Investigation of defective products and how to reduce them

A case study at a Scandinavian plastic manufacturer

Research area: Industrial engineering and supply chain management
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Abstract

Purpose – The purpose of the research is to explore how defective parts and products affect the sustainability aspect of manufacturing companies and how defects can be reduced.

Method – To reach the purpose of the study, a single case study and literature review have been conducted. The single case study has used an abductive approach throughout the study with the use of quantitative and qualitative data. The different methods to collect the data throughout the study were observations, interviews, questionnaires, and document studies. The empirical data was later analysed with pattern matching against the theoretical framework to reach results.

Findings – It is clear that defective parts and products have a negative effect on manufacturers’ sustainability performance. The use of lean methodology and its tools can provide manufacturing companies with accurate information on what defects they have and the causes behind, in order to reduce the number of defects and improve the sustainability aspect.

Limitations – The research has been limited to one company and a certain area within its production. The studied area was further narrowed down to only include the closest processes to the machines, hence, processes before and after the area are not covered in this research.

Keywords – Defects, Sustainability, Production, Lean, Plastic injection moulding, Process.
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1 Introduction

This section will describe the background of the research and the problem area in which the research is based. It continues with presenting the purpose and research questions of the study. Furthermore, scope and delimitations are outlined, and the section ends with the disposition of the research.

1.1 Background

The plastic industry has been and is a debated topic for several years. The use of plastic packaging has increased because of the lightweight which in turn has made it possible to transport more goods and at the same time reduce the waste of packaging material. These two aspects contribute to reduced CO2 emission and by removing plastic packaging with other substitutes would have a huge negative impact on the environment (Grant et al., 2017). The downside with plastic packaging is that if the waste is not handled properly, not ending up at recycling stations, it will harm the environment since plastic is not biodegradable. The lack of proper handling of the plastic waste in terms of recycling has more or less forced the plastic industry to change their thinking into developing more biodegradable packaging material (Grant et al., 2017).

Since plastic is a hot topic to debate, manufacturing companies within the plastic industry needs not only to change their mindset regarding more biodegradable material, they need to deal with different wastes inhouse to show that they take responsibility. One way to deal with waste reduction for manufacturing companies is by applying Lean manufacturing. Lean manufacturing has its origin in the automotive industry in Japan and the main goals are to eliminate different types of waste and add value for the customer (Fercoq et al., 2016). Companies applying Lean manufacturing has not only shown great results in waste reduction but also great results regarding economic and operational performance (Henao et al., 2019). In a Lean context, the seven waste is a known concept that companies try to reduce and in best cases completely eliminate. These seven wastes are; inventory, over-production, transportation and motion, over-processing, defects, and waiting. Producing defect parts and products means that the parts or products need to be recycled or in worst case disposal (Fercoq et al., 2016). Defects in production are related to quality problem and a common method to tackle quality problem is by using Deming’s cycle in combination with other quality tools like Check sheet and Pareto chart, which are two of the 7 basic quality tools (Lopes Silva et al., 2013). How companies implement Lean manufacturing and use different methods and tools to reduce defected parts and products differ. What is very common though is that when one’s needs to understand and solve a problem related to quality, the term process needs to be understood. A process can be defined as the step that refines the product or service that is offered to the customer (Petersson et al., 2015). The understanding of what a process is helps, companies to create greater value for the customer by optimising the processes.

Lean manufacturing is proved in some cases to go hand in hand with the steadily growing awareness of sustainability performance. Previously research has shown that Lean manufacturing, in some cases, has a positive effect on all the three pillars in the Triple Bottom Line (TBL); environmental, social and economic. In other cases, it reveals that trade-offs between the three pillars in the TBL are performed (Henao et al., 2019).
1.1.1 Company background

The case company operates within the plastic industry and manufactures packages that are delivered to different customers around the Nordic. The company is a medium sized with close to 200 employees at site. The company is part of a bigger business group that spreads out globally, however, this company is based in Scandinavia. To produce the products, the company uses plastic injection moulding machines, these machines work that plastic is melted and then shoots into a mould, then the plastic cools down and one product is finished. The company holds about 70 of these machines that vary in size and therefore different machines produce different sizes of products. In this process, labels are also melted into the packages, this type of technique is called “in-mould labelling” (IML) which makes the label an integrated part of the product. The product range consists of roughly 1900 different products that are produced at the company, in which some are produced on a more frequent basis than others. At the company, they have rather newly implemented an automated packaging system. That system is a convoy that surrounds 7 plastic injection moulding machines, at the machines, some robots that puts the finished products on to the convoy which is then transported and placed on an EU pallet. The machines and processes connected to this convoy system will be the main focus of this report. The company works in 5 shifts, and the factory is operating 24 hours every day of the week.

1.2 Problem description

The company puts a lot of value in delivering products that are of the highest quality, no defects are accepted by the company. While discussing with people at the company it is also said that the competition is hard within the industry, making it very important for the company to show that they can deliver products without any flaws.

The processes are not as clear to everyone as the company would like them to be, meaning that the company has found it difficult to implement a fixed way of performing quality controls of the products. Because of the different shifts at the company, it is most likely that different shifts are performing their quality control checks differently, leading to a variety and uncertainty in quality.

There has been an issue with different types of defects in the production at the case company. Since the products are automatically put on pallets, it leaves little room for detecting defects before the products are delivered to customers. The rate of defects needs to be very low. The company has little knowledge to what extent the different types of defects occur, meaning that there is a general picture of what the problem is but without any precise evidence leading to difficulties in establishing the root cause of the problem.

1.3 Purpose and research questions

The plastic industry is a debated area because of the view people have on plastic, that it has a negative effect on the environment. Therefore, manufactures within the plastic industry need to shift their mindset towards a more sustainable view by producing
biodegradable products. At the same time, manufacturers strive to reduce defect parts and products since they have a negative effect on their revenue.

Based on the problem formulation, the purpose of this research is to explore how defective parts and products affects the sustainability aspect of manufacturing companies and how defects can be reduced.
To reach the purpose of the research, three research questions has been formulated. This leads to the first research question of this report (RQ1):

How can reduction of defective parts and products improve the sustainability aspect of manufacturing companies?

It is stated that the manufacture has a problem with defected parts and products to some extent that needs to be reduced. It includes collecting data and analyse the data that is collected. When analysing the data this report aims to identify the most common defected types in production at certain processes. This leads to the second research question (RQ2):

What are the most common defects in the processes and what are the causes behind?

When the most common defects are identified, the certain processes surrounding the automated packaging system needs to be sorted out and understandable. Then it is possible to improve the processes surrounding the automated packaging system in order to decrease the number of defected parts and products. The processes that are investigated are based upon what are the most occurring defects. This leads to the third research question of this report (RQ3):

How can the processes be improved in order to decrease the number of defects?

To answer these questions, a case study will be conducted at the company.

1.4 Scope and delimitations

The studied area of this thesis is limited to one company and a certain set of machines and their processes. Defective parts and products that could be identified in the processes before the studied area, the supply of raw material and components to the machines, is not included. Defected parts and products that could be identified in the processes after the studied area are not being included in this thesis report.

