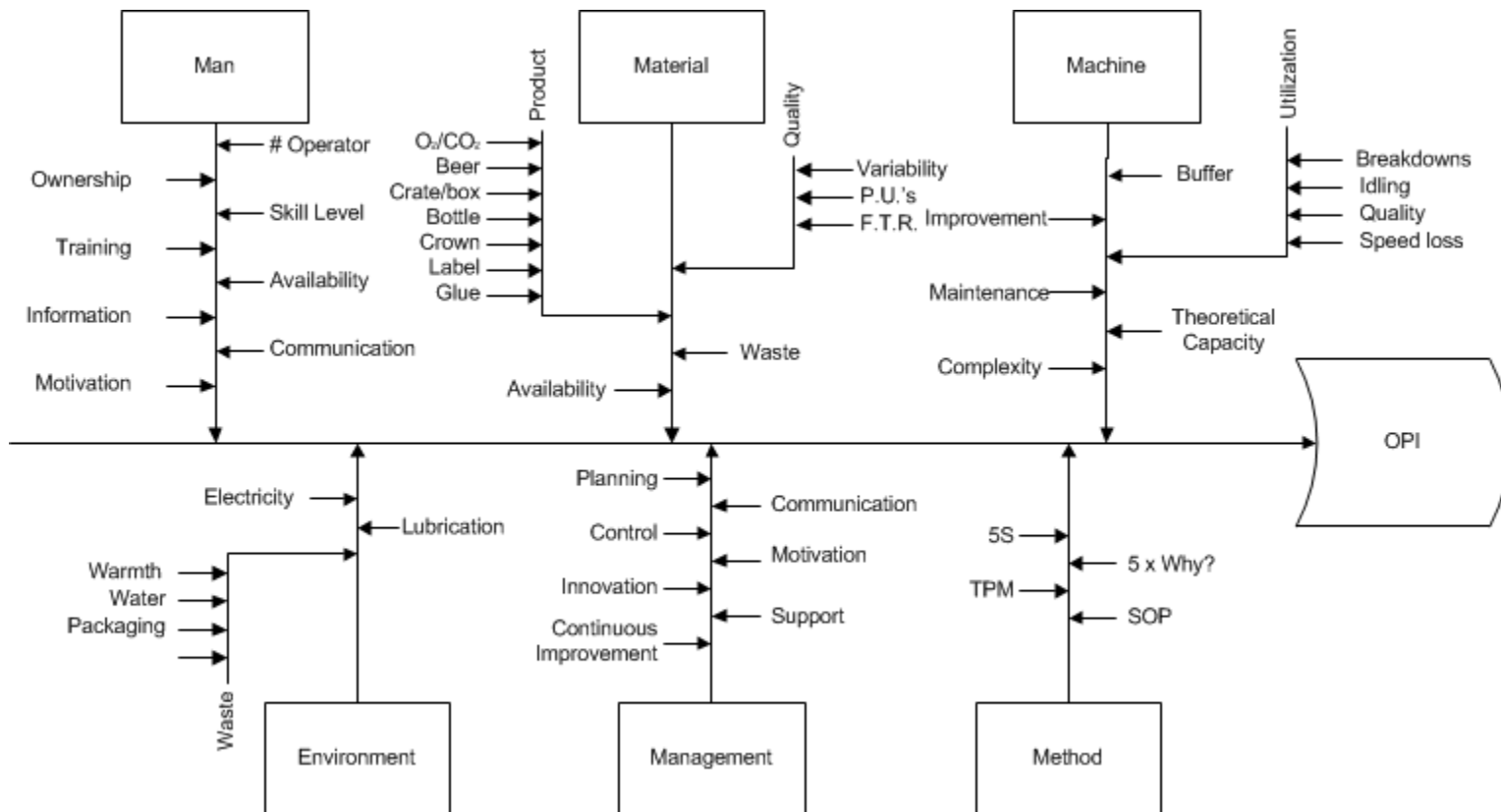


Figure 11 - Fishbone diagram 6M causes of OPI loss

The fishbone diagram shows a cause-effect relationship between the 6-M causes (squares) and the Operational Performance Indicator (Fish head on the right). Each cause has a number of possible underlying aspects that might cause the OPI to increase or decrease. The (possible) combination of multiple causes for certain behavior of the system makes the root cause analysis of issues difficult. This diagram is aimed to provide a general insight in the diversity of these causes and the complexity it creates for analysis. As can be seen, numerous aspects are tangible (quality of used crown corks) or intangible (ownership of operators). Important to state here is that this is not a complete overview of, but an indication of the diversity of possible causes of production loss.

5. Organization of Production Process

The goal in this chapter is to formulate propositions that form the basis of answering two research questions. These questions are focused on how the organizational characteristics and the implementation of continuous improvement strategies affect operational efficiency. By testing these propositions in Chapter 7, an answer to these research questions can be found. The propositions are formulated by systematically analyzing how Heineken's packaging process is organized, looking at the relevant theory. In Paragraph 5.1 Heineken's continuous improvement strategy TPM is analyzed. In Paragraph 5.2 Heineken's organizational structure and characteristics are analyzed and in Paragraph 5.3 the findings are translated into propositions.

5.1. Continuous Improvement

In order to know how Heineken continuously improves its operational performance and how to improve this, a comparison between Heineken's Total Productive Management and alternative improvement strategies in literature is made. Based on this comparison the strengths and weaknesses of Heineken's TPM are illustrated and propositions will be formulated that will be tested in Chapter 7. Figure 12 illustrates the relation of this paragraph to the other research subjects.



Figure 12 - Relation of research subjects, focus on Paragraph 5.1

5.1.1. Continuous Improvement strategies in theory

As introduced in Chapter 1, Continuous Improvement (CI) strategies are hard to see separately from each other. Examples of closely related programs are Total Quality Management (Cua et al., 2001), Just in Time (Cua et al., 2001), Preventive Maintenance, 5S Workplace Management System (Moradi et al., 2011), Lean (Arlbjørn & Freytag, 2013), Theory of Constraints (Rahman, 1998) and Six Sigma (de Mast & Lokkerbol, 2012; Schroeder et al., 2008). In this paragraph four of the leading improvement strategies will be discussed: Lean management, Six Sigma, Theory of Constraints (ToC), and Total Productive Maintenance. In general, these improvement strategies have over time grown into comprehensive management strategies. Implementing them requires changing a working culture towards a continuous improvement culture, which can prove to be difficult and have an impact on involved personnel (Arca & Prado, 2008; Farris, Van Aken, Doolen, & Worley, 2009; Sim & Rogers, 2008). For each strategy an analysis is made in literature on the underlying theory, the focal point of the strategy, assumptions made, the intended effects and the main critique.

Lean management

Due to the fact that there is no commonly accepted definition or boundary of the lean philosophy, principles and tools there are a number of different views on the subject: "Ranging from a focus on waste elimination, utilizing operational tools and implementing specific production-related principles, to identifying conditions that are linked to the product and/or the service and the predictability of demand and its stability" (Arlbjørn & Freytag, 2013). However, the basic principle of lean thinking involves

eliminating waste. With waste is meant anything in an organization that is not necessary to produce the actual product (or service). The assumption is that by eliminating waste the overall business performance will increase. Rather than making large system analyses, the focus lies on making many small improvements. This way the overall flow time can be reduced (by lowering change-over times for example), the variation can be decreased, there is a lower need for inventory and the quality will increase (Shah & Ward, 2003). Critique involves a lack of statistical and system analysis within the lean philosophy. On a more operational level the critique involves the decrease in operator autonomy, multi-skill requirement, and work intensification (Arezes, Carvalho, & Alves, 2010).

Six Sigma

Developed at Motorola in the 1980's and made popular at General Electric 10 years later, Six Sigma is one of the leading improvement strategies around. Referring to a statistical quality level of 3.4 defects per million, Six Sigma aims to solve problems from a data driven point of view (Brady & Allen, 2006; Pepper & Spedding, 2010). Where lean is focused on process waste reduction, Six Sigma primarily focuses on process variation reduction. Project-by-project problems are addressed from start to finish. Each project is signed off by a certified project leader (black-belt) only when the target financial savings are verified (Bendell, 2006). The vision of the methodology is that by lowering the variation in processes, the system output will improve automatically and the amount of waste will diminish. Next to that, the quality will increase because the output is more uniform. The critique on the methodology is aimed on three aspects: (i) a lack of taking into account the overall system interaction, (ii) a cost down driven approach in reality, instead of a customer focus and (iii) the main tools are data driven (i.e. statistical, failure mode), with a lack of soft tools (i.e. creativity, innovation) (Bendell, 2006).

Theory of Constraints

The Theory of Constraints is developed by E. Goldratt (Goldratt, 1990). The concept behind the Theory of Constraints can be summarized into two statements (Rahman, 1998):

- Every system must have at least one constraint (without constraints organizations would make unlimited profit)
- The existence of constraints represents opportunities for improvement (Constraints are therefore positive and determine the performance of a system)

So managing these constraints should be the focus of improving production processes. Removing these constraints and pampering your designed bottleneck is the key to a successful production line. By removing constraints, the emphasis should lie on increasing or optimizing production speed and enlarging or optimizing production volume. It is essential to realize that every link in a production process is dependent on the other links. This interdependency should drive the choices one makes in allocating resources. The aimed effect is not surprisingly fast throughput, improved quality and less waste. Six interesting assumptions can be distilled from this theory:

- Balance flow, not capacity
- The level of utilization of a non-bottleneck is not determined by its own potential but by some other constraint in the system
- Utilization and activation of a resource are not synonymous

- An hour lost at a bottleneck is an hour lost for the total system
- An hour saved at a non-bottleneck is just a mirage
- Bottlenecks govern both throughput and inventories

Next to pampering designed bottlenecks, the theory also involves searching for hidden bottlenecks. Based on wrong assumptions or misleading data a part of the process can prove to be such a big constraint it has become a second, or even the new bottleneck of a process. The critique on the theory is aimed at the lack of involvement of operating employees. Because the theory is focused at the whole system, employees working at parts of this process can contribute in a very limited way.

Total Productive Maintenance

From an academic perspective, the current research performed on the TP Maintenance methodology in general can be summarized into the following categories: “maintenance techniques, framework of TP Maintenance, overall equipment effectiveness (OEE), TP Maintenance implementation practices, barriers and success factors in TP Maintenance implementation and the contributions of strategic TP Maintenance programs towards improving manufacturing competencies of the organizations” (Ahuja & Khamba, 2008c). The definition in literature states that Total Productive Maintenance is a methodology to continuously manage, optimize and improve a supply chain by eliminating all losses, involving all employees of the organization (Ahuja & Khamba, 2008b). The methodology aims to “increase the availability and effectiveness of existing equipment in a given situation, through the effort of minimizing input and the investment in human resources which results in better hardware utilization (Chan, Lau, Ip, Chan, & Kong, 2005).” TP Maintenance is applied through the entire organization and involves directors, management, support and operators. By training employees, a working culture can be created in which losses are not accepted and processes are structurally improved. TP Maintenance in theory is able to facilitate in achieving a company’s goals on Productivity, Quality, Cost, Delivery, Safety and Morale (Ahuja & Khamba, 2008a). (Willmott & McCarthy, 2001) emphasize the importance of the TPM methodology as a facilitator for management and shopfloor operators excel, rather than a ‘simple’ maintenance tool. Due to its focus on personnel, the fragile point of the methodology is the capability of the personnel.

Critique on TP Maintenance focuses mostly on personnel-related factors that influence failure (Rodrigues & Hatakeyama, 2006): ranging from ‘increasing daily rhythm of production, with the same team’ and ‘lack of time for the autonomous maintenance’ to ‘work stress’ and ‘non-truly commitment of the immediate bosses and superior staff’. Next to that, Crawford (1998) states that when the workforce is faced with the implementation of TP Maintenance, this may lead to cultural resistance of change, lack of organizational communication, use of inappropriate performance measurement, and poor quality. However, according to (McKone, Schroeder, & Cua, 2001) multiple studies have shown that TP Maintenance has a positive and significant relationship with low cost, high levels of quality and strong delivery performance.

Overview

The findings of this review are summarized below, in Table 2.

Strategy	Lean Management	Six Sigma	Theory of Constraints	Total Productive Maintenance
<i>Theory</i>	Removing waste	Reducing variation	Managing constraints	Maximize Equipment effectiveness
<i>Focus</i>	Flow Focused	Problem Focused	System Constraints	Machine Condition
<i>Assumption</i>	Waste removal will improve business performance	System output improves if variation in all processes is reduced.	Emphasis on speed and volume. Process interdependence	Creating a working culture in which losses are not accepted and processes are structurally improved
<i>Effect</i>	Reduced Flow time, Less variation, Less inventory, Improved quality	Uniform Process output. Less waste	Fast throughput, Improved quality, Less inventory/waste	Low cost, high levels of quality and strong delivery performance
<i>Critique</i>	System analysis not valued	System interaction not taken into account	Minimal worker input. Data analysis not valued	Chance for cultural resistance of change, lack of organizational communication, use of inappropriate performance measurement, and poor quality

Table 2 - Overview of different aspects of Continuous Improvement Strategies

Next to these specific critiques, there is some overall critique on improvement strategies. When looking at implementing these types of strategies in the organization, resistance to change can occur. Case studies at large manufacturing firms have been performed to find out where the barriers to implementation lie. In some instances it is found that employees do not feel valued when contributing to the improvement process and that 100 per cent of the hourly male employees disagreed on the statement that "The Company considers the employees as the most important asset and will do whatever they can to keep their people" (Sim & Rogers, 2008). In general it can be said that these strategies address management theory as secondary or tertiary issue, don't address policies, formal or informal, don't address how managers are measured and rewarded for process improvements, don't address the general theory of management used by the organization, and don't address the organizations values (Nave, 2002).

5.1.2. Continuous Improvement Strategy at Heineken

The following is based on (i) an interview with F. Jacobs (2014), TPM Manager at Heineken Zoeterwoude and (ii) information gained from Heineken's database (Lotus). Total Productive Management is implemented at Heineken in 2003, based on advice from consultant EFESO. The aim for this project is to develop one language for running operations and the improvement of processes. Heineken perceives

TPM to be the methodology for achieving World Class Operations Management (WCOM). The three pillars of WCOM at Heineken consist of Lean Management, Total Productive Maintenance and Six Sigma. Lean Management in the form of minimizing waste in the production process and all related processes. Total Productive Maintenance in the form of continuous preventive maintenance in order to maximize the machine life cycles and minimize maintenance costs. Six Sigma is used order to control and organize the highest product quality. In the five years following 2003, the TPM methodology is tested and tailor-made for Heineken. By structuring processes, setting up standards and by minimizing waste, the variability in production performance could be minimized.

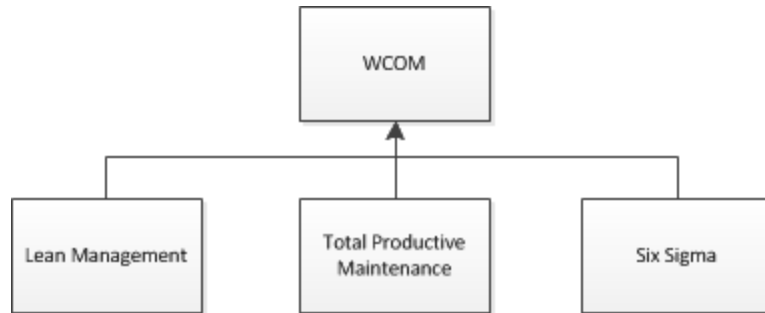


Figure 13 - Total Productive Management at Heineken to gain World Class Operations Management

TPM is focused on two departments: Brewing and Packaging. Looking at the supply chain, this has an impact on suppliers, in-house stakeholders and customers. The demands for high quality and on-time delivery are set high. Communication with the mentioned stakeholders has to be quick and clear.

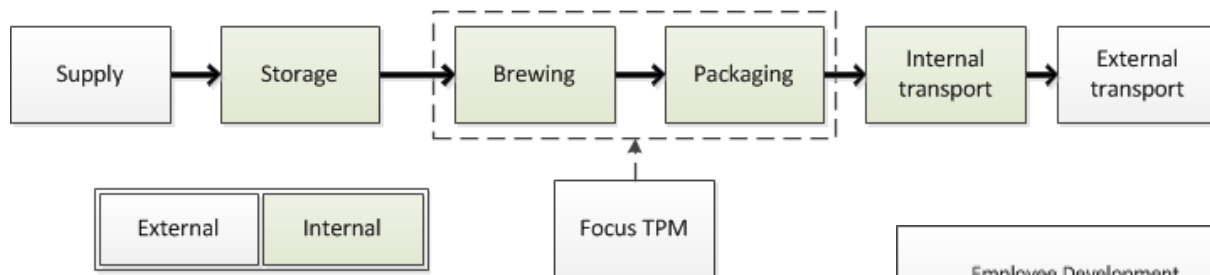


Figure 14 - Focus area of Total Production Management at Heineken

TPM focuses on the basis of the production company in order to influence final results. The idea is that by training employees (using the People Development-Pillar) in the TPM-philosophy of continuous improvement and preventive maintenance a mind-shift in the working culture can be created. When the entire company from the bottom up makes this shift in working culture, the focus of the entire company will be on better processes. If this succeeds, this will automatically lead to better processes with a zero-loss goal. Better processes in their turn will enable the organization to perform at its best. So by starting at the core of the organization’s production process, the employees, the basis

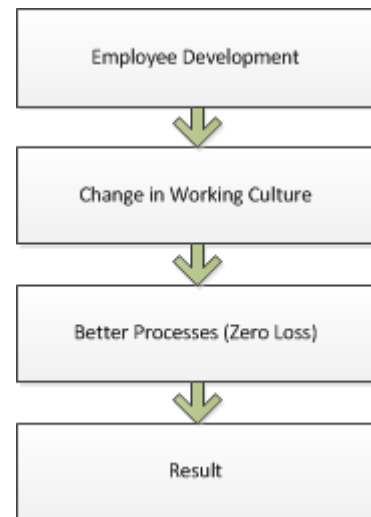


Figure 15 - Shopfloor excellence through Culture

will be set for better results in the long term.

This presented process from a vision to eventual results is illustrated in Figure 16. The Driving System consists of the strategy developing management layer. This management layer is the group of people that develop a vision on where the company could be in the long term. This vision is translated into goals. These goals are compared with the current situation and a gap can be identified. However, overcoming this gap can be complicated and actions to be taken might be unclear. To make the step from taking action to setting up standards, the improvement cycle is in place. In this improvement cycle all available TPM tools are present. These tools range from small one-man projects that are done in a day time (Breakdown Analysis) to large multidisciplinary loss reduction teams that can take 1 to 3 months. The next step is to embed these standards on the shopfloor in such a way that it is structurally implemented. That requires a plan to implement: making sure it is done, and monitor the way it is done. This will in the end make for better processes, thus better results. If the results are improved, a new vision can be developed and the cycle can start again.

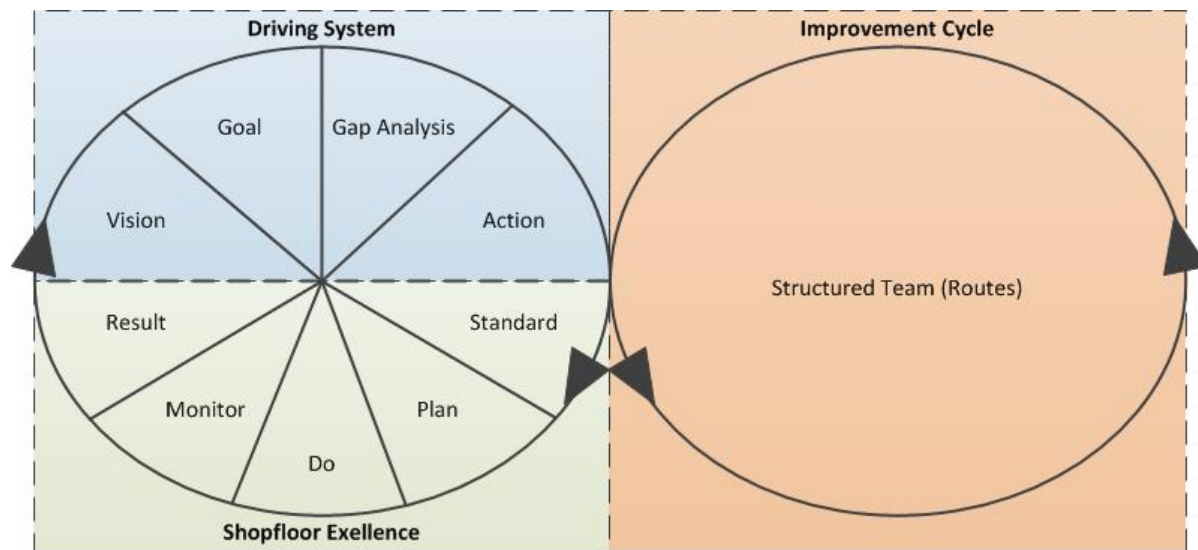


Figure 16 - TPM Cycle of continuous improvement

When looking at the drivers of loss-based improvement, six layers can be identified (see Figure 17): (i) based on losses, (ii) tools are used to eliminate them. (iii) There are defined processes to using these tools, called routes. These routes are aimed to determine (iv) standards, bring back systems to these standards and making sure these standards are maintained in the future. The standards of all processes, machines, materials and methods make up the (v) systems that drive the entire production process. The (vi) Skills within the organization determine how good these systems are and how well they are operated. When the systems are perfect, the skills within the organization determine its overall performance.

Within TPM these five layers (excluding Skills) are organized in pillars. These pillars are departments on their own that contain the parts of all the five layers, mentioned above, and focused on one subject. The six TPM pillars at Heineken are: Focused Improvement (FI), Autonomous Management (AM), Planned Maintenance (PM), Progressive Quality (PQ), Training and Education (T&E) and Safety and Environment

(S&E). As a consequence of this, all production lines individually interfere with all pillars. By performing the processes in the different pillars, the organization can improve its skills. With these skills, the production line can improve its processes and consequently its performance, hence increasing result.

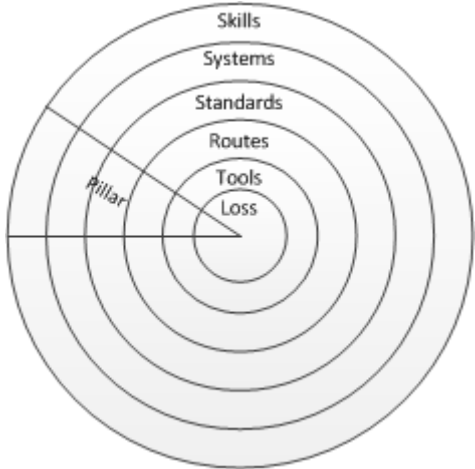


Figure 17 - TPM Pillar build up in different layers and focused on one subject

The overall goal is to make the production process needs driven (what is needed to make/keep the process standard), where shopfloor operators are leading. At this moment management is leading and so the process is performance driven. As mentioned in paragraph 3.2, performance management of operators is based on output performance (as they are judged on that their selves) instead of how well operators are able to perform their tasks (Cleaning, inspection, or keeping process in standard).

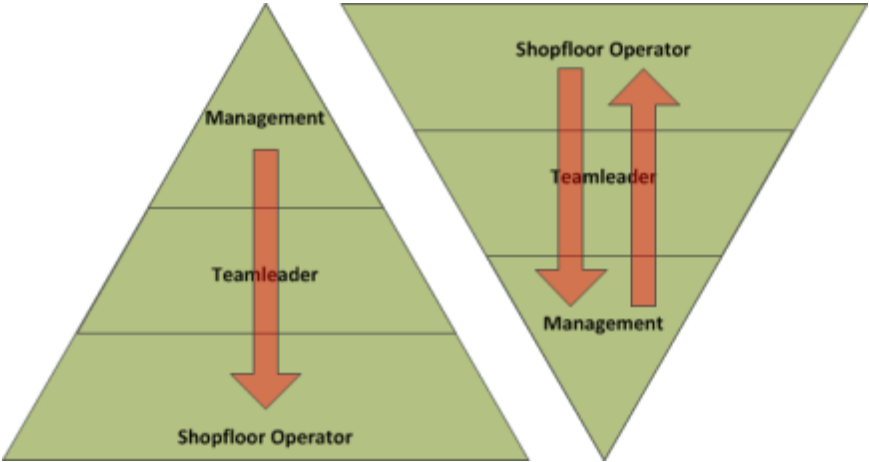


Figure 18 - Culture shift from Top-down (performance driven) to Bottom-up (needs driven)

TPM is part of a global strategy to improve the entire Heineken organization. For the implementation of TPM per brewery a standard process is developed and divided into four phases are: Preparation, Pilot, Expansion and Stabilization. In order to assess the different breweries in their progress of implementation an award system is developed. Based on elaborate criteria three awards can be earned:

Bronze, Silver and Gold. For the bronze award all pillars must be developed completely. The Zoeterwoude brewery obtained the Bronze Award in 2013, following Den Bosch's achievement a year earlier. The Silver Award can be obtained by showing accelerated results, based on trained employees. For Zoeterwoude at this moment (2014) this means training all 300 employees thoroughly. The Gold Award can be obtained by showing to be able of performing on a World Class Brewery Organization level. Figure 19 illustrates this implementation process. By obtaining the Bronze Award the Zoeterwoude brewery entered the last phase of implementation and aims to gain the next award in 2016.

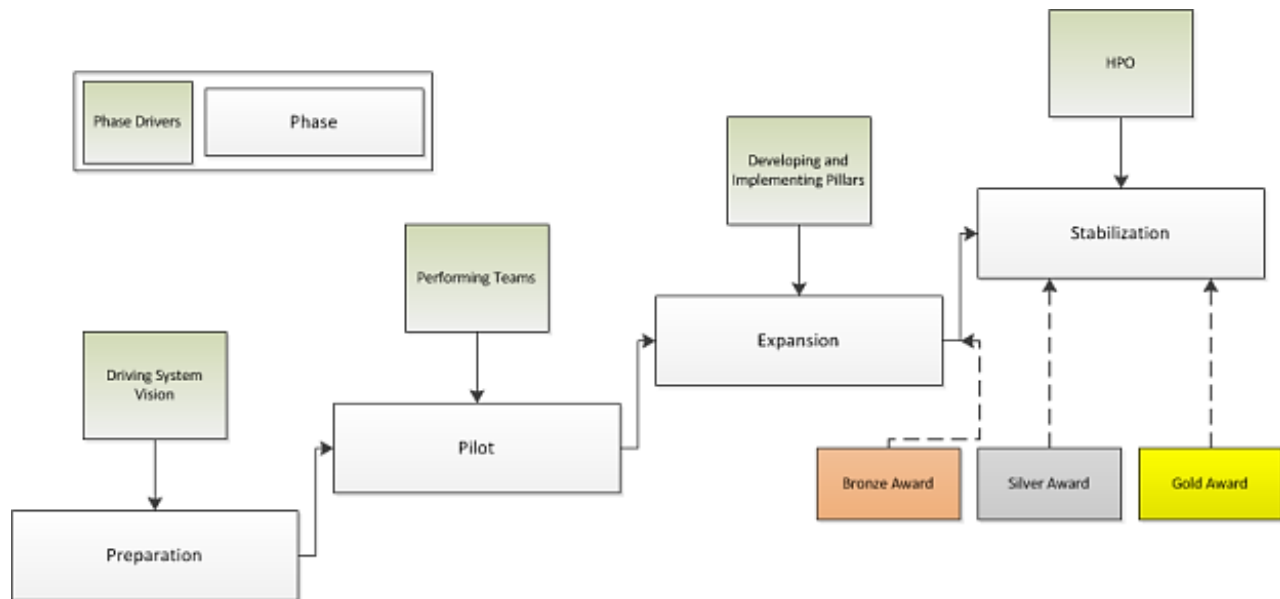


Figure 19 - TPM Implementation route at Heineken in general

In the implementation phase of TPM, a lot of progress has been made. However, looking at the gap analysis made by the TPM department, a number of steps have to be taken to achieve World Class Operations Management. The ongoing implementation of TPM brings forward a number of implications on its own. Its goal is to make a shift in working culture towards improving the production process with the entire organization. Therefore all employees have to be involved. How this human factor is incorporated is closely related to the overall success or failure of the TPM program (Ahuja & Khamba, 2008b; Cooke, Bosma, & Härte, 2005; Farris et al., 2009; Ng, Goh, & Eze, 2011; Rodrigues & Hatakeyama, 2006; Willmott & McCarthy, 2001). The HPO driver of the last phase is derived from the High Performance Organization framework, which describes the traits of highly competitive organizations (Waal, 2007). The main success factors of this theoretical framework are described as: quality of management, openness & action orientation, long-term orientation, continuous improvement & renewal, and quality of employees.

5.1.3. Gap Analysis

In Section 5.1.1 a general framework of continuous improvement strategies is developed and in Section 5.1.2 the continuous improvement strategy of Heineken, Total Productive Management is analyzed. This section will provide an overview of the gap between the two, using the developed framework. First, it is interesting to look whether the general findings for barriers and opportunities for CI strategies have an

impact on Heineken’s TPM. The general barriers and critique can be summarized in the occurrence of resistance to change and a lack of addressing company unique characteristics. Resistance to change can be caused by: (i) Not feeling valued and lack of organizational communication, (ii) Work stress (not enough time to act), (iii) Non-commitment of superior staff, (iv) Inappropriate performance measurement, or (v) Cultural barrier. Lack of addressing company unique characteristics can occur in the form of not addressing formal/informal policies and values, and secondly by not addressing how managers are measured and rewarded for improvement.

Second, it is interesting to look how TPM at Heineken can be compared to the developed framework. Table 3 gives an overview of this application. The critique on the strategy in this case has to be interpreted as possible threats, instead of critique. A thorough analysis has not yet been done at this point.

Strategy	Total Productive Management
<i>Theory</i>	Maximize Equipment effectiveness and minimize waste
<i>Focus</i>	Machine condition, waste and quality
<i>Assumption</i>	By training employees and preventive maintenance a mind-shift in the working culture can be created
<i>Effect</i>	Creating this working culture in which losses are not accepted and processes are structurally improved. Good processes turn into good result
<i>Critique</i>	Analysis of the system as a whole in terms of throughput and its constraints not addressed thoroughly. Chance for cultural resistance of change, lack of organizational communication, use of inappropriate performance measurement

Table 3 - Total Productive Management applied on the CI strategy framework

When looking at the threats, opportunities lie in analyzing the total production line, looking at the total throughput and its constraints (following the Theory of Constraints). Also, resistance to change, lack of communication or an inappropriate performance measurement system might be present. If that is the case, solutions can be found to overcome these problems. Last, it appears that at Heineken dealing with these specific challenges is not the highest priority, which is understandable. Safety, quality, cost and performance are more important in this aspect. However, Heineken is a very open organization where communication is direct. Next to that, the organization is in place to cope with these challenges. The identified threats are however very relevant for the organization.

Concluding, looking at the Continuous Improvement strategy of Heineken, one opportunity and three threats have been identified. The opportunity arises because TPM at Heineken is built up from Lean, Six Sigma and Total Productive Maintenance. In the TPM methodology the production process and its optimal flow are not analyzed on a periodic basis. Applying the tools used in the Theory of Constraints, might provide a new insight in the performance of the production line. The identified threats are a potential lack of organizational communication and a chance for a cultural resistance to change. In Paragraph 5.2 these three threats are further investigated by analyzing the organizational characteristics of the packaging department.

5.2. Organizational Structure

Now it is clear in what way Heineken continuously improves its operational performance, it is time to look at the environment this all takes place. In this paragraph the organizational structure of Heineken will be analyzed, based on an analysis of the corresponding theory. This analysis will provide insight in the dynamics that are present at the organization. Based on this analysis propositions will be formulated that will be tested in Chapter 7. Figure 20 illustrates the relation of this paragraph to the other research subjects.

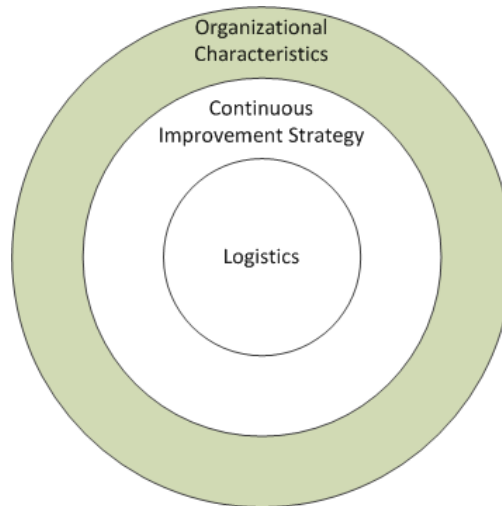


Figure 20 - Relation of research subjects, focus on Paragraph 5.2

5.2.1. Organizational Structure in theory

When looking at organizational structures, the founding literature is written by Henry Mintzberg. His 'structures in fives' gives a general overview of all structures possible in organizations (Mintzberg, 1980). Organizations are characterized on the basis of their key coordinating mechanism (such as direct supervision or standardization), their design parameters (such as unit size or decentralization) and their contingency factors (such as age and environment).

When applying this characterization on the Heineken organization, one outcome seems logical. Heineken is organized in the divisionalized form, being market-based, with central headquarters overseeing a set of divisions. First of all, in such an environment targets are set by higher (external) management. Because the department has to report to higher management, there is a need for more standardization. Mintzberg states that because these targets are operational, data driven and consistent in the entire organization, the divisions (in this case, the packaging department) must be machine bureaucracies. Zooming in on this machine bureaucracy, Figure 21 illustrates this organizational structure. The basis shows large-sized units in the operating core. Decision power is centralized and there is a sharp distinction between line and staff. Above all, this type of organization relies on the standardization of work processes and formal communication is preferred. In short, the more external control the more standardization and centralization, which are the key drivers of a Machine bureaucracy.

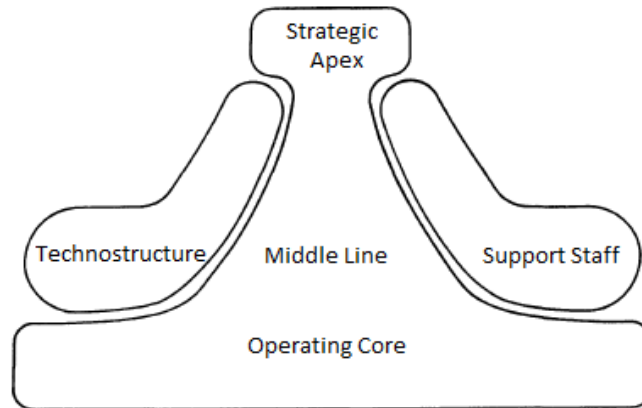


Figure 21 - Machine Bureaucracy structure according to Mintzberg (1980)

However, in the last two decades a lot of changes have been made in the organization. Firstly, due to far going automation of the production process the technical system is getting more complex. Mintzberg describes this distinction as the difference between a regulating technical system (routine work, enabling standardization) and a sophisticated or automated technical system. The latter would imply another configuration than a machine bureaucracy. Secondly, the workforce in the operating core has significantly been diminished. Per unit the operating staff sometimes only consists of two employees. There is a shift from standardization of work to standardization of skills. The amounts of training operators get increases significantly in the TPM methodology due to this fact. Operators are therefore making a shift from performing highly specialized routine tasks to being highly trained specialists, or professionals, which gives them considerable autonomy. The latter is actually one of the goals of the TPM methodology, as is explained in detail in Paragraph 5.1.2. Lastly, the same goes for the environment, which is getting more complex (due to new product introductions for example).

This shift from a typical Machine Bureaucracy towards a Professional Bureaucracy can be described as going from a Simple environment (predictable) to a more Complex one (not able to standardize). This would indicate a configuration shift from a Machine to a Professional Bureaucracy. However, the packaging department cannot be characterized as a fully Professional Bureaucracy. In a Professional Bureaucracy the operating core (professionals) controls their own work and maintains control of the administrative apparatus of the organization. Next to that, in this pure Professional Bureaucracy, the output cannot be standardized by performance control systems and the technical system is not automated. The packaging department can therefore be categorized as in between a Machine and a Professional Bureaucracy. It is interesting to look at the implications this might have.

In a Professional Bureaucracy information asymmetry between management and operating core is present. The consequence is that the principal-agent dilemma might be an issue (Bergen, Dutta, & Walker, 1992). The principal-agent dilemma occurs between agents (in the case of Heineken: shopfloor operators) and principals (at Heineken: team leaders and management). In such a situation the relation between agent and principle can be or become unstable.

The dilemma between principal and agent is based on four assumptions:

- Both are motivated by self-interest
- Principals are risk-neutral and agents are risk averse
- Principal's knowledge on agent's action on the job is neither perfect nor complete
- Agent has information that principal would like to obtain

According to the theory, problems arise when there are conflicting goals (Bergen et al., 1992). Because of the information asymmetry an unstable relationship can be formed. A situation might arise where agents take actions that might be non-desirable for principals. Because principals do not have complete information, mistrust can be a consequence. This of course is a situation that is not beneficial for both principal and agent.

5.2.2. Packaging department Organizational Structure at Heineken

A stakeholder analysis is performed in order to get an overview of the current situation and analyze where opportunities or barriers exist when implementing solutions (Appendix D – Stakeholder analysis). In the basis, the interests and objectives of the involved stakeholders align. Apart from possible different underlying motivations, all stakeholders share the same goals. There is a common goal for making the bottling line produce as good as it can. Managers have this goal because of the aim for a higher efficiency, thus profit. Operators on the other hand are motivated by the fact they can control the process and there is thus a lower need for reactive work. The only difference in this aspect can be found in the dedication of the stakeholders. Operators appear to be the only non-dedicated stakeholders. However, the cause of this is not based on resistance, but rather on the lack of believe that proposed solutions can solve the problems they perceive. So, while the goals are the same, they are perceived to be not aligned. As seen in the previous paragraph, conflicting goals may cause the principal-agent dilemma.

The second observation is that communication and standardization could help solve the problems perceived by multiple stakeholders (among others installation manager and operators). The cause of this is that operators and management do not always speak the same language. Where operators signal and communicate symptoms of process failures (recurring and significant ones), management expects to be notified about root causes of these failures and sustainable solutions for them.

Third, when looking at the important resources the different stakeholders possess, it can be seen that operators do have a unique position in the organization. They are the only ones who have the specialized information about what actually happens on the shopfloor. When looking at the continuity of the organization, the operators have the longest lifespan as employees in the brewery. Team leaders and rayon managers change jobs every 2 to 4 years. Operators can stay with the company up to 30 years. This makes them the most stable assets in the company and critical for structurally improving the system in the long term.

Lastly, there are a number of subjects where management and operators have a different perspective on: in-company communication, process control, tools to analyze and improve processes, change in the organization and personal goals. Table 4 provides an overview of these differences. This table is obtained by shadowing operators and management and discussing the topics.

	Communication	Control	Tools	Change	Goals
<i>Management</i>	Formal communication (about defects) through official documentation and methodology (TPM)	Low variability in output performance. Higher control means higher predictability	TPM methodology, based on finding root-cause for everything. Even the smallest defects. Data-based analysis	Change is positive, it brings innovation and everybody benefits	Company goals: Standardized KPI's are measurable and reflect overall performance. These must be maximized.
<i>Operator</i>	All communication quick and simple. Face-to-face, using e-mail or calling	Being owner of the process instead of being process led. High MTBA means lower work pressure	Tacit knowledge-based analysis. E-mail and label to alert symptoms. Complex analysis is for others	Change means more work through adoption period. Experience shows examples of failures	Personal goals: Lower amount of work, higher satisfaction and appreciation of work done.

Table 4 - Overview of different perspectives from Management and operators on certain subjects

The different view in communication is crucial in the relation between operators and management. For example, when an operator notices a recurring breakdown on a machine he is working on he will most likely write a label and put it next to the machine. This label contains a description of a machine malfunctioning in a certain way. In addition the operator can let a team leader know with an e-mail or face-to-face, and this way the malfunction is reported. Management however, has no useful information to act on, because in order to resolve the malfunction a lot more information is needed. The consequence is that management will not act on the information provided by the operator. This may cause the operator to not provide the information, when facing a similar situation. In this situation, operators do not feel like they get listened to and management has too few information to act on.

Control can be defined in several ways, depending on the perspective taken. Kathleen M. Eisenhardt (1985) notes that there are five (sometimes conflicting) different views between organizational and operational approaches on control: on costs, rewards, social control, role of information and uncertainty. At Heineken two distinct perspectives can be seen. Management desires a predictable process, with a steady output that is created with a high efficiency. An operator however sees control in a more detailed level. During work an operator wants to be in control of the process, because otherwise the process will control the operator. The higher the MTBA is, the more time the operator has to proactively maintain and clean. The lower the MTBA is, the more an operator is busy with reactive solving issues.

Driven by the board of directors, management is proactively using and pushing to use the TPM methodology and the corresponding tools. When looking at improvement projects the methodology assists in finding all root-causes, from the largest breakdowns to the smallest defects. In order to solve a problem, data has to be acquired from the database and the shopfloor. Operators however, aim to solve

problems based on experience or intuition. When an analysis appears to be too complex, the common believe is that other employees should take care of it.

With the introduction of TPM and the drive to improve efficiency, operators perceive change in a different way than management does. Due to the continuous reductions in workforce, operators appear to have a low incentive to reduce the workload in their working area. This is because if one FTE can get reduced, somebody might lose their job. Next to that, change means more work through an adoption period. Experience has shown examples of failing implementation attempts (TPM has been tried before). Operators are therefore a bit reluctant to invest time into something that might go away again. Management is on the other hand always looking for change, for it might bring something positive and might prevent the organization to stop improving. Stagnation means regression.

As showed in the stakeholder analysis, the goals of operators and management align. However, the underlying goals are quite different. In contrast to management, operators are not incentivized by reducing costs, optimizing production, increasing OPI or other KPI's. Increasing MTBA however, is a strong incentive. Increasing that lowers need for assists, so less work. Being in control of process instead of being led by process is a strong motivation.

In conclusion, operators are the only non-committed stakeholder in terms of continuous improvement. This is actually counter-intuitive, because for operators, TPM could provide a tool for achieving multiple goals. By using standardized ways of communicating, management will be able to recognize and value their work. By getting training and more responsibilities, operators can work towards job security (getting more valuable). By being in control through the methodology (leading the machine instead of being led by it) work will be easier and more rewarding.

5.2.3. Gap Analysis

In Section 5.2.1 a general overview of organizational structures is provided and in Section 5.2.2 the organizational structure of Heineken's packaging department is analyzed. This section will provide an overview of the findings of this analysis and formulate propositions that will be tested in Chapter 7.