Constrains regarding the time aspect, this study is narrowed down as further into the project it gets. The focus area that contains 7 machines have been narrowed down to 2-3 machines, chosen with regards towards the highest percentage of defects. To include all 7 machines through the whole study would be time-consuming and could lead to a vague result for this thesis. To answer the second research question, this study has been further narrowed down regarding the different types and classification of defects. Hence, the types and classification of defects that stand for the highest percentage regarding defects is in main focus.
1.5 Outline

The second section of this report describes what type of method that has been used throughout the study. It describes the work process of the study and the implementation of the chosen method.

The third section of this report contains the Theoretical Framework. Relevant concepts and terms are presented in this section that further on is contributing to the study and different theories that are brought up and compared towards each other.

The fourth section of the report is outlining the empirical data that has been gathered during the study. The empirical data is presenting the current state of the studied area at the company and contribute to the purpose of the study.

After the empirical data section, the analysis takes form. In this section of the report, the empirical data gathered is analysed in combination with the theoretical framework section. Hence, the analysis is based on the studies of empirical data and theories.

The last section of the report is the discussion and conclusion part. This section is describing the study’s results and implications, further recommendations and solutions to the purpose of the report.
2 Methodology

This section starts with describing the connection between the research questions and the methods that have been chosen. The section progresses with describing the timeframe in which the thesis has taken place and which processes that have been worked on during specific weeks. The research questions are then described, and the methods used to answer these research questions are defined and motivated.

2.1 Connection between research question and method

The following sub-section describes what methods have been used in order to answer this report’s research questions. Figure 2.1 is presenting a visual illustration of the connection between the research question of this report and the methods used to answer these research questions.

![Figure 2.1 – Connection between research questions and methods](image)

To answer the first research question, a literature review of the subject is conducted. The search engine PRIMO at Jönköping University is used to get reliable sources and references, books related to sustainability are also used.

To answer the second research question for the study, company documents regarding defects related to the processes investigated are gathered in combination with informal interviews with different employees at the company. Observations are performed at the plant, around the chosen processes. The informal interviews with the project manager are carried out continuously through the project. However, at the beginning of the case study, the interviews are performed in order to grasp the problem situation. The informal interviews with the project manager are crucial for collecting relevant empirical data for the case study. Other informal interviews are carried out with
different operators that worked closely with the processes analysed. The collected company documents that are analysed contained data regarding the number of defects, defects categorisation, in what processes and what type of product.

To answer the third research question, previous results from interviews, observations and document studies lay the foundation for working with the improvement of the processes. A literature review and interviews are performed, and a questionnaire is analysed. The interviews carried out at this stage of the study are both formal and informal.

2.2 Working process

The timeframe for this case study is stretched between January 2020 and May 2020, and the work process can be described throughout five different main phases. The writing of the report has been carried out continuously throughout the timeframe. The work process of the study is illustrated in Figure 2.2. The purpose of the illustrated Figure is to give the authors a structured way to perform the different phases, and easily conclude if the project is in phase or not.

![Figure 2.2 – visualisation of the working process during the study](image)

The first phase, illustrated in Figure 2.2, is the introduction phase. Within this phase, the authors create the purpose and formulate the research questions. A meeting with the supervisor at the case company created the foundation for the problem formulation by explaining the objectives of the case. After the introduction phase, the selection of relevant methods is carried out. The methodology phase and literature phase are partially simultaneously performed in order to strengthen and help the authors to choose relevant methods. The empirical phase is also partially carried out simultaneously with the literature review to support and contribute towards the gathered data. The empirical phase contained various interviews, documentation studies, observations and a
questionnaire, i.e. both primary and secondary data. The purpose of the empirical phase is to gather an extensive amount of data regarding the problem studied, to give the study a fair/right possibility to succeed. The last phase contains analysis of the empirical data, a result section followed up with discussion and conclusion, and ending up with how further research within the subject could proceed.

2.3 Research approach

To successfully fulfill the purpose of this report, both a quantitative and a qualitative approach is used. Since the performed case study is quite specific, the reader must get the whole picture of the situation at the case company to fully understand the content of this case study.

The quantitative approach is used in examining the data regarding the amount of defected parts in the production. Collecting numerical data to reach the relationships between different factors and further develop a conclusion that can be generalised is referred as a quantitative approach (Bell & Waters, 2014). By doing this, the report is be able to get more into depth in finding reasons that contribute to an increase of defected parts. The qualitative approach is used more in the latter part of the report where the different reasons that contribute to an increase in defects are being examined. Bell and Waters (2014) point out that a qualitative approach is more focusing on perceptions of individuals and generally contains non-numerical data and uses different methods at the beginning of the case study to further funnel it down as the case study progresses.

By approaching this report from an inductive approach, the authors get the opportunity to be open towards many possible ways of answering the research questions, however, according to Larsen (2017), it is impossible to be exclusively inductive or deductive. Therefore, this report has an abductive approach, which is a mix between inductive and deductive approach (Patel & Davidsson, 2019). By analysing the collected empirical data through its concepts and patterns, that later can be related to some theory, while other concepts and patterns may not be found in theory, is known as abductive reasoning (DePoy & Gitlin, 2005). The risk with having an abductive approach is that the authors could turn to look at situations where they already have experience from before, instead of looking at the actual problem (Patel & Davidsson, 2019). On the other hand, choosing the abductive reasoning approach gives the opportunity to generate a new theoretical ground from the study and at the same confirm the result with already existing theory (DePoy & Gitlin, 2005).

2.4 Design

The research approach used for the project is a single-case study. A single-case study refers to when the research only contains one case in one context (Yin, 2012). Case studies are pleasant to use when conducting an individual research project and the time aspect does not need to be considered. Case studies are a good method to use when one wants to study a problem more in-depth and could be used as a follow-up for a survey that has pinpointed out a problem that needs further investigation. However, case studies are more common to be used interdependently of a survey for example and could be referred as an exercise with no constrains. To collect evidence for the researched carried out, empirical data are most common to be collected through interviews and observations within a case study. Another vital aspect that case studies researchers aim
to map out is the unique and common features that individuals or organisations have. Features that can influence different functions for an organisation and how different systems within the organisation can be affected by implementation of new methods (Bell & Waters, 2014).

2.5 Data collection

According to Bell and Waters (2014), to strengthen the study, more than one method is used to collect the empirical data. Therefore, multiple methods of collecting data are used throughout the study to enhance the result. Using multiple methods is called triangulation in literature and means that using different methods to study the same problem, allows the researcher the opportunity to study the problem from a different perspective. However, if there is a mismatch between the results it could be time-consuming to examining and find the reason behind, since it does not necessarily mean that the data collected is faulty (Bell & Waters, 2014).