Looking at the theory on organizational structures it can be said that Heineken's packaging department is neither a typical Machine Bureaucracy, nor a typical Professional Bureaucracy. Due to the shift between the two configurations the principal-agent dilemma can be a problem within the Heineken organization. The premise on which problems arise is when there are conflicting goals between operators and management. The stakeholder analysis showed that there are actually no conflicting goals. However, the perception of these goals appears to be different between operators and management. The expectation is therefore that the principal-agent dilemma causes problems within the Heineken organization. The assumption is that operators are hesitant to use the TPM tools pro-actively, because they perceive the tools to be not in line with their personal goals.

5.3. Conclusion

The aim of this chapter is to formulate propositions that can be tested in Chapter 7. Once tested, these propositions can answer the research questions of this research. So, the organizational structure and continuous optimization strategy are compared to theory and the relevant findings are translated into propositions. After reviewing Total Productive Management at Heineken compared to the main continuous improvement strategies in theory, it is found that there are opportunities in using the tools presented in the Theory of Constraints. Since this theory focuses on a whole system analysis, rather than on details, this perspective is expected to provide new insights for Heineken in terms of improving operational efficiency. The identified threats that can cause a lower operational efficiency are a potential lack of organizational communication and a chance for a cultural resistance to change.

When looking at the organizational structure it is important to take into account the different perspectives between management and operators. From the theory follows that in order to improve the operational efficiency in a structural way, it is essential to communicate with operators in such a way the new approach aligns with their goals. That means selling the methodology to operators in terms that operators relate to. For example, investing time in an improvement project now will provide you with more time in the future. In other words, that means showing operators the potential and true goals of TPM. One of the most important means the organization has for this is the Workplace Organization (WPO). The goal of this weekly meeting is to bring management and operators together in such a way management can support operators to perform the best they can. In this meeting operators are in the lead. This meeting provides opportunities for significantly improving communication in the organization.

The propositions that follow from the analysis of the organization of Heineken's production process are as follows:

- Applying the Theory of Constraints provides a new perspective for Heineken and will improve the operational efficiency
- A lack of organizational communication and a cultural resistance to change prohibit the operational efficiency to improve
- Convincing operators based on their personal goals and needs will improve how well TPM-projects are executed

6. Performance of Production Process

In the previous chapter the organization of the packaging process is analyzed. Propositions have been formulated that form the basis of answering two research questions. In this chapter the focus will lie on how well the packaging process performs in this environment. The aim is to analyze the current state of the packaging process by looking at company data. By doing this the last research questions can be addressed: How is the operational efficiency affected from a logistical point of view? In paragraph 6.1 the current operational performance is analyzed. The research zooms in on the bottleneck of the production process in Paragraph 6.2 and a conclusion is made based on the findings in Paragraph 6.3.

6.1. Operational Performance Analysis

In order to analyze the operational performance of Heineken's packaging process, it is necessary to look at the current state of the logistical system. Figure 22 illustrates the relation of this chapter to the other research subjects.

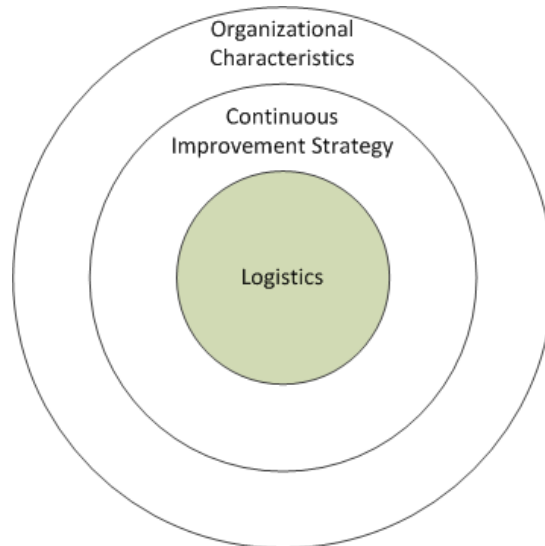


Figure 22 - Relation of research subjects, focus on Chapter 6

During a six month period, the production process and its performance are analyzed. The first step is identifying the bottleneck, because the losses on this machine have the biggest impact on the overall performance of the process (Chiang, Kuo, & Meerkov, 1998; Hopp & Spearman, 2011; Kuo, Lim, & Meerkov, 1996; Wang, Zhao, & Zheng, 2005). Heineken's philosophy regarding production line design is described by (Härte, 1997). In this design, the so-called V-graph is the basis for optimal line efficiency. As can be seen in Figure 23, the machines before and after the slowest (often most expensive) machine are designed to be faster. The slowest machine determines the output rate of the total line and is called the bottleneck (Hopp & Spearman, 2011).

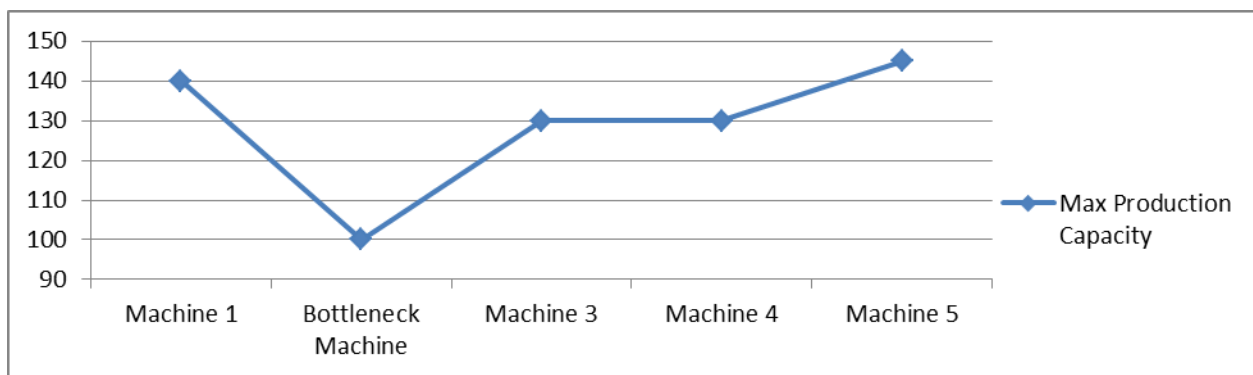


Figure 23 - V-graph design production line example (maximum production capacity per machine)

The first step in identifying the bottleneck is determining the right definition for the term bottleneck, as applied to the case of Heineken. The definition of bottlenecks in literature can be divided into two categories: Performance in Processing based and sensitivity based. PIP based definitions focuses more on real-time performances and the latter pays more attention to potential improvements (Wang et al.,

2005). When looking at the sensitivity of machines, this production line can be categorized as a serial Bernoulli production line (Chiang et al., 1998). Bernoulli based production lines are characterized by relative small down-times, where a continuous flow is the goal. In this type of production line the production rate can be defined by a single parameter: number of bottles produced per time unit. Looking at the KPI OPI NoNa, an average score around 60% (as seen in Paragraph 4.5) indicates that factors like manufacturing starvation, blockage and breakdowns are crucial in this analysis. Therefore only looking at production rate might not give a satisfactory explanation. In this research two definitions of bottlenecks will be explored. The first one is based on Performance in Processing and described by (Hopp & Spearman, 2011). The second is sensitivity based and described by (Kuo et al., 1996). Hopp and Spearman (2011) state that: the machine with the highest long-term average utilization is the bottleneck of the process and compute utilization as follows:

Equation 2
$$Utilization = \frac{Arrival\ Rate}{Effective\ Production\ Rate}$$

Here, the arrival rate is calculated as the amount of bottles produced per time unit and where the effective production rate is defined as the maximum average rate at which the workstation can process parts, considering the effects of failures, set-ups and all other detractors that are relevant over the planning period of interest. Figure 24 and Figure 25 illustrate the outcome of the utilization based bottleneck analysis of production line 81. Important to note is that only the machines that are part of the serial process are included. Since there are essentially two serial processes (for producing 6-and 24-pack and for producing 12-pack), both are displayed. The outcome corresponds with the design of the production line, based on the above mentioned V-graph philosophy. The filler is in both serial processes the bottleneck according to the utilization based definition.

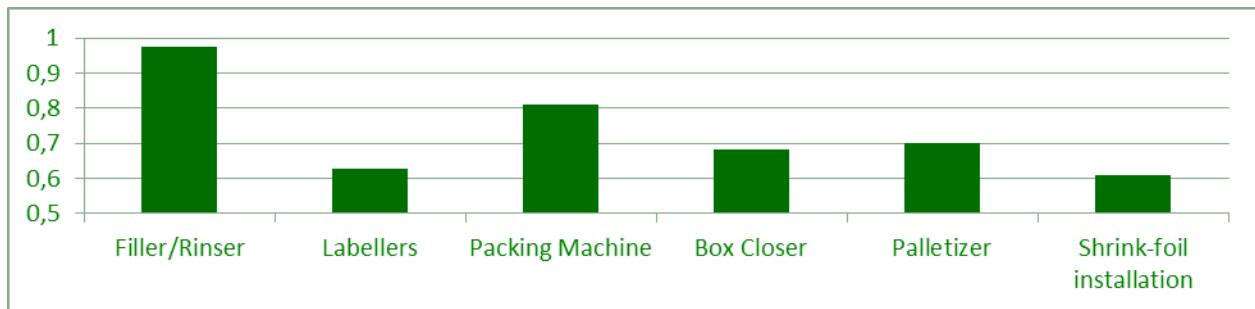


Figure 24 - Utilization of Heineken packaging line 81 producing 6-/24-packs

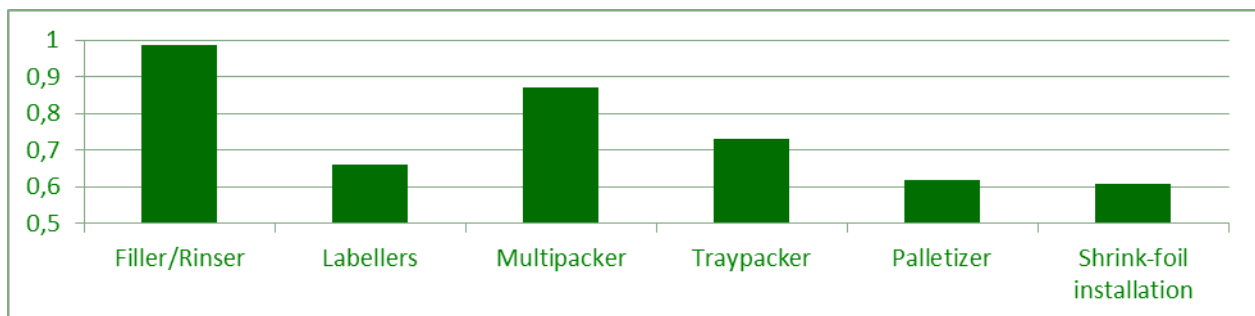


Figure 25 - Utilization of Heineken packaging line 81 producing 12-packs

The sensitivity based approach described by (Kuo et al., 1996) states that a machine is the bottleneck if the sensitivity of the system's performance index to its production rate in isolation is the largest, as compared to all other machines. In other words, the authors compare the performance of the entire production line to the performance of the individual machines, as if they were in isolation. They offer a simple and systematic tool for finding this bottleneck, based on manufacturing blockage and starvation. Where machine m_i is said to be **blocked** during a time slot if buffer b_i is full at the beginning of this time slot, and m_{i+1} fails to take a part from b_i at the beginning of this time slot and where machine m_i is said to be **starved** during a time slot if buffer b_{i-1} is empty at the beginning of this time slot. The bottle identification rule works as follows: looking at machine m_i , if its amount of blockage is larger than the starvation of machine m_{i+1} , the bottleneck is downstream of machine m_i . If the starvation of machine m_i is larger than the blockage of m_{i-1} , the bottleneck is upstream of machine m_i .

In Appendix E3 – Bottleneck analysis model outcomes this bottleneck analysis is performed. It can be concluded that there is a distinctive second bottleneck to be found using this method. Following the identification rule in both the 6-pack and the 12-pack process a machine can be identified that fits the description and is not the Filler. Both the Multipacker and the Packer machine have a lower blockage than the starvation of the palletizer and no higher starvation than the blockage of the labelers. Looking back at the V-Graph design of the line, the findings of a second bottleneck can be illustrated by looking at the isolated production rates. Equation 3 displays how the isolated production rate is calculated. Production, starvation, and blockage time refer to time the machines are in a certain state (see Paragraph 4.4 for a detailed description). Starvation and blockage prevent a machine from producing due to breakdowns upstream and downstream of the machine respectively. By including production, starvation and blockage time the isolated performance can be analyzed. In other words, looking how good the machines perform when only taking into account production loss caused by the machines themselves.

$$(Production\ time + Starvation\ time + Blockage\ time)(hour) * Maximum\ Capacity \left(\frac{bottle}{hour}\right)$$

Equation 3

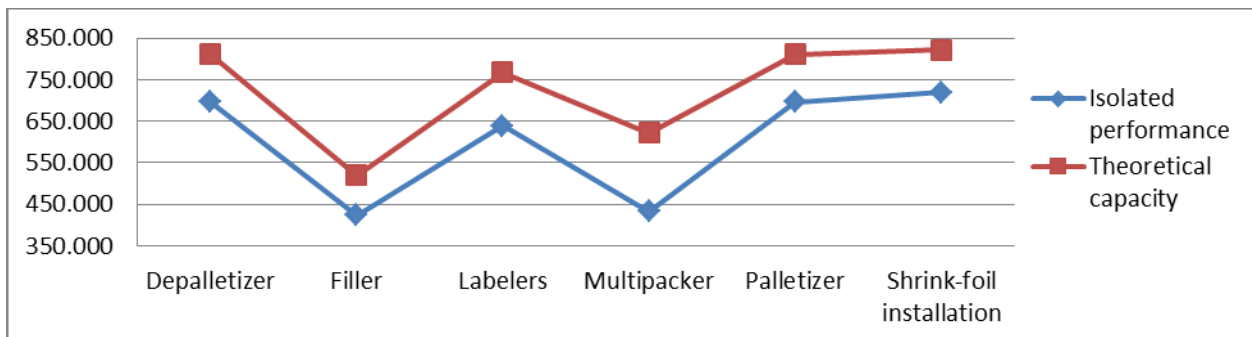


Figure 26 - V-Graph theory compared with isolated performance line 81 Multipacker

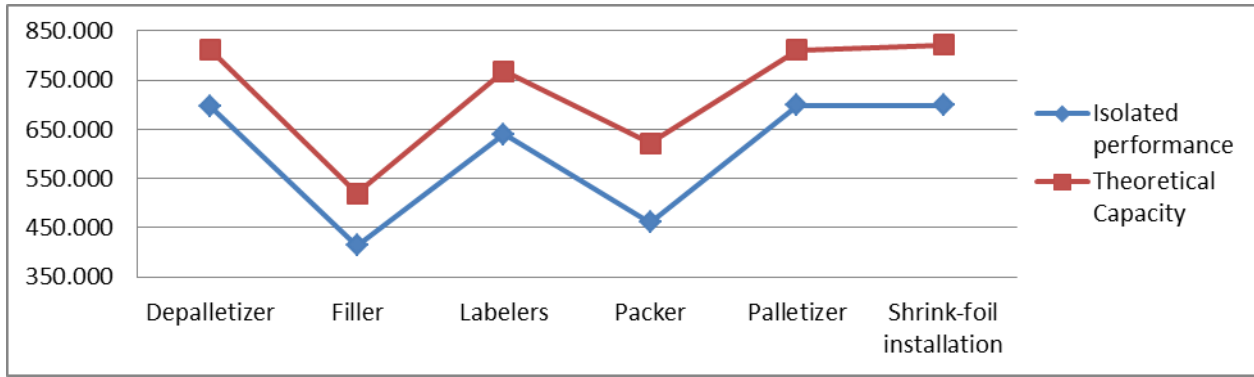


Figure 27 - V-Graph theory compared with isolated performance line 81 Packer

Looking at Figure 26 and Figure 27 the findings are illustrated by comparing the theoretical capacity (line design) with the isolated performance. The designed capacity difference between the filler and the packers is 102,080 bottles per shift. Looking at the isolated performance the difference between the filler and the Multipacker and Packer has shrunk to 10,010 and 46,750 respectively. The filler can produce 65,000 bottles an hour, so the 10,000 bottles difference for the Multipacker can be considered as very small. For the Packer the situation is a bit more complex, since it has to deal with starvation from a side process of 4 serial machines that deliver empty boxes. Due to this starvation, the actual isolated performance rate of the Packer is estimated to be significantly lower than depicted in Figure 27. Because no distinction is made between starvation from the main process and the side process in the Heineken database, this actual performance could not be calculated. Using the tools provided by the Theory of Constraints, it can be seen that there is in fact a hidden bottleneck in the production process. According to the theory the next step is to remove these constraints. Paragraph 6.2 will analyze the found hidden bottlenecks in more detail.

6.2. Detailed Bottleneck Analysis

Heineken's management operates, based on the knowledge that the filler is the bottleneck of the packaging process. Because the two identified machines are not perceived as bottleneck, they have not been analyzed as such. This paragraph will focus on analyzing the Multipacker and the Packer as bottlenecks and finding what causes the production loss on these machines. For each machine four causes for loss will be discussed and analyzed: Blockage, starvation, speed loss, and breakdown. In Table 5 and Table 6 a breakdown is displayed of these major production losses of the Multipacker and the Packer machine. This breakdown is based on a daily average loss of production time over the period 2-1-2014 to 21-3-2014 and is in minutes.

12-pack n=61	Mean	Stdev
Blockage	50.87	40.96
Starvation	18.32	16.89
Breakdown	37.89	33.43
Unknown	8.94	7.93

Table 5 - Causes of production loss in minutes and percentage for Multipacker

6/24-pack n=122	Mean	Stdev
Blockage	44.44	43.55
Starvation	26.84	28.14
Breakdown	31.82	20.70
Unknown	6.98	11.09

Table 6 - Causes of production loss in minutes and percentage for Packer

In Appendix F – Breakdown causes, a Pareto overview can be found of the causes for the breakdown losses. For the Multipacker, a large part of the losses caused by breakdowns are material related. This is partly an external source (suppliers are involved continuously) and a project is already running to cope with this. For the Packing machine, a big part of the breakdowns is caused by falling bottles. For this problem there is also a project team present.

Speed loss in machines other than the filler is not taken into account in the Heineken database (MES). However, as machines do not change speeds from full capacity to a stop instantly, speed loss occurs. Next to that, machines can be manually or automatically changed in production speeds, lower than its maximum. As can be seen in this Pareto overview for both the Multipacker and the Packer machine, the frequency of breakdowns is fairly high. If that is combined with all the times the machines face starvation and blockage, this amount of speed loss can be expected. It is difficult to focus improvement on just speed loss, since it is a result rather than a cause. However, it should be taken into account that when diminishing the frequency (not duration) of breakdowns, starvation or blockage the effect is larger due to a lower speed loss (i.e. can be a significant improvement). The Multipacker can only have starvation due to a lack of bottles or a lack of manually put in boxes. The first is not interesting for this analysis, since starvation should be considered as a preferred circumstance. This means that the machines downstream of the bottleneck machine create room for the bottleneck to produce. The second cause of starvation has no big impact compared to the other causes. Looking at the Packer, the amount of starvation is significantly larger. This is caused by the four machines that feed empty boxes to the Packer. This ‘mini-production line’ has a high relative dependency between the machines due to a small buffer capacity.

Most interesting in this analysis is the relatively large amount of blockage of both machines. In the bottleneck analysis can be seen that both machines have a higher utilization than the machines downstream of the production line. Because of that, it is not expected that the amount of blockage is this high for both machines. An analysis is made to locate the source of this blockage and can be found in Appendix G – Blockage cause analysis. Based on this analysis a number of conclusions are made. Despite a large buffer, a significant amount of blockage is caused by the Palletizer and Shrink-foil installation. Unlike the breakdowns in the Packer and Multipacker machines or the starvation on the Packer machine, the breakdowns causing blockage have a low frequency and a high duration (Appendix G3 – Pareto breakdown analysis). Despite the higher production capacity of the Palletizer and Shrink-foil installation and a significant buffer, the high duration of the breakdowns causes big amounts of blockage at both the Multipacker and the Packer machines.

6.3. Conclusion

The goal of this chapter is to determine what the current state of the operational performance of production line 81 is and contribute to answering the question: How is the operational efficiency affected from a logistical point of view? With an average output (OPI NoNa) of around 60%, the data shows that there is room for improvement. In order to find what affects the operational efficiency from a logistical point of view, the research showed that looking at the line’s bottleneck provides a good insight. By using two methods it has been shown that there are in fact two bottlenecks, instead of just the one designed bottleneck. This fact undermines the V-graph design of the production line and

strongly increases the sensitivity for breakdowns on these two machines in respect to total production loss. Due to the lack of a bigger production capacity of the two machines, the buffer before the machines is filled quickly and scarcely gets emptied during a shift. In the case of multiple breakdowns or longer breakdowns, this has immediate consequences for the designed bottleneck (filler) in terms of blockage. Blockage on the filler machine is directly lowering the performance indicator OPI NoNa. The losses with the biggest impact are the ones that are inflicted upon the found second bottleneck. For the Multipacker they are breakdowns involving material (external source) and blockage caused by low frequency, long duration breakdowns on the Palletizer and Shrink-foil installation. The latter also has a big impact on the Packer, together with starvation caused by the feed of empty boxes and breakdowns by falling bottles. The production time lost is actually larger than the amount shown in the database (MES), due to the speed loss caused by slowing down and starting up again. Next to that, the starvation of the Packer machine is still a big issue. Improving this should be given priority. But last and foremost, the blockage caused by low frequency, long duration breakdowns of the Palletizer and Shrink-foil installation should be solved. For this research, four projects are started to find and solve the causes of these breakdowns. These projects are described in detail in the next chapter.