2.5.1 Interviews

One of the methods chosen for collecting the empirical data is through interviews. The quick response and the opportunity for the interviewed person to clarify its response during an interview is of major advantages compared to answering a questionnaire (Bell & Waters, 2014). The choice of conducting interviews gives the authors a greater insight into the problem and the current state at the case company by performing interviews with managers and operators. Bell and Waters (2014, p.178) continue to state that ”It is a highly subjective technique and therefore there is always the danger of bias”. By using interviews as a method, one’s needs, therefore, to be aware of the weaknesses it can have in wording the question, interpreting the response and/or notes taken from the interview (Bell & Waters, 2014). To address the weaknesses, both authors participate and takes notes from the interviews, and ask the respondent to clarify answer whenever necessary. It is also decided to use a mix of semi-structured and unstructured interview style to avoid wording problems with the questions. The chosen interview-style allows the authors to guide the interview towards the goal with both open and pre-formulated questions which gives the respondent the opportunity to assist with valuable information that could be missed. Table 2.1, presented below, shows how and when the different interviews were performed. Table 2.1 also shows the interviewed employee and time spent on each interview.

| Table 2.1 – interviews performed at the case company |
| --- | --- | --- | --- |
| Date       | Method         | Position             | Time (h) |
| 2020-01-20 | Semi-structured | Improvement manager | 1,0      |
| 2020-01-28 | Semi-structured | Planning manager    | 0,5      |
| 2020-01-28 | Semi-structured | Develop manager     | 0,5      |
| 2020-02-05 | Semi-structured | Improvement manager | 1,0      |
| 2020-02-05 | Unstructured   | Operator             | 0,5      |
| 2020-02-19 | Unstructured   | Improvement manager | 0,5      |
Methodology

<table>
<thead>
<tr>
<th>Date</th>
<th>Method</th>
<th>Role</th>
<th>Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020-02-19</td>
<td>Unstructured</td>
<td>Technician</td>
<td>0,5</td>
</tr>
<tr>
<td>2020-02-26</td>
<td>Semi-structured</td>
<td>Quality manager</td>
<td>0,2</td>
</tr>
<tr>
<td>2020-02-26</td>
<td>Unstructured</td>
<td>Quality controller</td>
<td>0,5</td>
</tr>
<tr>
<td>2020-03-05</td>
<td>Semi-structured</td>
<td>Improvement manager</td>
<td>0,5</td>
</tr>
<tr>
<td>2020-03-11</td>
<td>Unstructured</td>
<td>Improvement manager</td>
<td>0,5</td>
</tr>
<tr>
<td>2020-03-11</td>
<td>Unstructured</td>
<td>Technician</td>
<td>0,3</td>
</tr>
<tr>
<td>2020-03-11</td>
<td>Unstructured</td>
<td>Operator</td>
<td>0,3</td>
</tr>
</tbody>
</table>

The interviews are mainly performed individually with managers and operators that work or is involved with the processes studied. The interviews with the operators give insight into how they perceived the problem while the interviews with managers gives a broader perspective of the situation and deeper knowledge about the processes.

2.5.2 Observations

Observation is referred as a technique to gather data by watching a task or multiple actions being performed of someone and is a good complement to use after conducting interviews (Bell & Waters, 2014). To strengthen the information of the current situation at the company, provided by interviews, observations of the processes are conducted. The study is using a *direct observation* method, which allows the observers to study real-world events, which is seen to be a major advantage in case studies (Yin, 2012). The main purpose of the observations is to collect primary data about the current state of the processes and gather data that can provide valuable data to answer the second research question. The study has used unstructured observation at the beginning of the case study which is a common approach to use when the level of detail is low, but the purpose is clear (Bell & Waters, 2014). As the study emerges and the different objectives to study more in-depth is set, a structured observation approach is performed. The observation itself is a process, a process that verifies if processes observed are carried out as they are meant to and is therefore conducted at the plant after the interviews (Bell & Waters, 2014). According to Bell and Waters (2014), conducting observations along can be seen as bias, hence, all observations are performed by both authors which makes the study more reliable. Yin (2012) further describes another aspect that observers should have in mind, prescheduled observations. Conducting preschedule observations allows the observed participants to perform their activities in another way that might not reveal reality. Table 2.2 presents information regarding the performed observations at the case company.

*Table 2.2 – Observations performed at the case company*

<table>
<thead>
<tr>
<th>Date</th>
<th>Method</th>
<th>Time (h)</th>
</tr>
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<tbody>
<tr>
<td>2020-01-28</td>
<td>Unstructured</td>
<td>3,5</td>
</tr>
<tr>
<td>2020-02-05</td>
<td>Unstructured</td>
<td>4,0</td>
</tr>
<tr>
<td>2020-02-19</td>
<td>Unstructured</td>
<td>3,0</td>
</tr>
<tr>
<td>2020-02-26</td>
<td>Structured</td>
<td>4,5</td>
</tr>
<tr>
<td>2020-03-05</td>
<td>Structured</td>
<td>4,0</td>
</tr>
<tr>
<td>2020-03-11</td>
<td>Structured</td>
<td>5,0</td>
</tr>
</tbody>
</table>
2.5.3 Document studies

Documents provided by the case company have been of great importance for the case study and play an important role in answering the second research question. One of the studied documents contain historical numerical data and information about defected parts and products. This document is collected from their data system and exported to an Excel sheet. The ability to export the data to an Excel sheet made it possible for the authors to structure up the data in their way and filter out data that are not connected to the processes studied. However, using secondary data increase the risk of bias (Bell & Waters, 2014). To handle the concern regarding secondary data to some degree, further interviews with managers are performed.

Documents regarding quality-controls are studied to compare the data collected from the interviews, observations and the questionnaire. Carried out document studies are presented in Table 2.3.

<table>
<thead>
<tr>
<th>Date</th>
<th>Document Type</th>
<th>Type of Data</th>
<th>Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020-02-05</td>
<td>Company data system</td>
<td>Secondary data</td>
<td>1.5</td>
</tr>
<tr>
<td>2020-02-19</td>
<td>Company data system</td>
<td>Secondary data</td>
<td>1.0</td>
</tr>
<tr>
<td>2020-02-26</td>
<td>Quality check</td>
<td>Secondary data</td>
<td>1.0</td>
</tr>
<tr>
<td>2020-03-05</td>
<td>Company data system</td>
<td>Secondary data</td>
<td>1.5</td>
</tr>
<tr>
<td>2020-03-05</td>
<td>Questionnaire</td>
<td>Primary data</td>
<td>1.5</td>
</tr>
</tbody>
</table>

2.5.4 Questionnaire

The purpose of the conducted questionnaire is to collect data regarding the operators’ attitudes and feelings about the current standard of quality-controls and defect-registration. According to Bell and Waters (2014), the most suitable question type to use when one’s wanting to have knowledge about the respondent’s attitudes and feelings are scales questions. To avoid some of the pitfalls that Bell and Waters (2014) describes when it comes to wording the question and develop a questionnaire, the avoidance lack in knowledge is taking into consideration by offering to the respondent to tick in the column “Don’t know”. The developed questionnaire is inspired by a simplified Likert scale, offering the respondent to choose between five different answers. All respondents are handled with anonymity in order to protect the participants and avoid biased answers.