7. Intervention

In Chapter 5 two propositions have been formulated on how Heineken's organization might affect operational efficiency: applying the Theory of Constraints will provide a new perspective for Heineken and improve the operational efficiency, a lack of organizational communication and a cultural resistance to change prohibit the operational efficiency to improve, and convincing operators based on their personal goals and needs will improve how well TPM-projects are executed. In Chapter 6 an analysis on the logistics of the production process showed that there is a second bottleneck in the production process. The proposition is therefore that performing TPM-based projects on this bottleneck will directly improve the operational efficiency. In this chapter the input of the previous two chapters is used to organize and execute four intervention projects that are expected to improve the operational efficiency. In Paragraph 7.1 the projects are explained in detail, in Paragraph 7.2 the result of these interventions is described. In Paragraph 7.3 the propositions of Chapter 5 & 6 will be reflected upon. Last, in Paragraph 7.4 the three research sub-questions are answered.

7.1. Intervention projects

In order to find and solve the causes for the identified sources of loss, four Minor Stoppage Analysis projects have been executed (MSAS-projects). These projects are part of Heineken's TPM methodology and are standardized throughout the organization. Three project teams have been formed, including operators of different teams, a member of the supporting staff and a project team leader. The general build-up of these projects is as follows: (i) Data collection, (ii) Determining Failure Mode, (iii) Root Cause Analysis, (iv) Countermeasure(s), (v) Standardize. So first a defect is selected and described (for example: bike has a flat tire and cannot ride). Secondly, in order to not fix a symptom but the disease, the root cause has to be found (piece of glass in tire). Once this cause is determined, a permanent solution can be proposed and implemented (check all possible pieces of glass, remove the glass, and fill the hole). Following implementation the after-care is important (teach bike rider to avoid glass). The solution has to be checked on how well it fulfills its purpose in the long run. Here, one project will be explained in detail including the used analysis sheet template (template in Figure 29 on next page). The project is carried out on the Palletizer machine, where a collection of long duration short stops was signaled by operators and was found in the data reporting system as well. The involved short stop is reported as an error in the layer length-control of the machine. The data collection (step 1) showed that the stops had four different errors that were reported in the database (MES). On average, the stop occurred 2.33 times per 24 hours and lasted for 432 seconds. In step 2, the cause that actually stops the machine is described and analyzed. Boxes filled with bottles arrive at the Palletizer and are formed by two robot arms into patterns. When such a pattern is not formed correctly, a box will stick out and block the machine, causing it to stop (see Figure 28). The root cause analysis (step 3) showed that the robot arms are not programmed correctly. This results in the robot arms not leaving enough space between the boxes, causing them to hit each other and turn. The proposed counter measure (step 4) was to increase the space between the boxes in the software program. Lastly, this adaption has been standardized over all programs in this Palletizer, and the Palletizer of the neighboring production line 82.



Figure 28 - Picture of blocked palletizer machine due to wrong pattern


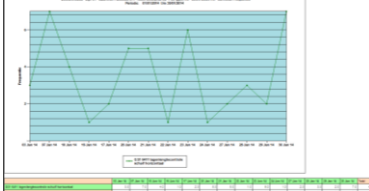
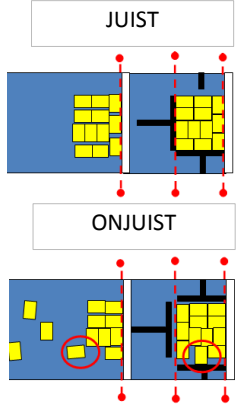
Minor Stop Analysis Sheet							
D a t a c o l l e c t i e	1 Lijn, machine en product: 8, Palletiser 81, flessen			Team: Floris Vijfhuizen Steffan Heemskerk			
	Korte stops: Stapel verschoven Storing: Lagenlengtecontrole schuif horizontaal Frequentie: 49 Duur totaal: 352,4 min 			Deelstorings / failure modes van de gekozen korte stop <div style="border: 1px solid green; padding: 5px; margin-bottom: 5px;">GS1 6411 lagenlengtecontrole schuif horizontaal</div> <div style="border: 1px solid green; padding: 5px; margin-bottom: 5px;">GS1 6511 schuif verticaal vertikal gebotst</div> <div style="border: 1px solid green; padding: 5px; margin-bottom: 5px;">GS1 6611 Laag voorgroepering onjuist</div> <div style="border: 1px solid green; padding: 5px;">GS1 6711 storing trajectregistratie verstelling re</div>			
Gekozen deelstoring / failure mode: GS1 6411 Lagenlengtecontrole schuif horizontaal			Storingsduur (sec): 432	Huidig aantal / 24 uur 2.33	Doel aantal / 24 uur 0.2	Start stap 1: 30/01/2014	
F a i l u r e m o d e	2 Omschrijving werking: Dozen komen vanaf de twee roboboxen op formeertafel 1 terecht waar ze tegen gehouden worden door een plaat. Doordat ze tegen worden gehouden en in de roboboxen goed zijn gedraaid/geplaatst wordt er een patroon gevormd op formeertafel 1. Dit patroon staat nog niet strak aaneengesloten.			Schets of foto werking: Tussen de dozen in op formeertafel 1 zitten spaties zodat de dozen elkaar niet op verkeerde plekken raken. Wanneer de spaties niet groot genoeg zijn gaan de dozen elkaar op verkeerde plekken raken. <div style="text-align: center;">  </div>			Start stap 2: 30/01/2014
	Parameters / afstelling:		Waarde / referentie:				
	Wat is er verbeterd:		Labels / OPL / referentie:				
	Failure mode omschrijving (één of meerdere failure modes): Een doos heeft een andere doos geraakt op een verkeerd punt			Huidige werkwijze om te detecteren, oplossen en restarten machine: Detecteren -> Storing GS1 6411 lagenlengtecontrole/ GS1 6611 Laag voorgroepering onjuist verschijnt in beeld. Oplossen -> Het patroon wordt goed neergelegd op de formeertafel. Restarten -> Machine wordt zonder te resetten herstart.			Start stap 3: 30/01/2014
H o o f d	3 Waarom 1 Spaties tussen de dozen zijn te kritisch	3 Waarom 2 Robokoppen plaatsen de dozen niet ver genoeg uit elkaar	3 Waarom 3 De robokoppen zijn verkeerd geprogrammeerd	3 Waarom 4	3 Waarom 5	4 Tegenmaatregel Patroon breder zetten zodat de spaties op formeertafel 1 groter zijn tussen de dozen	Implement datum: Week 7/8
	3 Deel						
S t a n d a a r d	5 Standaarden : (veranderingen in bijvoorbeeld SOP, CLT of OHP standaarden)			Horizontale expansie: (eventueel naar andere producten, machine of lijn) Alle pakketten op Palletiser 81 en 82.			Start stap 5:
							Datum gereed:

Figure 29 - Minor stoppage analysis sheet continuous palletizer breakdown

Following the first example, three other projects were executed. Table 7 below gives an overview of all four projects, their defects, root causes and implemented solutions.

Project	Defect	Root cause	Intervention
<i>Destacker blocks pallet</i>	When an empty pallet is transported crooked towards the palletizer machine, the pallet can be stuck underneath the destacking machine. When the pallet isn't removed before the next pallet is destacked, the machine will block the pallet and break down	Pallets were placed crooked by CS&L forklift drivers and machine software was not programmed correctly	Moving the entire deployment wall in such a way that drivers were forced to place pallets straight and letting mechanic reprogram the machine software
<i>Layer length- control (lagenlengte controle) Palletizer</i>	Group of failures that cause the palletizer to wrongly sort boxes for placing on a pallet, which caused long breakdowns	Machine software was not programmed correctly	involving machine manufacturer to reprogram machine software
<i>Empty Pallet Arrival Palletizer</i>	Unseen machine short stop. Because there is no differentiation between starvation due to lack of boxes and starvation due to lack of empty pallets, the latter is often noticed late	pallets were placed crooked by CS&L forklift drivers	moving the deployment wall, in such a way that drivers were forced to place pallets straight
<i>Pallet stopper Shrink-Foil Installation</i>	As a part of the Shrink-foil installation, two small pins are present to make sure pallets stop at precisely the right place. These pins could in some instances break the incoming pallets, instead of stopping them. The result is a big breakdown, where operators need crowbars to relief the pallets	The combination of small pins and weak pallets could cause the pins to break the pallets.	broadening the pins which spread out the force over a broader surface

Table 7 - Minor Stop Analysis-project overview

7.2. Intervention Results

The goal for carrying out the four intervention projects is to minimize the blockage on the Packer and Multipacker machines. That is done by implementing solutions for the low frequency, long duration breakdowns on the Palletizer and Shrink-Foil Installation. The implementation period is illustrated with two dotted arrows in Figure 30 below. The figure illustrates four major breakdowns that occurred on the palletizer machine. In the period after implementation two large breakdowns occurred, with duration of 80 and 162 minutes respectively. These two exemptions are left out of this overview, because they were caused by unique circumstances.

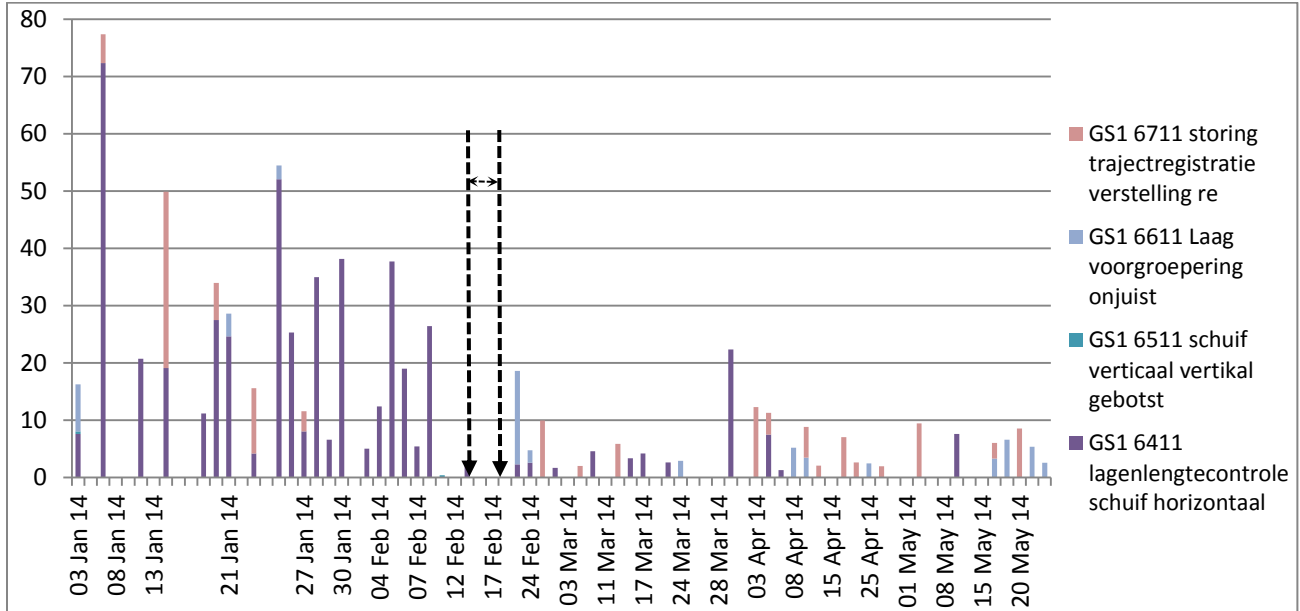


Figure 30 - Overview of downtime (minutes) caused by breakdown on Palletizer machine

The figure gives an indication that besides a structurally lower amount of breakdown time, the variance of the breakdowns appears lower. An overview of the impact the interventions had on the recurrence of the four breakdowns can be found in Table 8. Comparing the 36 days before and after the intervention, clear reduction in both mean and deviation can be found.

n=72 days	Before 15-02-2014	After 18-02-2014	Difference
Mean	24.28	7.87	↓-16.41
Standard Deviation	21.33	8.56	↓-12.77

Table 8 - Post-ante comparison of effect of intervention on Palletizer machine

Below, in Table 9 and Table 10, the overall performance of the Palletizer before and after intervention projects is compared, making a distinction in producing 12-pack and 24-pack respectively. Interesting to see is that by diminishing the impact of the four breakdowns, the mean of the overall breakdown of the Palletizer has diminished with 15 minutes and the deviation even with 40 minutes. This means that the main issue of the breakdowns on the Palletizer, low frequency high duration breakdowns, is diminished in a major way. The increase in starvation is marked red, but is not necessarily negative. Because the Palletizer is not a bottleneck machine, in a perfect situation it should experience as much starvation as it

its maximum capacity is larger than the machines upstream of the process. If anything, an increase in starvation actually indicates that the machine is performing better, compared to the upstream process.

12-pack <i>n=92</i>	Mean Before	Mean After	Mean Difference	Stdev Before	Stdev After	Stdev Difference
Blockage	23.14	17.49	↓-5.65	25.35	15.95	↓-9.39
Starvation	63.04	82.04	↑+19.00	51.99	38.30	↓-13.69
Breakdown	26.92	11.55	↓-15.37	61.24	20.39	↓-40.85
Unknown	6.47	1.73	↓-4.73	13.95	2.03	↓-11.91

Table 9 - Post-ante comparison of intervention projects on Palletizer machine, producing 12-pack

6/24-pack <i>n=340</i>	Mean Before	Mean After	Mean Difference	Stdev Before	Stdev After	Stdev Difference
Blockage	31.38	23.79	↓-7.59	30.86	25.04	↓-5.81
Starvation	55.07	72.31	↑+17.24	46.43	45.26	↓-1.17
Breakdown	25.16	13.84	↓-11.32	35.26	20.38	↓-14.89
Unknown	3.66	3.19	↓-0.47	10.04	6.19	↓-3.85

Table 10 - Post-ante comparison of intervention projects on Palletizer machine, producing 6-&24-pack

The next step is to see whether this major reduction in both mean and deviation also has the desired outcome, a lower amount of blockage on the Multipacker and Packer machines. In Table 11 and Table 12 the overview of this result is given, for the Multipacker and Packer respectively. An unexpected result is the increase in blockage for the Multipacker machine. An explanation for this follows from the major improvement in the amount of breakdown in the machine itself. When the machine is able to produce 25 minutes longer on average, the chance it has to wait for the downstream process increases. In Table 9 it can be seen that on average the Palletizer has 15 minutes less breakdown time. This is not in perspective with the 25 minute win in production time on the Multipacker. A positive result however is the major decrease of blockage at the Packer machine. The combination of the decrease in mean and deviation means that the process has gotten much better with respect to predictability and control. This, combined with a decrease in breakdowns (due to another improvement project on falling bottles at the Packer machine), improves the overall performance of the machine.

Multipacker <i>n=93</i>	Mean Before	Mean After	Mean Difference	Stdev Before	Stdev After	Stdev Difference
Blockage	37.76	39.97	↑+2.21	42.95	32.25	↓-10.70
Starvation	22.95	21.66	↓-1.29	23.13	19.18	↓-3.96
Breakdown	66.73	40.99	↓-25.74	36.29	37.79	↑+1.50
Unknown	18.50	8.29	↓-10.21	9.39	8.02	↓-1.37

Table 11 - Post-ante comparison of intervention projects on Multipacker machine

Packer <i>n=340</i>	Mean Before	Mean After	Mean Difference	Stdev Before	Stdev After	Stdev Difference
Blockage	49.21	34.21	↓-15.01	48.49	30.90	↓-17.59
Starvation	30.05	21.84	↓-8.21	30.63	23.21	↓-7.42
Breakdown	36.45	25.41	↓-11.05	26.98	19.35	↓-7.63
Unknown	10.99	5.99	↓-5.00	18.12	6.57	↓-11.56

Table 12 - Post-ante comparison of intervention projects on Packer machine

As analyzed in Chapter 6, these effects on the Multipacker and Packer machine should have a direct effect on the Filler machine as well. The prediction is that if the performance of the Multipacker and Packer machines increases, this will diminish the amount of blockage on the Filler machine in a major way. Table 13 and Table 14 give an overview of the performance of the Filler machine while producing 12-packs and 6/24-packs respectively, before and after the intervention projects.

12-pack <i>n=93</i>	Mean Before	Mean After	Mean Difference	Stdev Before	Stdev After	Stdev Difference
Blockage	107.88	85.22	↓-22.66	52.32	42.15	↓-10.16
Starvation	7.93	9.60	↑+1.67	9.88	10.16	↑+0.28
Breakdown	19.77	15.36	↓-4.41	26.94	19.77	↓-7.17
Unknown	2.27	1.18	↓-1.08	7.72	6.29	↓-1.43

Table 13 - Post-ante comparison of intervention projects on Filler machine, producing 12-packs

6/24-pack <i>n=340</i>	Mean Before	Mean After	Mean Difference	Stdev Before	Stdev After	Stdev Difference
Blockage	90.54	61.01	↓-29.53	52.32	42.15	↓-10.16
Starvation	12.38	9.94	↓-2.45	9.88	10.16	↑+0.28
Breakdown	22.02	16.37	↓-5.64	26.94	19.77	↓-7.17
Unknown	3.51	2.53	↓-0.99	7.72	6.29	↓-1.43

Table 14 - Post-ante comparison of intervention projects on Filler machine, producing 6/24-packs

A very clear improvement can be seen, while producing both the 12-pack and 6/24-pack. The amount of blockage has been diminished on average with 23 and 29 minutes respectively, while the deviation of the duration has diminished with 10 minutes. This is an important improvement, keeping in mind that improvements on the Filler machine have a direct effect on the performance indicator OPI NoNa. To put this in perspective, if on an 8 hour shift (480 minutes) the bottleneck machine is able to produce 30 minutes longer the OPI increases with around 6%.

The goal of the intervention projects was to improve the overall output performance. So lastly, Figure 31 illustrates the OPI NoNa of the entire production line 81. The black arrows indicate the implementation period of the projects, the blue line illustrates the realized output performance in percentage per week and the black line depicts a moving average per 12 weeks. The observed period after the intervention projects is two months. In this period the average OPI per week does not drop below 61% with an average of 65%. Table 15 gives an overview of the corresponding change in mean and standard deviation. It can be seen that both the mean and the deviation of the performance has improved. A lower deviation means that the process is more in control and easier to predict. The higher mean indicates a higher overall operational efficiency. Based on a statistical t-test it is found that the mean has significantly improved, on a 0.05 significance level (the details of the analysis can be found in Appendix B – Statistical t-Test Analysis)

<i>n=69</i>	Week 40-week 7	Week 7-week 21	Difference
Mean	58.61%	64.97%	↑+6.36
Standard Deviation	4.37%	2.74%	↓-1.63

Table 15 - Post-ante comparison intervention projects on the overall performance indicator OPI NoNa

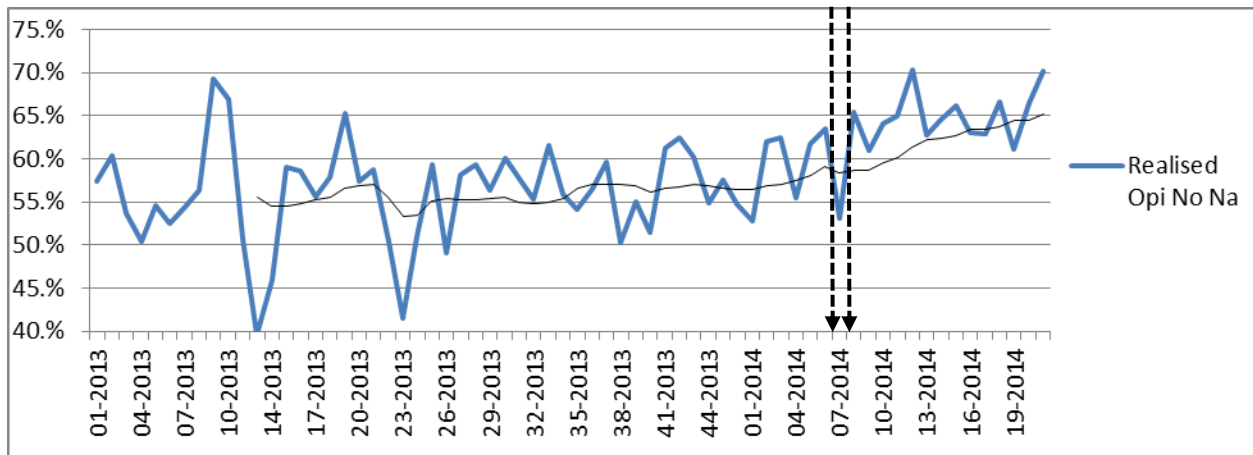


Figure 31 - Overview of the realized output performance (OPI NoNa) of production line 81

Besides a significant increase in mean, some side notes have to be made. As can be seen in Figure 31, the increase appears to start already a couple of weeks before the actual intervention projects. This is a result that can be explained by results that were described earlier in this paragraph, namely in Table 11 and Table 12. It can be seen that the amount of breakdown on these machines has dropped, as well as the amount of blockage. This is the result of other projects that were started, aimed to counter the status of the Packer machine being the bottleneck machine (amongst others a big project to counter the amount of falling bottles on the Packer machine). However, beside it not being projects carried out for the purpose of this research, they were started on the basis of the finding of this machine being a bottleneck. The combination of the two efforts is assumed to have the found effect. The effect on itself is nonetheless apparent, because the operational performance has significantly increased with 6.36 percent points. Heineken values a change in OPI at €18.145 per percent in non-cash savings per year. An increase of 6.36 could prove to be earning the company € 115.402 on a yearly basis in non-cash savings.

7.3. Lessons Learned

Besides the quantitative results, the goal of this research is also to look at the qualitative results of the intervention projects. The propositions that followed Chapter 5 and 6 have been tested during the execution of the intervention projects. In this paragraph the propositions are addressed.

Applying the Theory of Constraints provides a new perspective for Heineken and will improve the operational efficiency by performing TPM-based projects to solve identified constraints

The first part of the proposition was already tested in Chapter 6. A bottleneck-based approach for the entire production process is new and provided insights that were not identified. Most important in this aspect is finding a second bottleneck. Secondly, in this Chapter the result of applying the ToC is shown. Heineken's own TPM-based projects have been executed on crucial parts of the production process, identified with the ToC. In this chapter the results are analyzed. The operational efficiency has significantly improved, for which the basis is formed by applying the ToC. So, it can be said that the proposition is true. The most important aspect of the ToC for Heineken is how to assess production loss at a machine. Not every breakdown has an effect on the overall production output, but for other

breakdowns every lost minute is a minute production loss for the entire line. This perspective can help Heineken in prioritizing projects in order to optimize allocating resources.

A lack of organizational communication and a cultural resistance to change prohibit the operational efficiency to improve

During the period of working on the intervention projects a number of things were observed. When looking at resistance to adapting TPM and pro-actively using the tools, the reasons are not cultural. One of the most heard arguments for operators and team leaders to not apply the TPM-tools is that it takes too much time and it interferes with their day-to-day operations. A goal should be that operators know that solving problems is part of their day-to-day operations, not something extra. Most importantly, they should know that resources are available to execute these projects. An example of a resource can be hiring temporary employees to provide extra time for operators on certain shifts to work some hours on a problem they encountered. For support, the TPM-office and team leaders are available. Also, team leaders can involve more project members if the project becomes too complicated.

So, operators in general do not know precisely what is possible and how much support there is. Next to this the different TPM-tools and their differences are not clear. When to apply certain tools differs in the characteristics of the problem that has to be solved. The assumption that an MSAS-project has to be a big and complex project was heard often, which is of course not the case. If it is not clear for an operator what the available resources are, when to start a project and what the impact can be, reluctance to start a project is understandable. This knowledge gap has to be overcome by organizational communication. For starters, team leaders can be a driving force in instigating, controlling and guiding TPM-projects.

The proposition is therefore partly true. Heineken has successfully built an environment where change is possible and innovation is accepted. There is however some resistance to adapting this methodology. This can be overcome with specific organizational communication. Because everything is in place within Heineken to address this challenge, solving this is expected to happen in the short term.

Convincing operators, based on their personal goals and needs, will improve how well TPM-projects are executed

This proposition follows the expectation that operators perceive TPM-projects not to be in line with their personal goals. If this is true, the consequence will be that they are hesitant to pro-actively start these types of projects. The expectation is also that if operators can be motivated by linking the projects to their personal goals, this will increase their involvement and ownership. So, what does that mean in practice? It appears that operators perceive TPM as follows: the goal of TPM is to reduce the amount of work in total in order to operate with smaller teams, which poses a threat for an operator's job security instead of improving it. Filling in standardized forms feels like unnecessary extra administrative work, instead of a tool to analyze problems. Lastly, learning the new methodology requires time, which they perceive not to be available (as mentioned before). What does motivate the operators first is being in control of their process. That means not having to fix minor stops and breakdowns during the entire shift. Second, operators are motivated by being listened to by management. As described in Chapter 5, operators often indicate symptoms of problems to management, while management expects to be

briefed on root causes of these problems. So, despite efforts of signaling issues, the problems are not being fixed.

To anticipate the first struggle, the intervention projects have been selected by asking operators what short stops irritate them the most during a shift. This way, when the projects finished, the operators saw that the projects contributed to their personal goal, being in control of their process. Secondly, successfully communicating with management on issues that arise on the production line is difficult for operators. Therefore the projects were used as an example of communicating root causes of problems with the use of TPM-templates (an example is shown in Paragraph 7.1, Figure 28) contributes to that. Although operators were reluctant at first, the successful implementation of countermeasures provided useful arguments. Reflecting on the projects, the general consensus was that if projects will actually lead to implementing countermeasures, this is an absolute trigger to pro-actively start projects.

7.4. Conclusion

In this chapter the aim is to achieve two goals: (i) improve the operational efficiency at Heineken and (ii) test the propositions made in Chapter 5 and 6. Looking at improving the operational efficiency, it is shown that the output performance can be significantly improved by diminishing the blockage caused by the Palletizer and Shrink-foil installation. By using MSAS-projects on these machines for finding the root cause and implementing solutions this goal has been achieved. The KPI OPI NoNa has increased with 6.34 percentage points and the deviation of the indicator has diminished with 1.63 percentage points. If this major increase can be maintained in the future, this improvement could save the organization € 115,402 on a yearly basis in non-cash savings. This shows that using Total Productive Management is an effective tool for Heineken to structure its continuous improvement efforts.

Three propositions have been tested, on the Theory of Constraints, on cultural resistance to change and organizational communication, and on the link between motivation and execution of TPM-projects. The first and third propositions appeared to be true. The second proposition, on the lack of organizational communication and cultural resistance, appeared to be more complicated. A cultural resistance has not been found. If it exists nonetheless, the expectation is that its impact is lower than the found resistance, caused by something else. The found resistance is the result of different perspectives between management and the operational core. Therefore the mentioned organizational communication is not a cause of resistance, but rather a possible solution for it.

8. Conclusion and Recommendations

Based on the case study performed at Heineken, a thorough understanding of the packaging process of Heineken is obtained. With this knowledge the research sub questions can be answered, and based on that the main research question as well. In Paragraph 8.1 the answer on the main research question is given and in Paragraph 8.2 the sub questions are answered. Based on these conclusions, recommendations are given in Paragraph 8.3. The recommendations are divided in recommendations for Heineken specific (8.2.1) and for future research (8.2.2).

8.1. Conclusion based on main research question

The goal of this thesis is to answer the main research question, as formulated below:

How can large manufacturing companies identify causes of discrete production processes not performing in line with company goals?

In this research a three step approach is used. The first step is to zoom out from the logistic process and analyze the characteristics of the organization and the used continuous improvement strategy. By comparing the organizational characteristics with academic literature, strengths and weaknesses of the organization can be identified, and also the corresponding opportunities and threats. The used continuous improvement strategy is analyzed, for it is never flawless. Methodologies keep evolving and improving, and new theories are being developed and tested every day. Looking critical at the used improvement strategy will provide insight in missed opportunities and the importance of certain focal points in the organization. The second step is linking these findings to an analysis of the logistical process. It is important to determine how the operational efficiency is defined and how it is measured. Step one might provide a different perspective for analysis or focal points. In this step improvement projects can be selected and defined on an operational level. Step three consists of performing the selected improvement projects. It is important to incorporate the findings of step one into these projects. This way the findings in academic theory can be evaluated by testing in practice. This evaluation provides concrete feedback on the found causes of non-optimal performance of the production line. Combining these three steps will provide (i) a thorough analysis of the organization, (ii) identifications of barriers and enablers in the organization, and (iii) will present opportunities to improve the operational efficiency beyond the knowledge that is present in the organization. With the gained knowledge, step one can be repeated in order to create an iterative process for continuous improvement.

This approach is followed for the Heineken brewery in Zoeterwoude in a real life case study. It is shown that the approach can have significant results in terms of operational efficiency. The result can be summarized as follows. Based on a bottleneck analysis, following the Theory of Constraints, it is shown that the losses with the biggest impact on the total production line are found downstream of the designed bottleneck, signaling a hidden bottleneck. It is shown that the operational efficiency can be significantly improved by diminishing the amount of breakdown time in the machines downstream of this hidden bottleneck. By using TPM-tools root causes were found and structural solutions are implemented. The performance indicator OPI NoNa has increased with 6.34 percentage points and the deviation of this indicator has diminished with 1.63 percentage points. If this major increase can be maintained in the future, this improvement will save the organization € 115,402 on a yearly basis in non-cash savings.

This answer is a generalization of the findings in this research. The detailed findings are used to answer the research sub questions that form the basis of this conclusion. The three sub questions that are answered during this research will be elaborated upon in Paragraph 8.2.

8.2. Conclusion based on research sub questions

In order to answer the main research question, three sub questions have been formulated. The sub questions are answered based on the research performed during the case study at the Heineken brewery in Zoeterwoude. The questions are answered based on three steps: first, a theoretical analysis is made on the three subjects, second based on these analyses propositions have been formulated, and third these propositions have been tested in a real life case study. The general conclusions, drawn from these steps, form the basis for answering the main research question. In this paragraph, all the sub questions will be answered.

How does the used continuous improvement strategy affect operational efficiency?

It is crucial to analyze the continuous improvement strategy that is used, for it is never flawless. These strategies are the foundation for the structural improvement of the operational process in the long term. However, it is important to always be critical when applying these strategies. For they are designed to fulfill a general purpose, the ideal configuration will always have to be adapted towards the need of the company specifics. Fully implementing these strategies requires an integral shift in working culture in the entire organization.

The comparison between Heineken's Total Productive Management and other relevant continuous improvement strategies provided interesting insights. First of all, combining Lean Management, Six Sigma and Total Productive Maintenance provides a comprehensive and versatile base for the company to grow on. The larger part of critique, threats and weak points of the mentioned continuous improvement strategies are taken care of within the organization. The knowledge, resources and dedication of management inside the company provide a strong driver for the successful implementation of the methodology in the long run. However, opportunities for improvement are also identified. In the TPM methodology the production process and its optimal flow are not analyzed on a periodic basis. Applying the tools used in the Theory of Constraints provide a new insight in the performance of the production line, because this theory focuses on a whole system analysis, rather than on details. Next to opportunities, threats are identified: a lack of organizational communication and a chance for a cultural resistance to change.

Overall, the continuous improvement strategy TPM enables Heineken to structurally improve its operational efficiency. The bottom-up ideology fits the organization, top management is committed, and the resources are available to take the necessary steps. Competent employees are in the right places with the right resources in the organization to cope with the identified threats in the long term. For Heineken there are two aspects that negatively influence the operational efficiency. First, TPM does not focus on the throughput of the production process and its constraints. The consequence is that prioritizing of projects can be off and small issues at important points can be underestimated. Second, the resistance to applying TPM of operators can magnify underlying issues, such as the principal-agent dynamic. In other words, if operators are not convinced of the contribution the methodology can make to their personal goals, they will not contribute accordingly. The consequence is that an autonomous working operator that identifies and solves problems is not possible.

How do organizational characteristics affect operational efficiency?

For large manufacturing organizations the organizational structure and corresponding characteristics are crucial to take into account. Improvement projects can be performed by internal or external parties, but the result has to be imbedded in the organization, and thus in the involved employees. How to involve, motivate and communicate with them is critical for the structural success of the improvement project.

The organizational structure of the packaging department can be characterized as a machine bureaucracy, as formulated by Mintzberg (1980). A stable and predictable environment in which there is a clear hierarchical organization. In such an environment, external standardization is thriving, which can be seen in the performance management structure. However, due to the increasing job intensity and complexity of operators, and a sophisticated technical system, characteristics from a professional bureaucracy can be found. It is important as management of the production line to realize that the identified shift is taking place. Operators are becoming more like the theoretical professionals each time their function gets more complicated. The more complicated the job, the harder it is to standardize and control their actions. However, in a professional organization as Heineken, the intrinsic motivation of operators to perform well appears to be present. Therefore the focus should not be on controlling operators, but on enabling them to perform as well as they can. The research did show that among operators there is in fact a resistance to change, although it is not a matter of working culture. The different, but not conflicting, goals and perspective between operators and management can cause this resistance. Because operators do not perceive TPM to be in line with their personal goals, they are hesitant to pro-actively start projects or contribute to them fully.

How is the operational efficiency affected from a logistical point of view?

First of all it has to be clear in the company what defines the operational efficiency and how it is measured. In order to improve something, one has to know how to define and measure it. The current state of the operational performance at Heineken is not aligned with the company goals. With an annual decline of 3% per year of the main operational performance indicator, the process is not fully in control as defined by management. The research has shown that there are in fact two bottlenecks in the production process, instead of just the one designed bottleneck. Being a bottleneck strongly increases the sensitivity for breakdowns on such machines in respect to total production loss, following the Theory of Constraints. Because this newly identified bottleneck has not been researched as such before, the losses with the biggest impact on this machine are analyzed. For the Multipacker machine the losses with the biggest impact are breakdowns involving material (external source) and blockage caused by low frequency, long duration breakdowns on the Palletizer and Shrink-foil installation. The latter also has a big impact on the Packer, together with starvation caused by the feed of empty boxes and breakdowns by falling bottles. In this research it is shown that the output performance can be significantly improved by diminishing the blockage caused by the Palletizer and Shrink-foil installation. By using MSAS-projects on these machines for finding the root cause and implementing solutions this goal has been achieved. The pre-determined KPI OPI NoNa has increased with 6.34 percentage points and the deviation of the indicator has diminished with 1.63 percentage points. If this major increase can be maintained in the future, this improvement could save the organization € 115,402 on a yearly basis in non-cash savings.

8.3. Recommendations

Based on the answers on the research questions and the general findings in this research, recommendations are done in this paragraph. First, recommendations for Heineken specific are done and second recommendations are made for future research.

8.3.1. Recommendations for Heineken

From a logistical point of view it is important for Heineken to keep working on the newly identified bottlenecks, the Packer and Multipacker machines. Every minute won on these machines can directly benefit the operational efficiency of the entire line. If in the future these machines are not the bottleneck anymore, it is recommended to keep in mind the simple bottleneck identification rule: looking at machine m_i , if its amount of blockage is larger than the starvation of machine m_{i+1} , the bottleneck is downstream of machine m_i . If the starvation of machine m_i is larger than the blockage of m_{i-1} , the bottleneck is upstream of machine m_i . This is a simple method to check if the designed V-graph shape still works. The recommendation is therefore to involve this rule of thumb in the monthly meeting between a rayon manager and the installation manager. When the suspicion exists that the production line can perform better, this rule can indicate troubling points in the process. On top of that, in an environment where resources are scarce (time, money, employees) it is important to make a critical selection on the allocation of these resources. Following the Theory of Constraints it is recommended to allocate resources fully to the constraints that have a direct impact on the production line throughput. In other words, the prioritization of projects should be based on the amount of production loss they create for the entire production line, instead of the amount of production loss for one machine. The logistical findings are of course specific for production line 81 at the Zoeterwoude brewery. It can be very interesting to apply these findings at the other production lines in the brewery as well. This horizontal expansion can provide new insights into the general mechanisms of the entire brewery as well as specific improvement opportunities.

Looking at organizational characteristics, one proposed improvement was through organizational communication. One specific part is recommended to be improved. The communication on the difference between TPM-tools must be clear. At the TPM-office and in Lotus (internal communication tool) educational material is available to inform operators and team leaders in a simple way, what the possibilities of the methodology are. Figure 49 in Appendix I is an example of how easily a clear message can be sent to operators. Introducing the opportunities to operators in such a way that it aligns with their interests should be a focus of management in the near future. The weekly Workplace Organization meetings are a practical and suitable moment to give five minute presentations or Q&A's on the topic. This kind of face-to-face communication is found to be a strong contributor to successful application of continuous improvement (Oprime, Mendes, & Pimenta, 2011). The first step should be on general information on what is possible (BDA, MSAS, Kaizen, route) and an option is to select certain champions who can start projects and teach others. Next to that, asking questions on a regular basis on whether operators know which means they have to actually solve problems themselves. Crucial in this process should be the willingness for management to allocate resources to operators for them to actually work with TPM-tools. An example of a resource can be hiring temporary employees to provide extra time for operators on certain shifts to work some hours on a problem they encountered.

Last, if Heineken wants to cope with the found principal-agent dilemma, a thorough behavioral change is required in the organization. That means this has to happen for both the operating core and management. Many books and articles are written on how to accomplish this. One leading program is change management, founded by Kotter (1996). His eight steps are: Increase urgency, build the guiding team, get the vision right, communicate for buy in, enable action/empower action, create short term win, don't let up, and make it stick. For Heineken this will mean selecting the right people, communicate in a good way and celebrate successes. This is just an example of the many options there are in the field of change management. The recommendation is therefore to select a form of change management in order to structurally realize this behavioral change in the entire organization.

8.3.2. Recommendations for future research

The foremost recommendation in respect to strengthening the findings in this research is performing more similar case studies. A case study at a comparable manufacturing organization is necessary to compare results and draw conclusions on the extent to which the findings can be generalized. This follows the theory of Yin on case studies and the corresponding requirements for building theory. Because this research is based on one case study, the findings can serve as a starting point for future research. With multiple cases theory can be built, based on the findings in this research. There are a number of aspects that can be expanded this way.

First, the framework developed in Paragraph 5.1 on Continuous Improvement strategies is limited to five strategies. More strategies can be added to this framework in order to make it more comprehensive and easier for other cases to find opportunities for unique cases. Second, the expectation is that the found principal-agent dynamic at Heineken is strongly comparable to other large manufacturing organizations. The found shift between Mintzberg's configurations (in Paragraph 5.2) is an underlying driving force in this aspect and is likely to be found at other companies as well. If this is the case, this can be a highly interesting addition to the theory on organizational structures.

9. Discussion and Reflection

Lastly, now the research questions have been answered it is time to discuss the findings and reflect on the research approach. In Paragraph 9.1 the general findings are discussed and in Paragraph 9.2 the research process is reflected upon.

9.1. Discussion

Looking at the general approach of this research, I started with a broad scope and zoomed in to a detailed level. Because of this it was necessary to make a number of assumptions and choices. The reproducibility of the research can therefore seem to be limited. The analyzed production environment will always be changing, so the assumption and choices made will always be different than the ones I made. However, I am convinced that by following the approach tested in this case study any researcher will find opportunities and gain insight in the possibilities that are always present to improve the operational efficiency.

As showed most explicitly in the fishbone diagram in Paragraph 4.5, the operational efficiency of the Heineken production line has a very broad set of possible causes. The final results of an increase of operational performance of 6% can therefore never be seen as a pure result of this research. On the one hand there are factors that have contributed towards the final achievement that had few to do with this research. Also external factors could change and there is a chance that the results are partly coincidental. On the other hand, the insight into a hidden bottleneck has proved to be very valuable information for the organization. Other improvement projects were performed with this aspect in mind, which also benefited the results as could be seen in a decline of breakdowns on different machines. Next to that, constant attention to employees and asking questions that are outside the box can make a difference as well.

During this research an important subject was the behavior of different stakeholders in general. Due to the great variety of individuals in the organization, the statements made never fully apply to everybody. The arguments made in this thesis however focus on the general mechanisms that might have an influence on the organization. Comparable to how Mintzberg describes his organizational structures in extreme forms to make the theory clear; the identified mechanisms in this research are also sometimes made explicit. Next to that, the observations made can be subjective. The observed actions are always subject to my personal interpretation and the questions that were asked. However, all the observations have been discussed with employees of Heineken and fellow researchers.

9.2. Reflection

Reflecting on the general research approach, a number of things can be said. I started with this research based on the assignment I got from Heineken. This assignment was formulated very specific and was aimed at improving the operational efficiency by applying the available TPM-tools. As I eventually did, for my own research it would have been very interesting to start immediately with the questions: why does Heineken ask this question and how come they cannot answer the question themselves? This way I would have been able to make the connection quicker to looking at the environment the logistical question was placed in. Also, due to the enormous amount of information, making choices on research boundaries earlier in the process can save a lot of time.

The focal point of this thesis has been the Case Study at Heineken. The fact that this case study comprises a single-case, the goal of making a big contribution to the academic world is difficult. Purely looking at the single-case design the application of this research is limited. Being aware of this limitation, the focus of this research should be on the benefits this single-case design has. Due to its explorative

nature, there is an opportunity to be flexible. Instead of focusing on developing new theory, the focus should be on learning as much as possible from the available data.

Overall, the research has provided me with a lot of knowledge on the overall mechanisms that are present in large manufacturing organizations. Ranging from how people communicate, solve problems and get things done, to the everyday trade-offs between safety, costs, production and quality. The sheer amount of material, time and energy required to make this product is incredible. It is very interesting to see how people behave in an organization, what drives them and how they make decisions. The same goes for the assets of an organization. Why they perform well or how small the influence can be for malfunction of these assets. My main criticism to the literature I used is that in all theories, a current state is assumed and findings are generalized. Based on what I have seen, this is especially in management theory really difficult and often misleading. Assigning a characteristic or typology to certain behavior often assumes that this will not change over time. People and organizations are however continuously changing and are therefore ever more complicated to research and influence.