2.5.5 Literature review

The literature review is crucial for the researcher in terms of creating a broader view of the studied topic. It is a time-consuming process that involves interpretation of a vast amount of literature connected to the topic (Bell & Waters, 2014). Scientific articles, textbooks, and literature are included in the literature review.
The literature review for this case study takes its shape from the research questions with influences of the purpose. To get a good start of the literature review, Jönköping University’s own search-engine Primo, a developed search-engine containing a vast collection of databases, is used to find relevant search-terms and keywords. Progressing from the keywords and search-terms, the literature review moves towards specific databases that contained more relevant literature for the research topic. The main database used is Scopus. The chosen databases result in that the search-area is limited and yet give the authors relevant literature for the research. To strengthened and ensure that the report has sufficiently academic ground, the authors chose to filter-out articles that are not "peer-reviewed". To publish an article that has been examined by an individual of equal merit, but independently, within the topic is seen to be a "peer-reviewed" article. Table 2.4 presents the keywords and search-terms that have been used, combined with the number of hits from the database Scopus. The table reveals that the authors have used different techniques for searching in other to limit the number of hits.

### Table 2.4 – Search method used for finding literature

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Search-term</th>
<th>Nr. hits</th>
<th>Abstracts read</th>
<th>Used</th>
</tr>
</thead>
<tbody>
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<td>Sustainability, triple bottom line, supply chain</td>
<td>“Sustainability AND “triple bottom line” AND “supply chain”</td>
<td>269</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Process, Definition, Plastic injection molding, Optimization</td>
<td>Process AND “Plastic injection molding” AND Optimization</td>
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<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Production, defects, optimization, manufacturing</td>
<td>“production defects” AND Manufacturing</td>
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<td>3</td>
<td>1</td>
</tr>
<tr>
<td>5s, manufacturing, results</td>
<td>5s AND manufacturing AND impact</td>
<td>50</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Jidoka, manufacturing, results</td>
<td>Jidoka AND Manufacturing</td>
<td>31</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

### 2.6 Data analysis

The study is using both quantitative and qualitative data. As mentioned previously, qualitative data can be described as information gathered in non-numerical data while quantitative data is information gathered in numerical data (Yin, 2012). Yin (2012) further describes that to ensure a good start of the analysis part, systematic organisation of the collected data is performed. Five different methods, previously described, is used to collect the data and are illustrated in Figure 2.3. Figure 2.3 illustrates how the
different methods of data collection are displayed and how theory and the empirical data are analysed towards each other, hence the data analysis.

**Figure 2.3 – The data analysis of the study**

This type of data analysis is referred to as *pattern matching* and is an analytic technique that builds on patterns. The patterns found in the empirical data are compared to the theoretical patterns found in the literature review in order to find similarities, hence the name *pattern matching* (Yin, 2012).

### 2.7 Reliability and validity

There are both advantages and disadvantages in choosing a case study as the research methodology. A disadvantage is that it could be difficult to get a result that is generalising and not to specific, however, a case study provides the opportunity to study an aspect in depth (Bell & Waters, 2014).

Reliability is described as the ability of a process to produce the same results every time (Bell & Waters, 2014). The raw data that is gathered from the case company are known to not be perfect due to the lack of consistency in registering the data. Therefore, this is taken into consideration when analysing the data. The survey is tested on people with similar work tasks at the case company to increase the reliability of the survey.

Bell and Waters (2014) describe validity as a concept that is more complex. It is described as how the research is designed to provide trustworthy conclusions, furthermore, the research answers what it claims to answer. The survey of this report is tested on people with similar work tasks at the case company to make sure that the people answering the survey understands the questions, this to make sure that the real answers from the report gives a result that answers the questions of the report.

By using multiple methods, it allows the research to look at the problem from different angles that investigate similar things. This gives a more robust result and gives the report both more reliability and validity (Denscombe, 2017).
3  Theoretical framework

This section starts by describing the connection between the theories and the research questions. It continues with the theoretical part that is the supporting foundation of the study that will contribute to the purpose and the set research questions of the study.

3.1 Connection between theory and research questions

The following sub-section are describing the theoretical part of this study that is the foundation for answering the research questions of the report. Figure 3.1 illustrates the connection between the research questions and theories that have been used to answer the research question.

![Diagram showing the connection between RQ1, RQ2, and RQ3]

Figure 3.1 – The relation between theory and research questions

The theories that are the supporting ground to answer the first research question “How can reduction of defective parts and products improve the sustainability aspect of manufacturing companies?” are sustainability and processes. Furthermore, the different lean theories that have been chosen to study are lean manufacturing, seven waste +1, defects, and supporting tools within lean. The theory of sustainability is processed because the understanding of the concept sustainability is vital to understand before one’s can see if the reduction of defected parts and products has a positive or negative effect on the sustainability aspects. The theory of processes is used since manufacturing companies perform a vast amount of different processes and are therefore an important
theory to grasp that can support the answer. The lean theories are processed to support the findings of how different tools and methods within lean could play a role in improving the sustainability aspects.

The theories behind that are processed for the second research question “What are the most common defects in the processes and what are the causes behind?” are the theories of processes and the lean theories; seven waste +1, defects and tools. The theory of processes supports the answer in the way of understanding the concept and the processes used at the case company. The lean theories are used to evaluate and identify the different defects and their causes at the case company. To answer the third research question “How can the processes be improved in order to decrease the number of defects?”, the theory of processes and the lean theories; lean manufacturing, seven waste +1, defects, and tools are used. These theories are used to identify what possible actions can be performed to reduce the number of defects and, hence, the negative effect.

3.2 Sustainability

Sustainability is a commonly discussed topic in today’s society, one of the most used definitions of what sustainability is, “development that meets the needs of the present without compromising the ability of future generations to meet their needs” (Carter & Rogers, 2008 p. 363). Sustainability consists of three components, social, economic and environmental performance, which constitute the triple bottom line. Today, companies have a big influence on questions regarding sustainability, therefore they also have a big responsibility to not run their business in a way that endangers the environment or the social standards (Koplin et al., 2007).

One of the most used materials nowadays is the plastic, a fossil resource that is stated to be a non-renewable resource. To recycle non-renewable materials is of major importance to not reduce the availability of these materials even more and pollute our nature, however, statistics presented in 2012 showed that 36% of plastic materials were transformed into energy and 26% were recycled. This means that 38% of plastic materials were not handled with concerns to the environment and were placed in landfills. Recent studies have argued that greenhouse gases could be reduced up to 80%, if all plastic materials would be recycled, and that defected items and scrap from production of different plastic products should be seen as renewable. If manufacturers re-use defects and scrap in their production, and the use of recycled plastic materials, they will contribute to the sustainable development which is encouraged by the market (Gu et al., 2016).