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Appendices

Appendix A - Heineken Company Description

Appendix A1 – Heineken N.V. overview

History

In the last 150 years, Heineken has developed itself from a local Dutch brewer into a global beer, cider and beverage producing company. In 178 countries around the world, Heineken sells its products including more than 250 beer, cider and soft drink brands. In 2012 Heineken produced 171.7 million hectoliter beer, whereof 29.1 million hectoliter Heineken in the premium segment. The company employs more than 85,000 employees who work together with over 500 global and 34,000 local suppliers to produce the beer volumes in over 190 breweries in 71 countries. This makes Heineken the world’s most international brewer, with 65% of volumes and 50% of EBIT coming from the emerging markets in Africa and Middle East & Asia Pacific. Even now, the company continues to make significant investments in Africa, Asia, Latin America and the Caribbean. Figure 32 depicts the organizational structure of Heineken N.V. (Heineken, 2013a). Due to the sheer size of the company, Heineken B.V. is divided in Regional Departments. Within the West-Europe department, Heineken Netherlands is an important part of the company. Heineken Netherlands produced over 15,5 million hectoliter beer (in 2011), of which 72% was transported to 150 countries. The breweries in Zoeterwoude and Den Bosch are one of the most advanced breweries in the world and are therefore set as an example for the entire Heineken organization.

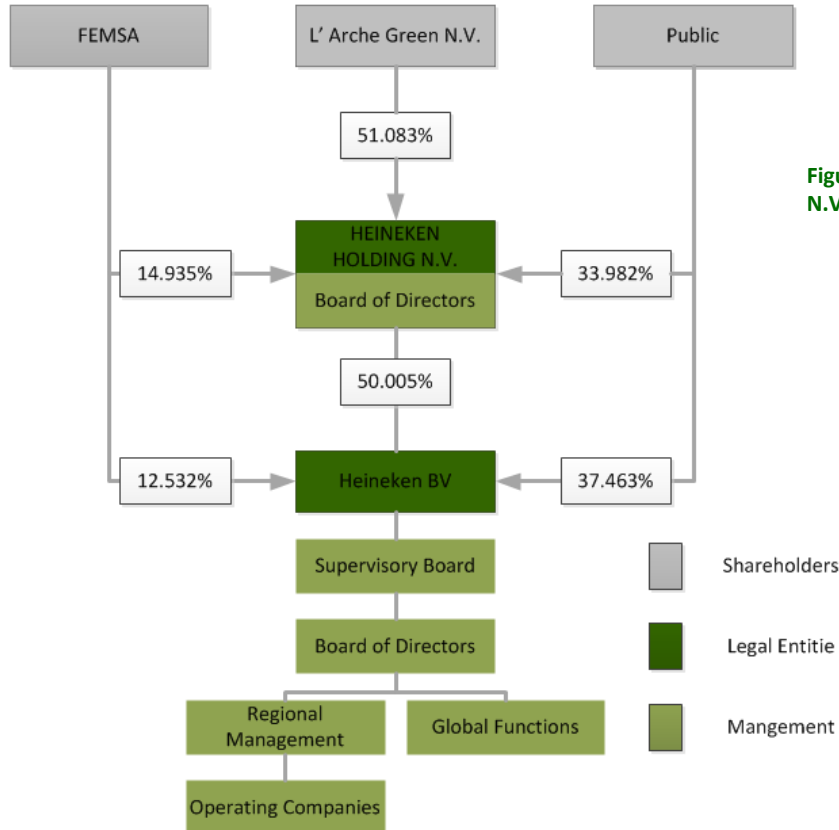


Figure 32 - Organizational structure Heineken N.V. (Heineken, 2012)

Strategy and Vision

When looking at the strategy and vision of the company, it can be seen that Heineken positions itself as the most global and sustainable brewer in the world (Heineken, 2013a). The company wants to be leading in the international premium segment and gain the opportunities that arise in upcoming markets. From a sustainable point of view, the company aims to imbed this into the entire company strategy. As can be seen in the annual sustainability report, sustainability is an important aspect of the company's future (Heineken, 2013b). The sustainability challenges focus on the aspects Heineken can have a direct impact on: Protecting water resources, Reducing CO2 emissions, Sourcing sustainably, and Advocating responsible consumption. Furthermore, in Figure 33 the other aspects of the Heineken strategy can be found. The company aims to grow the Heineken brand, internationally. Being consumer-inspired, customer-oriented and brand-led Heineken aims to capture opportunities in emerging markets. Lastly, personal leadership is one of the key company goals.

Our business priorities



Figure 33 – Link between business priorities and sustainability focus (Heineken, 2013b)

Financial overview

Despite the financial crisis and diminishing or stagnating markets, Heineken is still growing. With revenue of €19.203 million euro (€18.383 in 2012) and a consolidated beer volume of 178.3 million hectoliters (171.7 in 2012) Heineken remains one of the biggest brewers in the world. Due to the challenges in the beer market, Heineken has been forced to set challenging goals on cutting costs. Since 2006 Heineken realized cost savings of 1.4 billion euro. For the years 2012-2014 Heineken aims to save €625 million in operating costs. These cuts in costs caused group revenue growth to be lower than expected (1.3 per cent), what also is true for the operating profit (2.8 per cent). This resulted in a lower net profit (Before Exceptional Items and Amortization) of €1.585 million euro, compared to the year before (€1.661 in 2012). Heineken expects the beer volume to grow in developing markets in Africa Middle East, Asia Pacific, and Latin America and lower consumption in Europe. Due to the globalization of the company, the expectation is that the revenue will grow in 2014.

Beer Market

The beer market is getting more global each day: the historically important markets in Europe and the USA are stagnating, whereas Africa, Middle East and Asia are growing. After a contraction of the entire market in 2009, the market has been modestly growing between 2007 and 2011. The forecast is that the market will expand at a faster pace between 2012 and 2017 (Marketline, 2013). Globally, Heineken is one of the four big players in the beer market. Together with Belgian-Brazilian Anheuser-Busch InBev and South-African SABMiller, Heineken now is one of the biggest brewers in the world. These three companies, together with the Carlsberg make up for 50% of the total global beer market share, as can be seen in Figure 34. The enormous increase between 2000 and 2011 can be clarified by the big merges between already big brewers. In 2004, Belgian Interbrew and Brazilian AmBev merged. After taking over the biggest American brewer Anheuser-Busch, ABInBev was founded. SABMiller did comparable acquisitions, by taking over Bavaria S.A., the second largest brewer of South-America, and Fosters in the UK. Heineken did the same by taking over Scottish and Newcastle and APB, and merging with FEMSA. Characteristic for the beer market is that the differentiation between competitors is small, especially in the premium segment. This, combined with low switching costs of consumers, makes the beer market highly competitive.

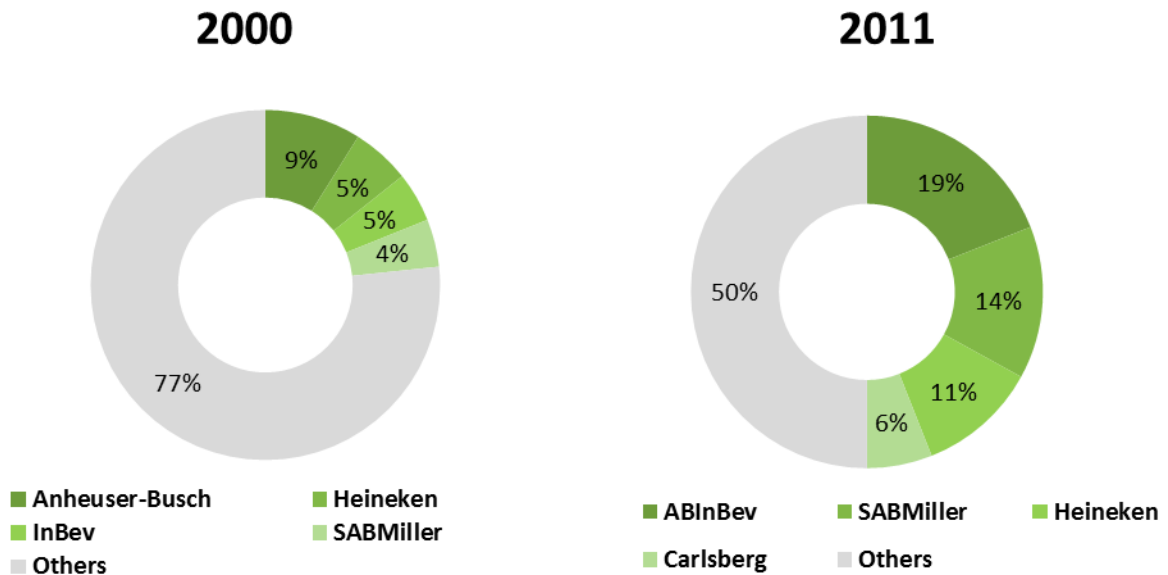


Figure 34 - Market segmentation (Marketline, 2013)

Appendix A2 - Heineken brewery Zoeterwoude

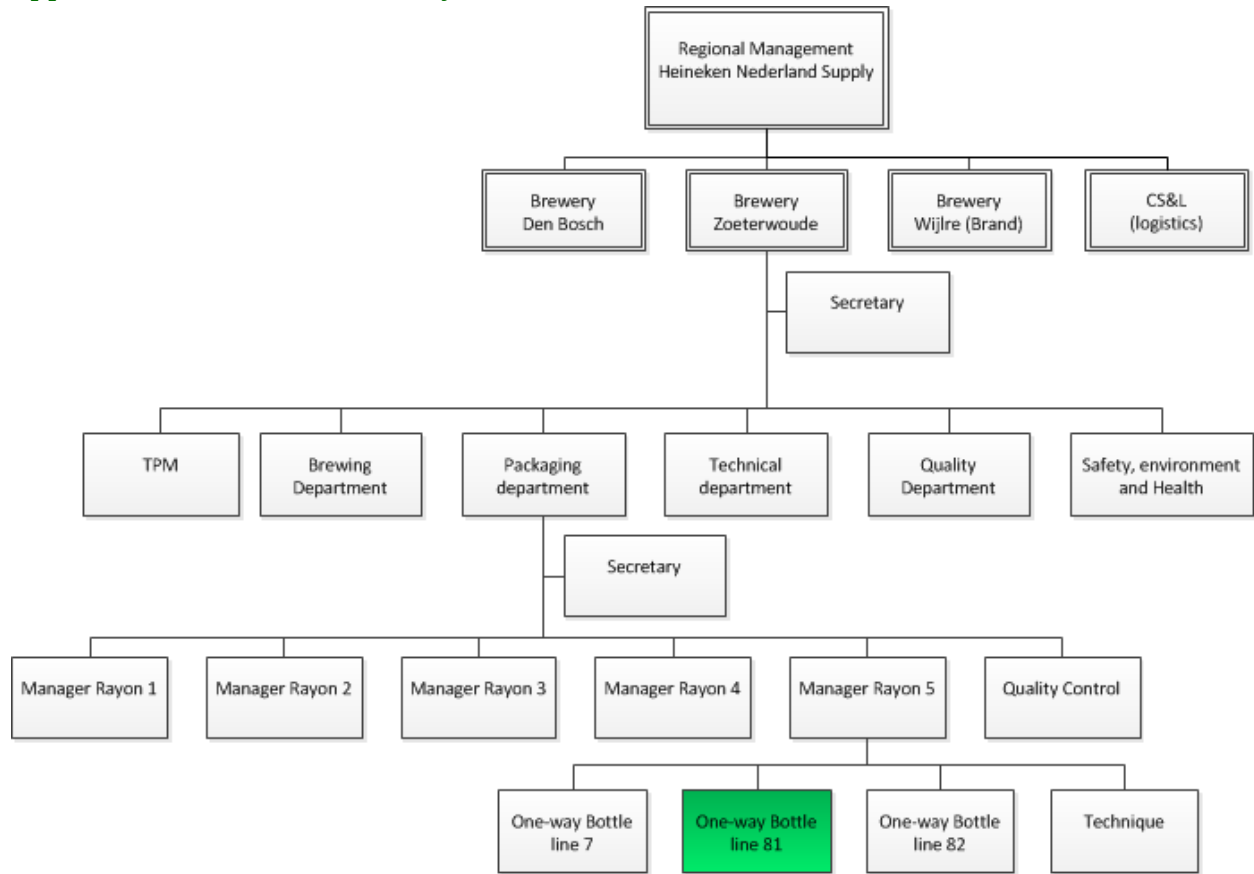


Figure 35 - Organizational overview Heineken Netherlands Supply

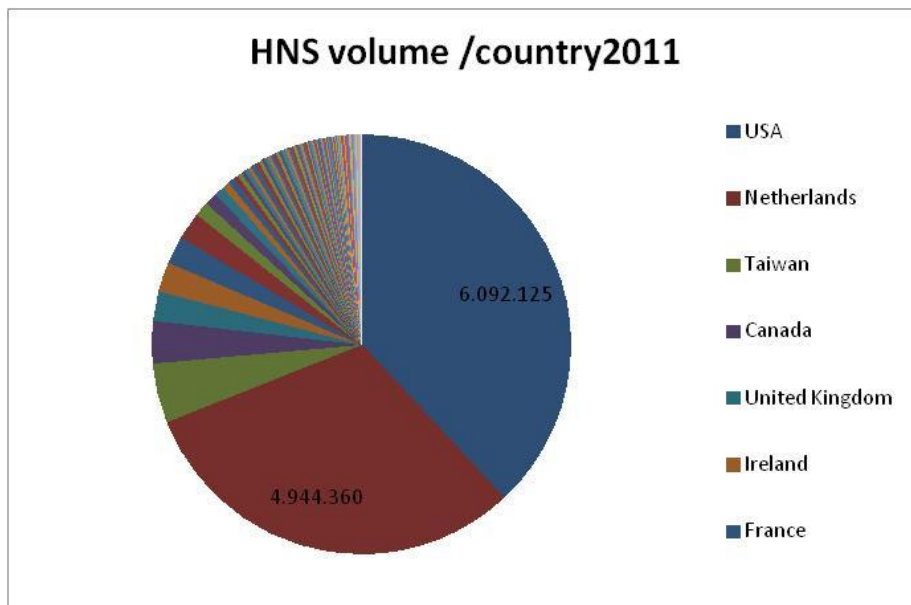


Figure 36 – Heineken Netherlands Supply Beer Volume per Country in 2011

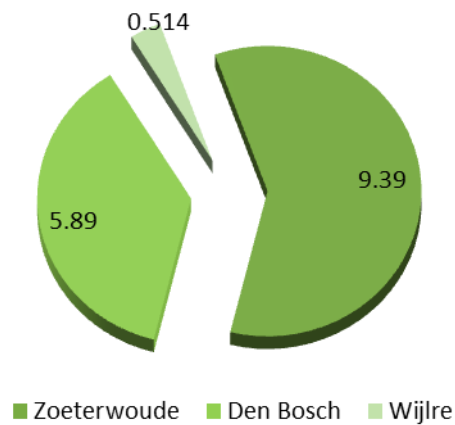


Figure 37 - Heineken Netherlands Supply Beer Volume per brewery in 2012

Line	Rayon	Line type	Packaging type	Capacity [item/hr]
Line 11	Rayon 1	Bottles, domestic	Returnable bottles	80.000
Line 12	Rayon 1	Bottles, domestic	Returnable bottles	80.000
Line 21	Rayon 2	Bottles, export	One-way bottles	40.000
Line 22	Rayon 2	Bottles, export	One-way bottles	40.000
Line 3	Rayon 2	Bottles, export	One-way bottles	84.000
Line 41	Rayon 4	Draught kegs	One-way kegs (5L)	1.400
Line 42	Rayon 4	Draught kegs	One-way kegs (5L)	1.400
Line 51	Rayon 3	Bottles, export	One-way bottles	80.000
Line 52	Rayon 3	Bottles, export	One-way bottles	80.000
Line 6	Rayon 4	Cans	One-way cans	60.000
Line 7	Rayon 5	Bottles, export	One-way bottles	80.000
Line 81	Rayon 5	Bottles, export	One-way bottles	65.000
Line 82	Rayon 5	Bottles, export	One-way bottles	65.000
Line 9	Rayon 1	Kegs	Returnable kegs (50L)	900

Figure 38 - Overview Packaging Lines Heineken Zoeterwoude

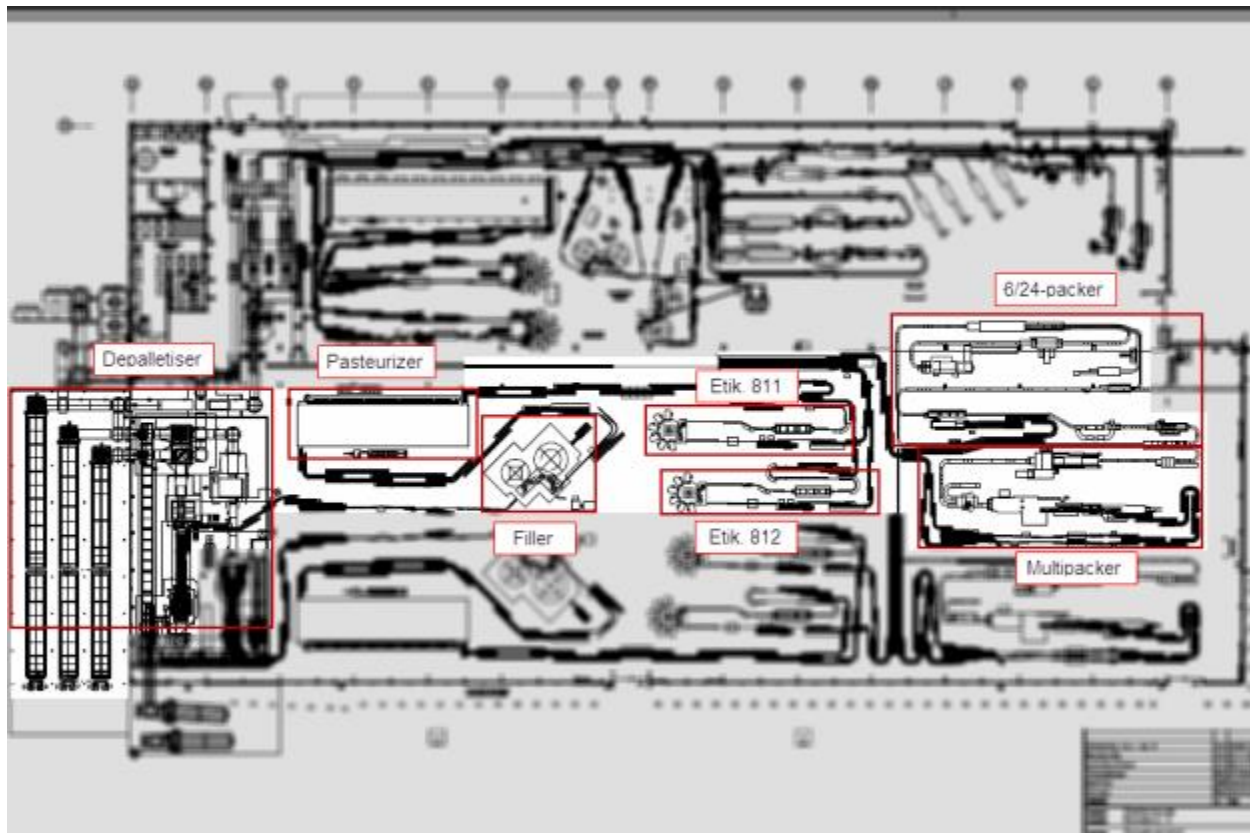


Figure 40 - Line 81 Highlighted including indications of different machines

Figure 40 above illustrates production line 81 including the different machines. The production line is able to produce Heineken, Heineken Light and Amstel Light in 6-, 12-, and 24-pack carton boxes. The depalletizer takes empty bottles from a pallet and places them on a bottle lane. This will bring the bottles to the rinser/filler, where bottles are cleaned, filled with beer and sealed off with a bottle cap. From there the pasteurizer will pasteurize the bottles and after being dried, the labelers (Etik. 811/812) will put labels on the bottles. From there the bottles are transported to the so-called dry area where the bottles are packed into boxes. Once packed, the bottles are transferred on to pallets and delivered to the Customer Service & Logistics department (CS&L)

Appendix B – Statistical t-Test Analysis

In order to determine whether the OPI in Figure 31 on average significantly improved, a Student t-test is performed. In order to identify which test has to be used, first an F-test is performed to determine whether the variance of the two samples is equal. As the results in Table 16 show, the variance of the two samples can be assumed to be equal. This is based on the fact that $F < F$ Critical one-tail, and therefore accepting the null hypothesis: the variance of the two samples is equal.