ISO 14001 is a set of guidelines that enables companies to reach sustainable goals. These guidelines also enable companies to cost savings through energy efficiency. During recent years there has been an increase in ISO 14001 certified companies throughout the world, in Europe. In the year of 2000 there was a total of 7253 certified companies. By the year of 2015 that number had risen to 119 754 companies. In Asia, the growth has been even bigger during the same time period where 5234 certified companies have become 173 324 (Salim et al., 2018). One of the area ISO 14001 covers is the environmental management system (EMS). According to Melnyk et al. (2003) an EMS consist of data based on several things, such as, procedures and processes of training employees, summarising and monitoring. They also continue by describing the EMS as crucial for companies to gain any competitive advantages in terms of
environmental goals. What the ISO 14001 standards do is that they enable the foundation of an EMS, which in turn enable the management to succeed with a number of things. Examples of this are, it gives the opportunity to develop an environmental policy that suits the company, it becomes possible to monitor the processes so that the policy is fulfilled. It also makes sure that laws regarding environmental performance are followed. it encourages people at the company to be aware about the environment, to protect it and encourage external parties to establish an EMS (Melynk et al., 2003). Research has shown that a presence of a certified EMS has a strong impact on the company’s environmental performance. It is also seen as a positive outcome with ISO 14001 that management is forced to evaluate the processes more than the final output from the company (Melynk et al., 2003).

3.3 Process

When looking up the word process in a dictionary it says “A controlled sequence of continuous or discrete events or actions designed to produce a pre-specified end result which may be a product” (Escudier & Atkins, 2019). Processes are a big part of the production and over 70% of today’s products have a relation to the plastic material and the industry of mould making, therefore, it plays an important part in today’s society. The constant changes in customer demands in form of different specification such as design features or quality, for example, has developed difficulties for the industry. The moulding process is a very complex process that demands highly experience management. One of the most important processes within this industry is the injecting moulding process and most of the manufacturers prefer to use this process since the advantages of highly complex items can be produced through plastic injecting moulding. The cycle time is considerably shorter than other plastic processes and the features of the products become more accurate. However, when the features shift and the specification of items require a reduced thickness of any wall at the items, defects are starting to occur (Tang et al., 2007).

Operating a plastic injection moulding machine comes with setting different process parameters, such as melt temperature, fill time, packing pressure, packing time, and mould temperature. Dang (2014) explains that having optimum process parameters has a great influence on the result of the moulded part, the optimum process time can reduce the cycle time and increase the quality of the product. Further, these process parameters are set by the operator of the machine, what parameters the operator is setting the machine to is based on his or her own experience.

3.4 Lean manufacturing

During the twenty-first century, the ever-growing need for customised products has forced manufacturing companies to deal with a more complex situation of mass production. The markets change to a customer-driven approach has made control systems and planning of the production to a major challenge for manufacturers. Furthermore, globalisation has increased the competition among manufacturers. They have been exposed to the global market and need to deal with and come up with a competitive advantage on the global stage (Bhamu & Singh Sangwan, 2014). On top of that, climate change is another aspect that different stakeholders, regulators and customers, etc, have raised their concerns about in recent years. This has resulted in even more pressured towards manufacturers to take responsibility and operate in a more
sustainable manner (Cherrafi et al., 2016). The situation of a more complex situation for manufacturers forced them to look for another strategy to overcome the problems, they needed to both be profitable and meet the new demands that the stakeholders raised. One way to attack the problems for manufacturers are to embrace and implement Lean manufacturing (Bhamu & Singh Sangwan, 2014).

Lean manufacturing has its origin in the Toyota Production System that was developed in Japan and then further, when it reached worldwide, it was more known as lean manufacturing (Verrier et al., 2016). Lean manufacturing was introduced for western manufacturers as a way to handle operations with excellent results through minimisation of waste and enhanced quality (Van Der Steen & Tillema, 2018). However, the definition of lean manufacturing is not accepted in literature and there are different ways of describing it. Bhamu and Singh Sangwan (2014) argues that the divided meaning in literature has to do with the long evolve of lean manufacturing and mention that lean manufacturing can be; a set of tools and technique, a process, an approach, a set of principles, a concept, a program, a philosophy, a model, a practice, a manufacturing paradigm or a system. In a recent paper written by Alhuraish et al. (2017), lean manufacturing is described as a methodology for organisations to use in order to remain or create a competitive advantage. This way of defining lean manufacturing goes in line with the scope and goals of lean manufacturing which is to reduce waste and act on customer demand (Bhamu & Singh Sangwan, 2014). By reaching that, Bhamu and Singh Sangwan (2014) further argue that the manufacturer reaches a competitive advantage in terms of increased quality, higher productivity and lower cost. Alhuraish et al. (2017) argue that lean manufacturing practitioners only can reach a competitive advantage through continuous improvement in sustainable development and waste reduction. This means that Bhamu and Singh Sangwan (2014) and Alhuraish et al. (2017) both see that competitive advantages are gained by implementing Lean manufacturing. This is further strengthened by Verrier et al. (2016) that describes that costs can decrease, and waste can be reduced through the implementation of lean manufacturing.

The connection between lean manufacturing and sustainability are not always clear at the beginning for manufacturers. The pre-conception has been that it is hard to achieve all three elements at the same time; environmental, economic, and social sustainability. The main barrier and pre-conception have been that an organisation cannot be economically sustainable if they want to be social and environmentally sustainable (Cherrafi et al., 2016). However, the shift from good-to-have to must-have, regarding sustainability, for organisation has progress the operations of how organisations need to overcome the barrier. To choose whether they want to take responsible actions towards economic or social and environmental is no longer an option. Cherrafi et al. (2016) further describe that organisations in the last decade have changed their view of the barrier previously described by realising that the outcome of being social and environmentally responsible has a positive effect on the economics. By implementing a lean manufacturing methodology, organisations do not longer need to choose.

To succeed with a lean manufacturing methodology, existing control systems at the manufacturer needs to be adjusted in a way that fits the purpose, to reduce waste and act on customer demand (Van Der Steen & Tillema, 2018). The need for adjustments in the manufacturer control system is strengthened by Alhuraish et al. (2017) that describes how lean manufacturing encourages the development of systems in an innovative way that improves sustainable development. Hence, knowledge of how to reduce waste and what different types of waste there is within the manufacturer needs to be understood in order to adjust the systems.
3.5 Seven waste +1 in Lean

Mentioned previously, the main goal of lean manufacturing is to reduce or, in the best possible outcome, eliminate waste. To produce products or services at an optimal quality level for the customers and at the same time reduce or eliminate waste could be seen as an easy task, but to identify the different waste for organisation could be difficult (Ghosh, 2012). The term itself, waste, is therefore a central and vital term in Lean and are described as a non-value adding activity that only has a negative effect on the manufacturer’s revenue (Neuwirth, 2019). To understand and distinguish between which activities that are non-value adding and value-adding, one needs to see the processes from the customers’ perspectives (Sternberg et al., 2012). The term waste was introduced and founded by the Japanese chief engineer Taiichi Ohno, who worked at Toyota and was the developer behind the Toyota Production System (Neuwirth, 2019). Within manufacturing processes, the methodology of lean has identified seven different waste that lean practitioners should focus on to reduce or eliminate. The positive effect of eliminating one of the wastes depends on what type of waste it is, which means that they are not seen as equal in the literature (Sternberg et al., 2012). The seven types of waste, or muda as Taiichi Ohno would say, are; inventory, over-production, motion, over-processing, defects, transportation and waiting (Neuwirth, 2019). Depending on what book or author, the name of each waste could be slightly different, but the content is the same. However, the seven waste has increased to eight since researchers have argued that unused creativity is a missed opportunity for the organisation (Sternberg et al., 2012).