F-Test Two-Sample for Variances

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	0.577248	0.641732
Variance	0.002002	0.001694
Observations	15	15
df	14	14
F	1.181982	
P(F<=f) one-tail	0.379391	
F Critical one-tail	2.483726	

Table 16 - F-test for comparing variances of two samples

Based on this result a normal t-test is performed. The results are shown in Table 17. The formulated null hypothesis is that the mean of Variable 2 is significantly higher than Variable 1. Based on the outcome the null hypothesis has to be accepted. Therefore, the mean of Variable 2 is significantly higher than Variable 1.

t-Test: Two-Sample Assuming Equal Variances

	<i>Variable 2</i>	<i>Variable 1</i>
Mean	0.641732	0.577248
Variance	0.001694	0.002002
Observations	15	15
Pooled Variance	0.001848	
Hypothesized Mean Difference	0.06	
df	28	
t Stat	0.285635	
P(T<=t) one-tail	0.38863	
t Critical one-tail	1.701131	
P(T<=t) two-tail	0.77726	
t Critical two-tail	2.048407	

Table 17 - Normal t-test assuming equal variances to compare means

Appendix C – KPI overview at Heineken Netherlands Supply

Appendix C1 - Overview

Category	Description
General	Volume produced [hl]
	Production personnel [fte]
	Number of lines bottle [-]
	Number of lines can [-]
	Number of lines keg [-]
	GTF production productivity vision [hl/fte]
Productivity & cost leadership	OPI nona [%]
	Set up loss
	Break down loss
	Short stop loss
	Speed losses
	Planned down maintenance
	Others loss
	Production productivity [hl/fte]
	Finished product stock level* [dy]
	Extract losses [%]
	Production packaging material losses [%]
	Fixed production cost [eur/hl]
	Cost from palletizer to first customer* [eur/hl]
Customer satisfaction	Packaging conformance to schedule [%]
	Short-term demand forecast accuracy* [%]
	Perfect customer order* [%]
Social responsibility	Water consumption [hl/hl]
	Electricity consumption [kwh/hl]
	Thermal energy consumption [mj/hl]
	Non-recycled industrial waste [kg/hl]
	Eco care indicator [%]
Organization & people development	Absence rate [%]
	Accident frequency [accidents/fte'00]
	Training [hr/fte]
	Training coverage [%]
	Corporate tpm audit [%]
Quality	Taste test score fresh [%]
	First time right brewhouse [%]

	First time right fermentation [%]
	First time right finished product [%]
	Justified product complaints bottle/can [complaints/unit]
	Justified product complaints keg [complaints/unit]
	Packaging sales quality [%]
	Freshness* [dy]
Others	Brewery award
	Cost of maintenance
	Total cost / hl

Table 18 - KPI Overview HNS

Appendix D – Stakeholder analysis

This stakeholder analysis is based on the methodology developed by (Enserink et al., 2010). The goal is to give an overview of the current situation and analyze where opportunities or barriers exist when implementing solutions. The method consists of six steps: problem formulation, inventory of involved stakeholders, describing formal relations, determining goals and interests, mapping interdependencies and drawing conclusions.

D1 – Problem formulation

The problem that is researched in this report is thoroughly described in Chapter 2. Regarding the stakeholder analysis, the problem can be formulated in short as follows. The Rayon Manager (RM) is responsible for a part of the packaging department and desires a highly efficient production process with low variability. Because the production process currently does not have either of these two desired states and there is no direct solution, the RM is the problem owner in this case.

D2 – Inventory of actors involved & D3- Formal chart

For an inventory of involved actors and their formal relations, a full overview can be found in Appendix A2 - Heineken brewery Zoeterwoude, in Figure 35. Figure 4 in Paragraph 4.1 shows a more detailed formal relation zoomed in on the production line itself.

D4 – Problem formulations of stakeholders

An analysis is made on the problem perceptions of the involved stakeholders. By comparing interests, desired situations, gaps and causes, an overview is created of the general problem perception. The following Table 19 is based on observations during the shadowing of the involved stakeholders in day to day operations (meetings, working, informal situations) during a six month period. Also, information is obtained by observing during the work in projects, together with several stakeholders. The consequence of these methods is that this is an analysis based on the researcher's interpretation of what is seen.

Stakeholders	Interests	Desired situation	Existing or expected situation and gap	Causes	Possible solutions
<i>Problem owner (RM)</i>	High OPI, low costs	>80% OPI, low variability in performance	60% OPI, high variability in performance	TPM not fully implemented, few resources	More resources, implementing TPM further
<i>Installation Manager (IM)</i>	Low Maintenance costs, Good working machines	No machine breakdowns, low maintenance costs, well formulated operational failures	Numerous breakdowns, delayed maintenance, troubleshooting	Recurring breakdowns, low quality information	Better communication (standardization)
<i>Team leader (TL)</i>	High OPI	Autonomous operators – focus on support, instead of troubleshooting	Now troubleshooting	Too much work, too little time. Process not in control	Allocate resources to get process in control structurally
<i>Operator</i>	Low work pressure. Good communication	Process under control: only maintenance and adjusting, not troubleshooting	Now troubleshooting, no good communication to supervisors	No knowledge of TPM, no standardization, diminishing workforce	Larger workforce, standardization, usage of TPM, better communication
<i>TPM facilitator</i>	Production standards	Autonomous operators, perfect standards, improvement culture	TPM not fully implemented (Gold standard)	Time, planning until 2015	Focus on right aspects, with regard for pitfalls
<i>Packaging director</i>	Overall Production performance	>80% OPI, low variability in performance	60% OPI, high variability in performance	TPM not fully implemented, few resources	More resources, implementing TPM further

Table 19 - Stakeholder analysis on interests, desired situation, gap, causes and solutions

D5 – Interdependency analysis

The interdependencies between involved stakeholders are analyzed by looking at resources, power and influence. Important to note is that this analysis will be solely used to illustrate the general mechanics between the stakeholders of Heineken’s packaging department. So, exceptions might be present in the department, due to generalization of groups of stakeholders (for example: operators). Also, stakeholders might not have determined their position yet; in those cases the researcher’s interpretation is used.

	Limited Importance	Great importance
Limited options to replace	Packaging director <i>Medium dependency</i>	RM, IM, TL, Operator <i>High dependency</i>
Can be easily replaced	TPM facilitator <i>Limited dependency</i>	<i>Medium dependency</i>

Table 20 - Resource Dependency

Stakeholder	Important resources	Dependency	Critical Stakeholder Yes/no
<i>Problem owner (RM)</i>	General information (trends), knowledge and skills, Allocation of resources , authority,	High	Yes
<i>Installation Manager</i>	Knowledge, Money, Authority, Allocation of resources	High	Yes
<i>Team leader</i>	Specialized Information, Semi authority, Allocation of resources	High	No
<i>Operator</i>	Highly specialized Information, skills	High	Yes
<i>TPM facilitator</i>	Knowledge	Limited	No
<i>Packaging director</i>	Authority, Money, General information (trends), Allocation of resources	Medium	No

Table 21 - Overview table for determining critical and non-critical stakeholders

	Dedicated stakeholders		Non-dedicated stakeholders	
	<i>Critical stakeholders</i>	<i>Non-critical stakeholders</i>	<i>Critical stakeholders</i>	<i>Non-critical stakeholders</i>
Similar/supportive interests and objective	RM, Installation Manager	Team Leader, TPM Facilitator, Packaging Director	Operator	
Conflicting interests and objectives			Operator	

Table 22 - Overview for classification of interdependencies

D6 – Conclusion

It is important to determine the consequences of these findings with regard to the problem formulation. There are some observations that illustrate the packaging department well. In the basis, the interests and objectives of the involved stakeholders align. Apart from perhaps different underlying motivations, all stakeholders share the same goals. There is a common goal for making the line produce at good as it can. Managers have this goal because of higher efficiency, thus profit. Operators on the other hand are motivated by the fact they can control the process, thus less reactive work. The only difference can be found in dedication of the stakeholders. But the cause of this is not the resistance, but rather the lack of believe that the proposed solutions can solve the perceived problems.

The second observation is that communication and standardization could help solve the problems perceived by multiple stakeholders (Installation manager and operators). The cause of this is that operators and management do not always speak the same language. Where operators signal and communicate symptoms (recurring and significant ones), management expects root to be notified about root causes and sustainable solutions.

Third, when looking at important resources, it can be seen that operators do have a position in the organization. They are the only ones who have the specialized information about what actually happens on the shopfloor. When looking at the continuity of the organization, the operators have the longest lifespan as employees in the brewery. Team leaders and rayon managers change jobs every 2 to 4 years. Operators can stay with the company up to 30 years. This makes them the most stable assets in the company and critical for structurally improving the system.

Appendix E – Bottleneck analysis model

Appendix E1 – Bottleneck analysis model formulas

Variable	Unit	Function	Excel
Utilization	% (bottles/(bottles))	$\frac{\text{Arrival Rate (bottle)}}{\text{Production time (hour)} * \text{Maximum Capacity } \left(\frac{\text{bottle}}{\text{hour}}\right)}$	=IFERROR((P13)/((E13/60)*'@list'!\$D\$15),NA()),"")
Isolated Production Rate	Bottle	$\left(\text{Production time} + \text{Starvation time} + \text{Blockage time (hour)}\right) * \text{Maximum Capacity } \left(\frac{\text{bottle}}{\text{hour}}\right)$	=IFERROR((((SUMIF(E13:G13,"<>",E13:G13))/60)*'@list'!\$D\$15),NA())
Speed loss	Minute	$(1 - \text{Utilization}) * \text{Production time (minute)}$	=IF((P13)>25,(1-Q13)*E13,"")
Downtime	Minute		=CUBEVALUE("nls1109 MES Verpak Downtime",\$B\$1,\$B\$2,\$A\$6,\$C36,D\$6)
Counter	Bottle		=CUBEVALUE("nls1109 MES Verpak Counter",\$N\$1,\$N\$2,\$M\$4,\$M36,\$O\$6)

Table 23 - Formulas used in bottleneck analysis model

Appendix E2 – Bottleneck analysis model interface

The interface is a blue panel with a white-bordered box containing filter options. At the top right of the panel is the label 'dienst:'. The filter options are:

- Startdatum:** 01/01/2014, with a dropdown menu set to 'nacht' and a 't/m' label.
- Einddatum:** 22/03/2014, with a dropdown menu set to 'nacht'.
- Exclude stopdiensten:** Exclude
- Exclude Sixpack:** Exclude
- Exclude Multipacker:** Exclude

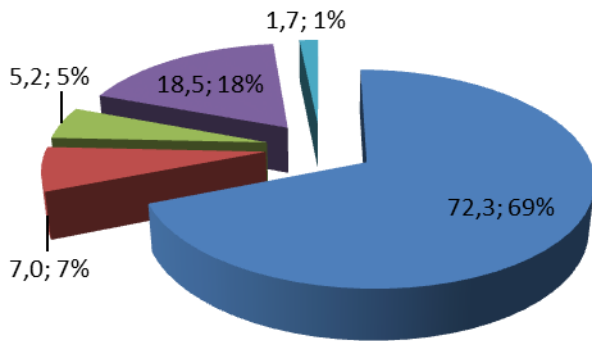
At the bottom of the panel are two buttons: 'VERVERS DATA' and 'VERVERS GRAFIEK'.

Figure 41 - Options to automatically filter bottleneck analysis model

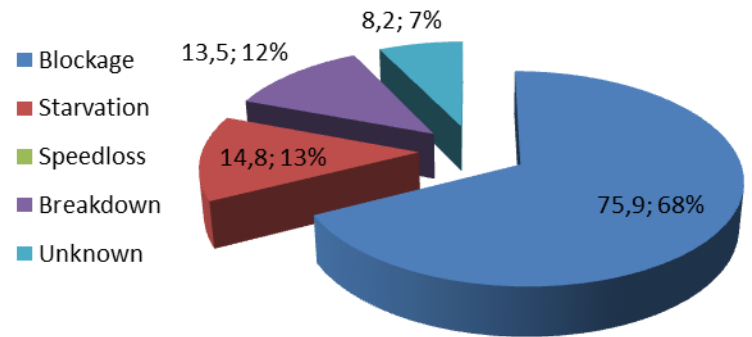
Options to filter the content of the model include filters on: date per shift, shifts per product package (six-pack, 12-pack or 24-pack), and shifts with or without production.

Appendix E3 – Bottleneck analysis model outcomes Multipacker line

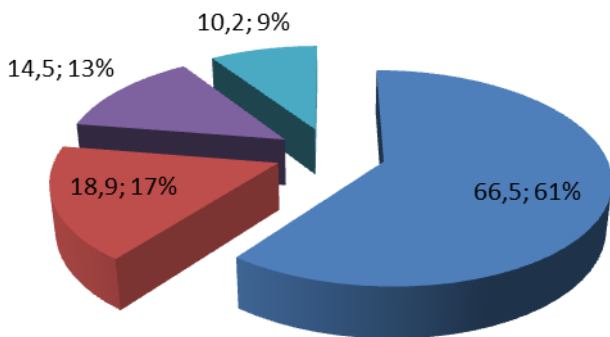
Filler/Rinser



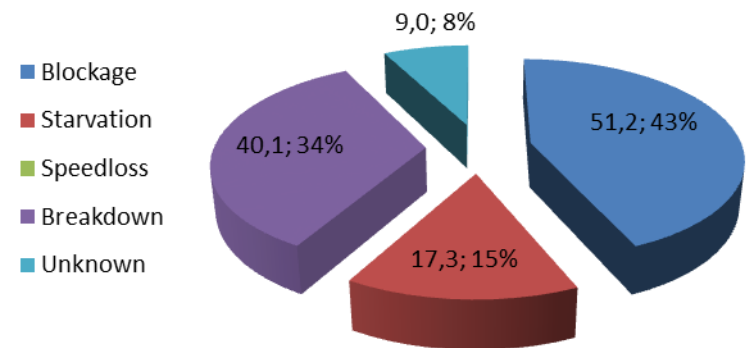
Labeller 811



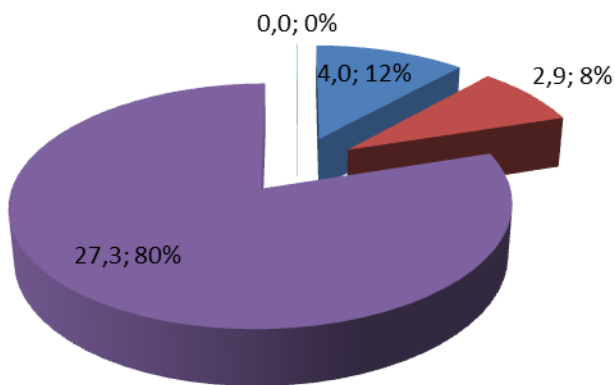
Labeller 812



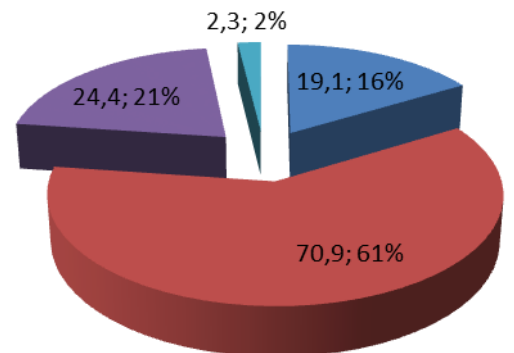
Multipacker



Traypacker

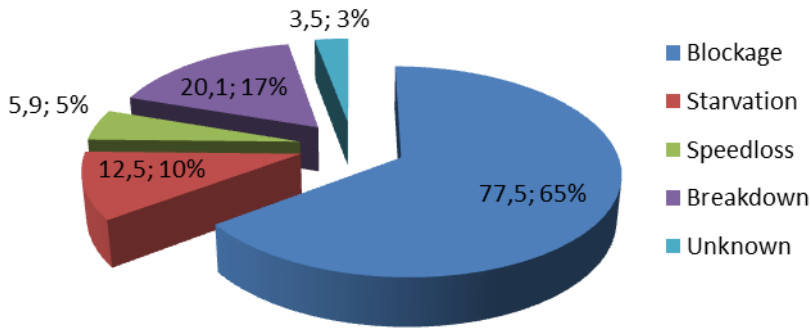


Palletizer

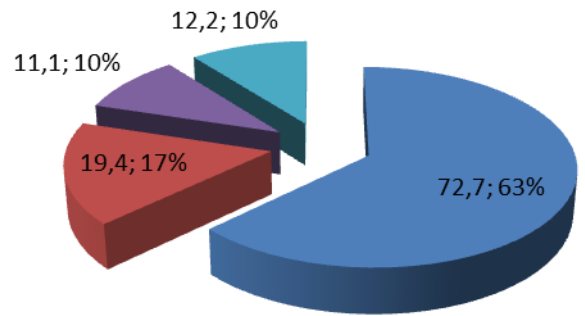


Appendix E4 - Bottleneck analysis model outcomes Packer line

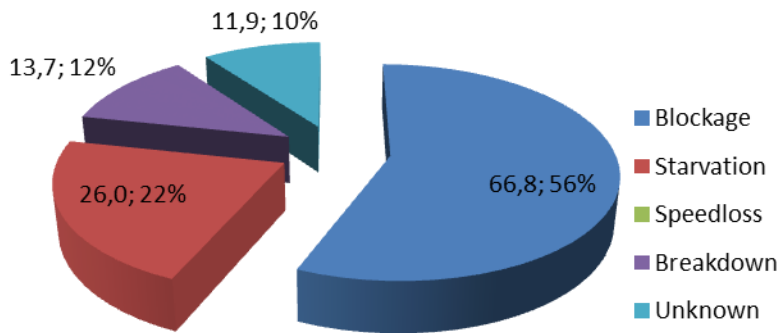
Filler/Rinser



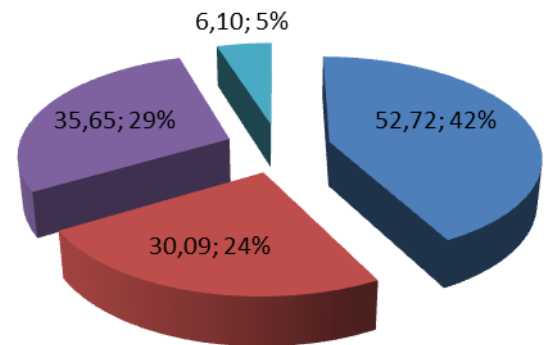
Labeller 811



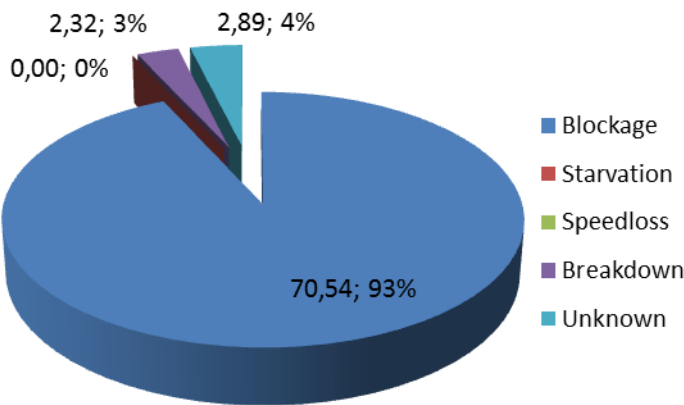
Labeller 812



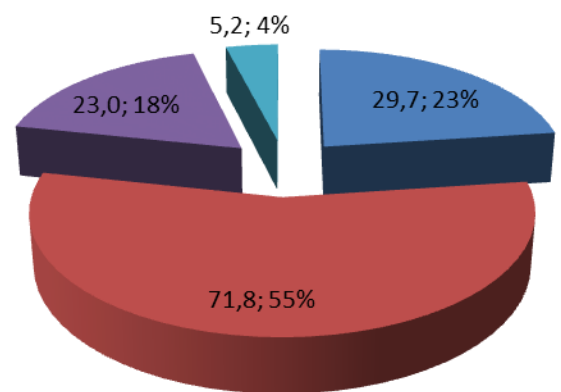
Packer



Box closer



Palletizer



Some notes have to be made on the validity of the presented pie-charts in the general sense:

- The data comes from Heineken measurement and control database MES. The data in its final version is retrieved on 20-03-2014.
- The data comes straight from the database and are summations of shifts of 8 hours (480 minutes). The aggregation level is therefore in its most detailed level in minutes per shift. In these charts it is assumed that it is unclear whether losses occur in total at once, evenly distributed across the shift or totally segmented. Due to the big amount of data the exceptions can be leveled out and conclusions can only be made for this general purpose.
- Some situations are not transferred correctly into the database. Not everything is programmed correctly and situations occur that have not been programmed at all. Operators can manually interfere in the system and often have to overwrite certain situations (during cleaning actions, the machine displays an error. This has to be overwritten as planned downtime). And there are more exceptions. Some of these specific instances are described below.

Specific errors in the MES database:

- Labelers 811 and 812 are able to automatically change production speeds in the case of starvation or blockage. The loss by not being operating full speed is incorporated in the model as speed loss. The formula for that can be found in Appendix E1 – Bottleneck analysis model formulas.
- The Box closing machine wrongfully displays starvation as blockage and starvation is never reported (see Figure 43)
- The Traypacker does not record blockage or starvation correctly at all (see Figure 42 for example)
- The shrink-foil installation reports an error if a roll of foil has to be replaced. Technically that would be starvation, as the required materials are not present.

In Figure 42 and Figure 43 two examples of the MES-database output can be seen. Per shift of eight hours, these pictures illustrate the statuses of the different machines. The process starts at the top with the first machine and the product works itself downwards. Green means production, blue means blockage, yellow means starvation, red means breakdown and purple means no production.