The waste Unused creativity is described by Liker and Meier (2006) as the loss of valuable resources that employees can give the organisation in the form of skills and improvements for example.

Excess inventory means not only that the manufacturer ties up capital in forms of goods, but also costs that can be associated with excess inventory. By building up an excessive inventory means that operational costs of holding that inventory increase and that the manufacturer is exposed to different types of risks. Obsolescence and damaged inventory are two potential risks that a manufacturer is exposed to when building up an excessive inventory. Factors that drive excess inventory could, for example, be uneven workflow and over-production (Neuwirth, 2019). Liker and Meier (2006) fill in that excess inventory is hiding a number of problems that can be hard to grasp and are described as factors that drive it. Therefore, Inventory is seen as a possible waste in lean literature.

By producing parts and products that there is no customer demand is seen as waste in terms of over-production (Sternberg et al., 2012). Waste in the form of material and labour efforts is two examples of outcomes that origin from over-production. There is also a clear connection between excess inventory and over-production, over-production drives excess inventory (Neuwirth, 2019). Liker and Meier (2006) add that this type of waste is perhaps the most important one to sort out since it is the root cause for many of the wastes.
**Theoretical framework**

*Motions* or unnecessary movement refers to how the employees are moving while performing their work tasks (Sternberg et al., 2012). This includes activities like searching and reaching for tools and parts etc (Liker & Meier, 2006).

*Over-processing* can be called incorrect processing and refers to when the manufacturer puts more effort to perform a process than necessary (Sternberg et al., 2012). Neuwirth (2019) describes over-processing as adding any feature to the product that is seen as unnecessary from the customers’ perspective. By adding a feature that increases the quality more than necessary can for an untrained eye seem reasonable, however, from a lean perspective, this is seen as a waste (Liker & Meier, 2006).

External and internal transportation is something that manufacturers need to perform. However, long repeated transports results in high operation costs in terms of labour efforts and time, hence waste that needs to be reduced. By reducing the distances and time spent on transporting, manufacturers can mitigate losses from *transportation* waste (Neuwirth, 2019). Despite this, Liker and Meier (2006) argue that even the short distances of moving parts etc, is a waste.

Queuing is probable the first thing one thinks of when hearing waiting time, and in terms of a waste, it refers to the waiting time for an operator (Sternberg et al., 2012). Poor planning of replenishment and inconsistent processes are two examples that can cause waiting time for the operators. Manufacturers should therefore strive to have as predictable flows as possible to reduce the waiting time, which is seen as one of the major wastes nowadays (Neuwirth, 2019).

When the produced part or product deviates from the normal distribution, inconsistent with the specification and quality requirement, it is seen as a *defect* (Neuwirth, 2019). By performing rework of defect products and parts, results in unnecessary effort and lost time (Liker & Meier, 2006). The reason behind a defected product could, for example, be a human error or wrong material used. One important aspect that manufacturers need to consider is that defects do not only have a negative effect on the manufacturer’s revenue, but it can also cause tremendous damage to the manufacturer’s image (Neuwirth, 2019).

### 3.6 Defects

A part or product is seen as defective when it deviates from the normal distribution, inconsistent with the quality requirements and the specification (Neuwirth, 2019). Pivachat and Chanongkorn (2015) describe a defected product from the usage perspective by saying that any flaws on the product that can expose the user of any danger are referred to as a defect product. Hill (2018) is more into the first explanation of defects by describing defects as any scrap that comes from the production process and items that needs rework. Defects could also be described as the difference between the actual output and the preferred output of a product or service (Dhafr et al., 2006). The definition of what defects is in literature are many, however, its meaning of defected parts and products are more or less the same.

Since manufacturers perform any kind of quality inspection to detect and sort out nonconforming parts and products, one’s can conclude that manufacturers know that their processes will produce defects (Dhafr et al., 2006). It is not only vital to identify
these defects in the production for manufacturers, to do it quickly is of major importance to reduce the number of defects (Neuwirth, 2019). However, when a defective part or product has been identified, that part or product is lost since it has already been produced in the process (Dhafr et al., 2006). The identifying step in the production processes should not only cover that one detects a defect, to clarify the cause or causes behind it is of importance to perform corrections (Neuwirth, 2019). The correction of defects could be an expensive activity for manufacturers to perform since these activities are related to costs that can arise during the problem-solving phase, rework of defects, detection of defects, etc (Neuwirth, 2019).

Neuwirth (2019) further describes that the cause, or causes, behind defects could be very different depending on what type of product that is produced. The cause behind a defect, according to Dhafr et al. (2006), is some kind of an error that could result in defects, but it is not always detected during quality checks and therefore it could lead to failure. However, the use of not proper materials, usage of non-optimal equipment, and human errors are common causes in the world of manufacturing according to Neuwirth (2019). What should be added is the process variation and the processes itself, meaning that the use of non-optimal process operations can result in defective parts and products. It can further be related to different variables within, or without, the processes that affect the processes (Dhafr et al., 2006). Dhafr et al. (2006) further describe these affecting variables to be; actions performed by humans, the experience and skill level at the employee, the surrounding environment at the process and the machines’ capabilities.

No matter the underlying cause or causes, defected parts and products that go to scrapping is not only a waste of materials, it results in loss of effort, wear of equipment, energy consumption, and time losses. Neuwirth (2019) further describes that the costs of the new parts or products that need to be produced to replace the defects are also a waste. To re-design the processes could be an option, or to implement tools that could identify and detect defects quicker to make corrections faster (Hill, 2018). It is not only crucial to identify the flaws in the process, to choose the most optimal tools and methods are as equally important when one is dealing with improvement projects (Dhafr et al., 2006).

3.7 Tools

5S stands for five actions within Lean manufacturing that is used to create a standardised and organised workplace. The five actions are, sort out, set in order, shine, standardise and sustain (Myerson, 2012). These five actions help creating a clean workplace and the effects of that are improved efficiency, fewer accidents, and also a foundation for all other lean tools. During the first S (sort out) the focus is put on eliminating unnecessary items from the area. During the second S (set in order), the goal is to create storage for everything that is supposed to be in the working area, the target is to have an effective and easy to find storage solution. The third S (shine), the entire working area are cleaned, here it is also important to understand that this is not a one-time operation, daily maintenance is required to sustain this standard. The fourth S (standardise), is about standardising the changes that have been made to make them permanent. Finally, the fifth S (sustain) is most common the hardest S to succeed with, mainly because changing people’s behaviour and habits are very difficult, the sustain stage focus on creating a new standard and everything that was before is supposed to
be forgotten (Bayo-Moriones et al., 2010). It is hard to define what 5s is since in Japan, it is seen as a philosophy, while in USA and the UK, it is seen more as a tool. However, 5s does help workers to reduce waste in the form of waiting and unplanned down time to mention two (Bayo-Moriones et al., 2010). When working with continuous improvement, 5s is a common starting point for many companies, it is also the most widely known methodology in improvement work (Bayo-Moriones et al., 2010).

A good tool that was developed in Japan by Dr Kaoru Ishikawa is the Ishikawa diagram, also known as the cause-and-effect diagram or fishbone diagram. As the name of the cause-and-effect diagram reveals more or less the purpose of it, to map out the different causes and their effects on the investigated problem. It is a tool that can be used to get to the root cause of the investigated problem. Compared to the fault tree analysis (FTA), the cause-and-effect diagram is a lighter version of the FTA and it can be wise to perform a cause-and-effect diagram before (Bergman & Klefsjö, 2010). Bergman and Klefsjö (2010) continue to describe how one’s can perform the cause-and-effect diagram by the first set up the main problem that should be investigated. After that, map out the main causes and then focus on one of them at the time. When the cause-and-effect diagram is finished, it should contain a lot of different branches so that the diagram looks more or less like a fish with its bone. The result of a performed cause-and-effect diagram in combination with data collected can result in that the project needs further data to solve the problem (Bergman & Klefsjö, 2010).

Another appropriate tool/method to use to explore the different types of causes behind a defected part or product is fault tree analysis (FTA) (Makajic-Nikolic et al., 2016). The idea behind the FTA is to illustrate a negative event, that one’s wants to minimise its occurrence of or eliminate, and its connections and relations to different causes that are on the underlying level in the system (Bergman & Klefsjö, 2010). Makajic-Nikolic et al. (2016) describe that FTA started to be used in the nuclear industry and has then further been spread to a wide set of different industries since it has been shown that it is applicable in almost every industry. To formulate and build its own tree should start with formulating the top event that needs to be minimised, or in best case eliminated, and thereafter identify the different causes that have the closest relation to the top event. These causes should have a logical gate to the top event and then one’s should link the underlying causes until it reaches the basic events that could be dependent or independent (Bergman & Klefsjö, 2010).

Another tool that could be useful in this case is Jidoka which according to Liker (2004) refers to autononmation which describes intelligent automation with a human touch, a system that is built into a machine so that the machine in itself can stop the production if something is wrong. Romero et al. (2019) describe Jidoka as both a system and a technique. From a technique perspective, Jidoka aims to give the operators more time from the machines to make it possible for operators to handle more machines, this is done by a set of design principles. Jidoka is also a system in the machines, in this perspective, Jidoka aims to detect abnormalities in the machine and then stop the machine or alert an operator that maintenance is required (Romero et al., 2019). The Jidoka systems have over the years developed to what it is today, it started rather simply with that the system was able to find abnormalities and with that conclusion stop the machine to not produce defected products, however, today Jidoka systems are more advanced. Today the Jidoka systems are designed in a way that eliminates some of the human responsibilities. Today sensors and controls can detect abnormalities before it
even happens which eliminates the need for future maintenance from an operator (Romero et al., 2019). Jidoka is described in research as much more than just a system for detecting single errors, it is described as an important part of an organisation continues improvement work of constantly making a production better. A big benefit from a Jidoka system is that it adds value for both internal customers as well as external customers, it does not only free time for employees working at the machines, it also contributes to a higher quality on the products that will satisfy the external customers (Romero et al., 2019).
4 Empirical data

This section provides a current state situation at the case company through gathering of data in the form of primary and secondary data.

4.1 Current state

Figure 4.1 illustrates the area investigated in the case company. The illustration is not in scale and the seven machines are operated by 1-2 operators per shift that have support from 1 technician. The machines are producing buckets in different colours and shapes, no lids are produced in these machines. The replenishment of the main raw material, in the form of hard small plastic balls, is done through pipes that are connected to each machine and the silos that are standing outhouse. All the machines are connected to a conveyor-belt that transports the products to the palletising area where there are two automated robots that stack the products on pallets and when the pallet with products on are complete, an operator moves the pallet to the plastic wrapping machine that is located just a few feet away from the palletising area.

![Figure 4.1 – Area investigated at the case company](image)

4.2 Machine process

The company produces plastic products with plastic injection moulding machines (PIMM), these machines differ in size, producing different sizes of products. The material is in granulate form, that transports into the machine through pipes coming through the ceiling. These pipes are connected to a big tank further away in the factory. To customise different products, colours are added. The colours are also in granulate form and get sucked into the machine from a smaller container standing next to the machine. When the plastic material and the colour are sucked into the machine, the colours and the raw material gets mixed by the machine and then melts it before the blend is injected into the mould. The mould then cools the product until it gets solid. Another process in the machines is the in-mould labelling (IML), this process melts a label on to the products. The IML are put in the machine and a robot uses vacuum to pick up the IML and places it in the machine. In conversations with employees, they explained that there are occasions when the IML are the reason for many defected products and that it is hard to do something about it. The employees explained that the IML folds due to the humidity, even though there are sprinklers in the roof which are supposed to set the right humidity. There are also different brands of the IML, and the information gives that there are brands that are better than others in terms of how many defects that they generate. The reason for why IML of brands that are worse could not
be answered by the employees. Another problem with the IML that was specified is that when the IML has been used, the IML that is not used is often put back on the shelf without being put in a protective packaging, which results in a worse quality on the IML once it is used once again.

4.2.1 Cleaning process

The cleaning process is performed when there is a new order of products that should be processed in the machine. The cleaning process occurs at the process of distribution colour balls to the injection of plastic that is placed on top of the machine. The stairs up to the plateau where the operator or technician needs to stand when performing the cleaning process are not high enough, which means that the operator or technician needs to stretch over the railing to perform the process. The material, the colour balls, lie in small containers on the floor with a pipe in which sucks up the material to the colour distribution process. Most of these containers for all seven machines are not fully sealed. Some of the colour balls bounce in the wrong container when the cleaning process is performed in the colour distribution process. This appears since it bounces off the machine when the technician, or the operator, opens a hutch to the colour distribution process. The opening of the hutch is necessary when performing the cleaning process. During observations, it appears that the process of product change takes place in different ways and the material required for a change has different results concerning the amount of material that it is wasted.

4.3 Palletising process

When the products roll over in this area of the production line, the products need to be thrown away because they have ended up on the ground and are considered as defected. According to interviews and document studies, it appears that this part does not constitute a large part of defected products. When a pallet within this area rolls over it is because the palled used has been bad condition or the operator happened to overturn the pallet when using the lift-truck. There are no set standards for how the pallets placed in this process should be and the operator have to look for themselves for what they believe is a good pallet. At the palletising process, a final check of the products must also be done and signed by the operator that this check has been done. The signing of the last check is something that is not followed to one hundred percent.

4.4 Quality control

The quality controls are performed both by the operators working at the machines that make a visual control to check that the product has the right shape, colour, and that nothing else has compromised its quality. Besides the operators, there are also employees working exclusively with performing more in-depth quality inspections. They use different tools to make sure the product is in the right condition, even though the human eye can detect any defects. The quality-control standard for the products is stated clear and consists that the operator should perform 4 quality-controls for each complete pallet of products. A complete pallet with finished products is different regarding the number of products because it depends on what product it is. The routines for the quality-control that the operators should perform were investigated through interviews, observations and a questionnaire. The idea behind the quality-controls is to detect defects in an early stage. The standard for the quality-control has got approved
Empirical data

from top-management level, however, the standard is not followed. The operator’s main argument for not following the quality-control standards is that it is too time-consuming to perform. The high work-pace and process pace contribute to the operator’s opinions regarding lack of time.