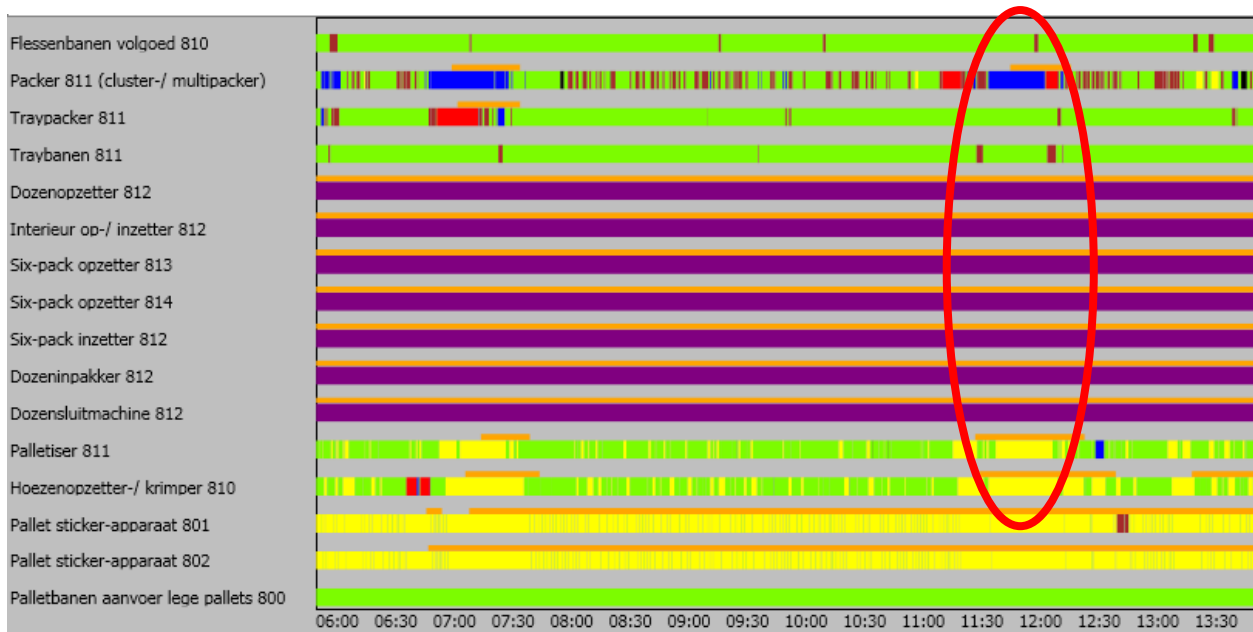


Figure 42 - Example of wrong MES data output Traypacker



Figure 43 - Example of wrong MES data output Box closer

Appendix F – Breakdown causes

Appendix F1 – Breakdown Causes Multipacker

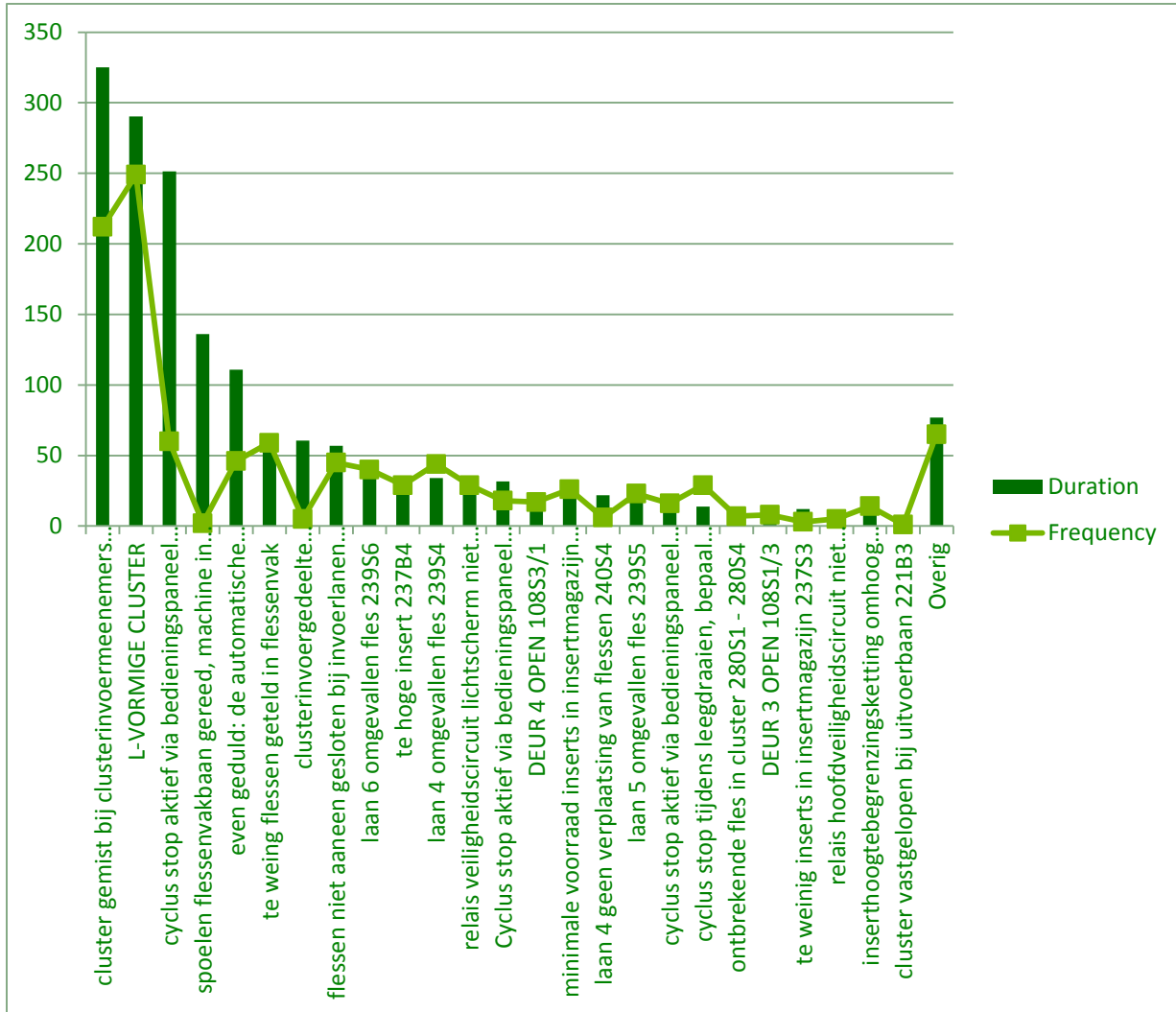


Figure 44 - Pareto overview breakdown causes Multipacker

Appendix F2 - Breakdown Causes Packer Machine

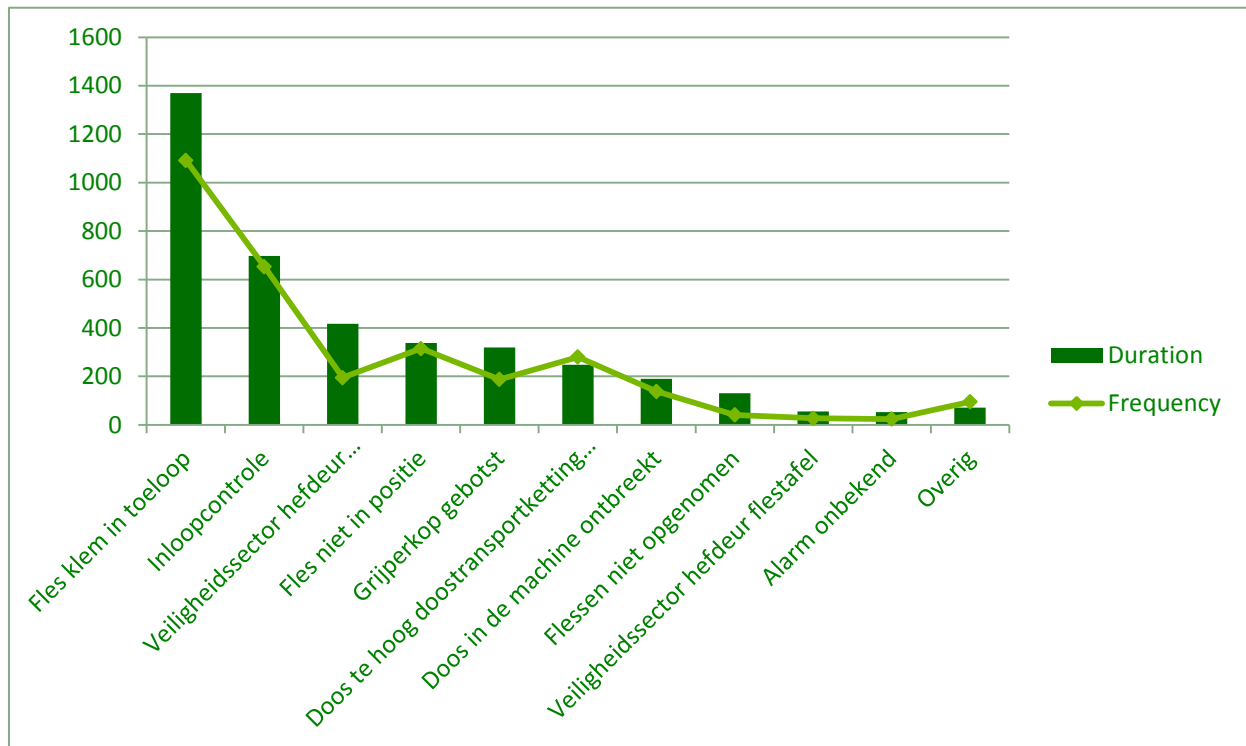


Figure 45 - Pareto overview breakdown causes Packer Machine

Appendix G – Blockage cause analysis

Appendix G1 – Blockage Multipacker

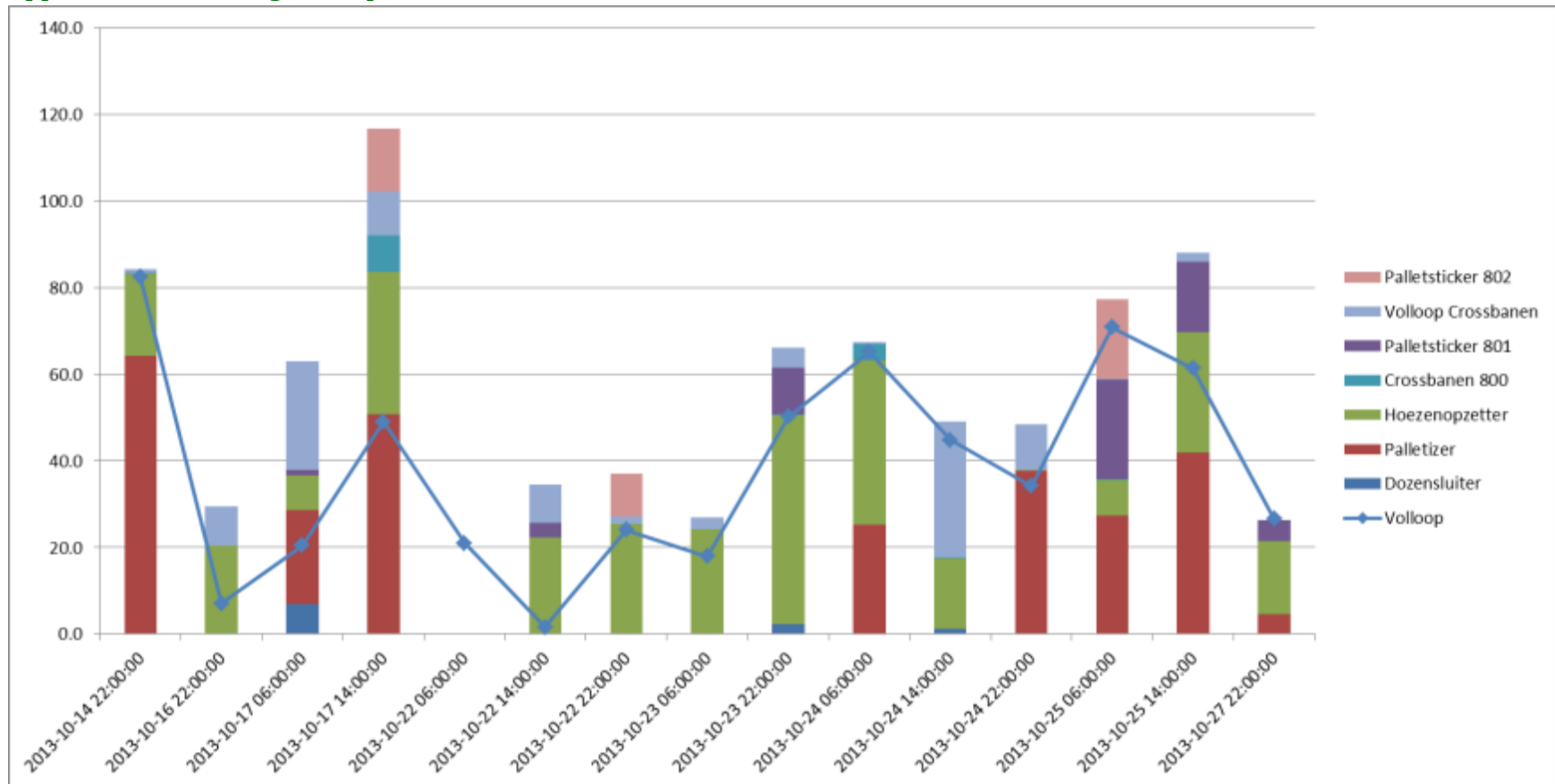


Figure 46 - Comparison between Multipacker blockage and downstream machine breakdowns

Appendix G2 - Blockage Packer Machine

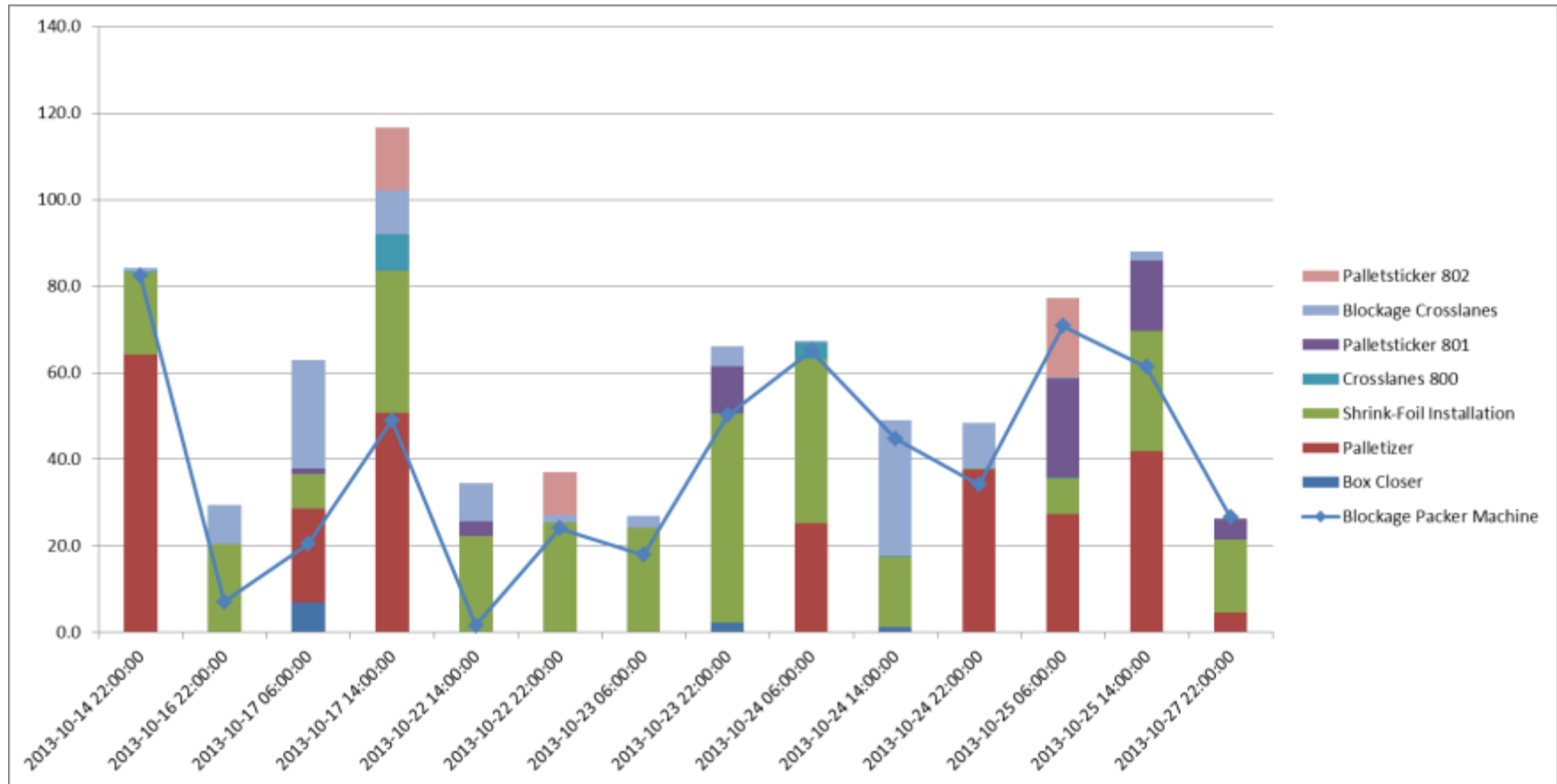


Figure 47 - Comparison between Packer Machine blockage and downstream machine breakdowns

Appendix G3 - Pareto breakdown analysis

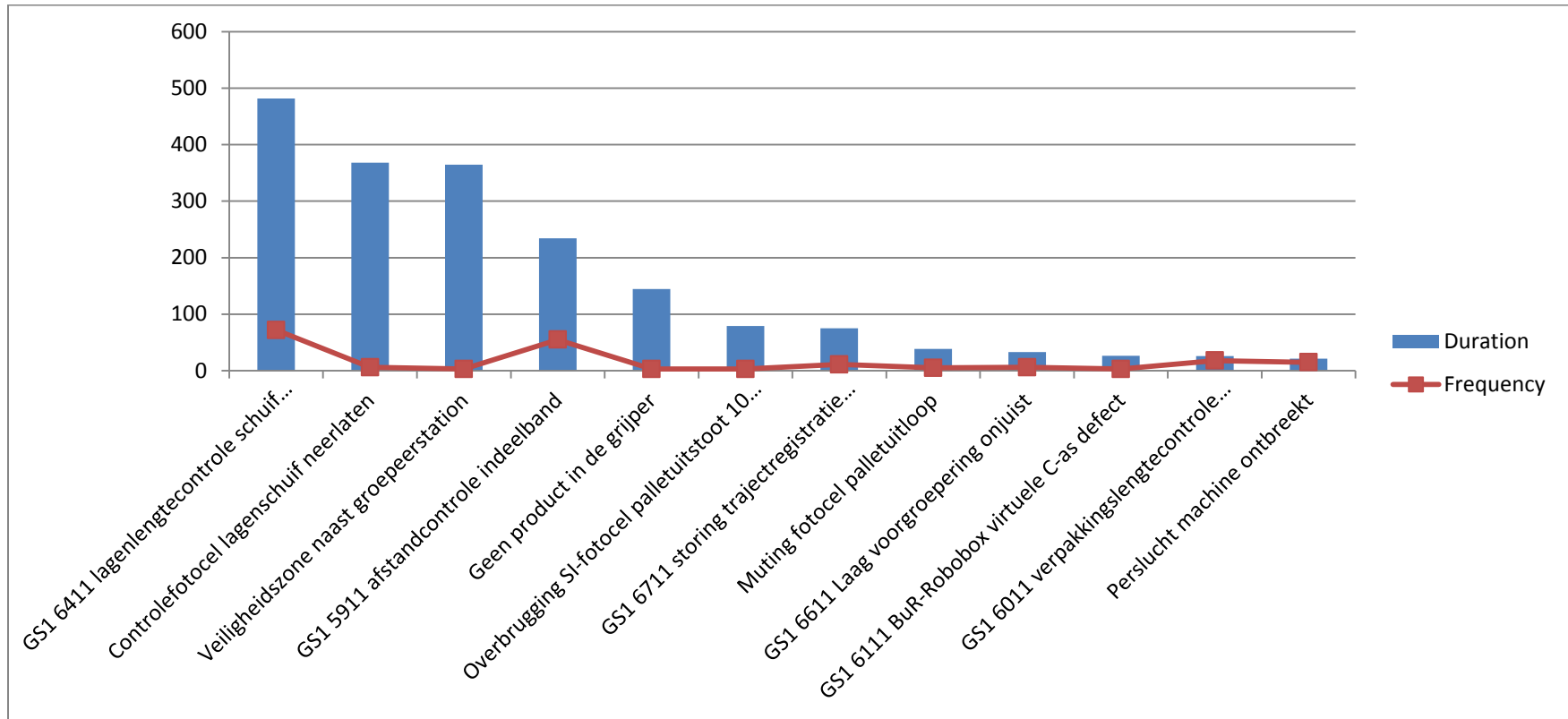


Figure 48 - Pareto breakdown analysis Palletizer

Appendix H – Educational Material for TPM

Types of problem solving tools: Process management				
What:	Who:	When:	Where:	How:
Team	Multi-discipline team	1-3 months	Office & Shop floor	Team board Skill matrix Activity planning Team identity
Kaizen	Team with operators & specialists	1-6 weeks	Shop floor & Office	A0 Kaizen sheet Team List Step Plan
RCFA	Technician/Operator	1-5 day	Shop floor	A3 RCFA sheet Owner & support Action follow up.
TAG	Operator	24-48 hours	Machine	A5 Card Owner & executer. Planning process

Figure 49- Example of educational material to be used to clarify TPM-tools to operators