Even though that the vision-system should detect defected products, sometimes it happens that the vision-system says that the products are within the range of what is good but the operators, later on, need to throw away the products because the vision-system had the wrong settings.

Table 4.1 illustrates the questionnaire, with the results, that was handed out to the operators that worked with the processes investigated. At the top of Table 4.1, the different qualification levels are displayed with a number and its coherent description. The numbers on the right-hand side of the questions in Table 4.1 is the number of employees who agreed on the qualification of each question. The number of participants of the questionnaire are 6 different employees. Question number 4 in Table 4.1 includes only 5 answers, and the reason behind is unknown.

The results from the questionnaire showed that the answer “Agree” was the most common answer with 34 marks. “Totally agree” which is the preferred answer, is the second most common answer with 15 marks. The answer “Partially agree” collected 12 marks and “Not correct at all” resulted in 4 marks.
### Table 4.1 – Questionnaire with results from the case company

<table>
<thead>
<tr>
<th>Question number</th>
<th>Questions answered</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The current quality-controls works in general well.</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>I know how the current standard regarding quality-controls should be performed.</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>I follow all parts in the current standard for quality-controls.</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>The current standard for quality-controls are easy to follow.</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>When I detect a quality fault, I always stops the machine to solve the problem.</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>When I detect a quality fault, I always document/report it.</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>The current defect-registration works in general well.</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>I know how the current standard regarding defect-registration should be performed.</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>I follow all parts in the current standard for defect-registration.</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>The current standard for defect-registration are easy to follow.</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>My experience is that the volume of defect are in general high in the production.</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Answer: 1 = Totally agree, 2 = Agree, 3 = Partially agrees, 4 = Not correct at all
4.4.1 Variation in performance

How the operators perform and act regarding quality-controls and registration of defects products is different from one operator to another operator. Comments from interviews on why the performance and acts regarding this appears, is that the training and learning are conducted differently. A few years ago, a newly employed operator got 10 days of training and learning the different work tasks and security around it. This was then shortened down to 5 days. To be trained and learned in 5 days is argued to be too short, the employee responsible for training the new employee did not successfully cover all parts that need to be covered during the training phase and the ability of learning differentiates from person to person.

4.5 Registration and detection of defects

Registration of defected products is something that the case company struggles with. The registered data of defects does not match reality, hence there is a huge number of defects that are not registered in their system. The registration of defected products is both handled manually and automatically. At each machine there is a small whiteboard placed were the operator is supposed to fill in the number of defects and the cause behind it. The whiteboards are supposed to serve as an aid for the operators by letting them fill in the whiteboards first and when time allows or after the shift, register it in the system. These whiteboards are empty even though the operators throw away defected products for recycling and at the same time do not register it in the system. The manual registration of defects allows the operators to choose between 12 different codes of the causes behind the defected products. For an untrained eyed, some of these codes are hard to differentiate between and see. Machine A-D has a vision-system that register defected products automatically. However, sometimes it is performed manually visual control by the operator of those products that the machine sorts out as defects. Through interviews and observations, it showed that operators perform the registration of defects differently, some of the operators perform the visual controls of the products that the vision-system has sorted out while some operators do not. The machines produce two product per cycle and the arms that put the products at the main conveyor-belt or at the conveyor-belt for defected products is constructed to place two products at each time. This results in that even when the vision-system detects that one of the two products in the cycle is defective, both products are placed on the conveyor-belt for defected products. Those operators that do not perform the manual visual control throws away both products instead. Registration of defected products connected to the machines E-G is only performed manually. After observations, interviews and the questionnaire, it showed that the set standard for registration of defects is considered to be tediously to perform, hence the standard is not followed. Through the document studies of the registered defects in the case company’s system, machine A-D that has the vision-system revealed that during some periods there are no defected products registered at all while the machines produces. If these machines produced products while the vision-system is off, means that the operators should register defects manually.

When a defect is detected, a technician is often called to the location. The technician investigates what type of defect it is and change the setting in the process and then goes...
to the next assignment. What sometimes occurs is that the technician has a preconceived
sense of what the right action is and change the settings, however, sometimes the
preconceived sense is incorrect. What happens then is that the machine continues to
produce defected products and the technician is recalled to the site.

4.5.1 Numerical data

The data that is gathered is secondary data from the companies own system where all
defected products are supposed to be registered. The data that is collected measures the
number of defects, what type of defect and what machine that has produced the defected
products. Figure 4.2 is an illustration of how the defects are divided on the machines at
the investigated area in the production.

![Figure 4.2 – Percentage of defects divided on individual machines](image)

The data, that Figure 4.2 illustrates, have been collected during a period of 43 days. One
can see that machine A-C stands for more than 70% of the defects, however, the number
of defects compared to the number of produced is not illustrated. Through interviews
and observations, it could be concluded that the numerical data of defects is not
representative of the reality, the reality contains more defects than what the data
provided to the authors was. From the numerical data collected, a standard mathematic
operation about probability could be performed. Machine A produces an average of 630
items per hour and roughly 15 items of them are defective. If the operator takes out a
sample of 30 items and then one uses the probability calculation; $P=1-P(\text{at least one}
defect)$, will give the probability of 52.3% that at least one of the 30 items are defective.
The calculations are displayed below.

Machine A: $P=1-P\left(\frac{615}{630}\right)\left(\frac{30}{30}\right)\approx 52.3\%$
Empirical data

Machine B: \[ P = 1 - P \left( \frac{779}{779} \right) \approx 37,3\% \]

Machine F: \[ P = 1 - P \left( \frac{785}{792} \right) \approx 23,8\% \]

The decision to go on with three out of the seven machines are done in order to narrow down the investigation. Machine A and B are chosen because they account for a large part of the defects and uses the same detection system. Machine F is chosen because it has the most defects out of those machines that do not have the same detection system as machine A-D have. Figure 4.3 illustrates how the defects are divided into the different types of defects that occurred at machine A, B and F. The data that are displayed in Figure 4.3 is a result of 43 days of data collection of defective products from machine A, B, and F at the case company. Each defect code has been calculated against the total number of defects and thus received a percentage of the whole.

![Figure 4.3 – percentage of defects divided on different causes](image)

The type of defect that stands out is the one “Cause cannot be found”. This type of defects, and “Cause missing” and “Auto scrap”, should be divided among the other types of defects. The type of defects “Start-up” is described as a need-to-have waste through the interviews, however, through observation, it could be seen that this type of defects has a strong relation to the type “Colour”.

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5 Analysis

This section provides an analysis where the empirical data and the literature review are compared. The section is divided into research questions.

5.1 Research question 1

How can reduction of defective parts and products improve the sustainability aspect of manufacturing companies?

Defected parts in the production that go to scrapping do not only result in material waste, it leads to a loss of effort, it wears out the equipment, consumes energy, and generates a loss in time. Plastic can be found in many products, according to Tang et al. (2007), over 70% of the products produced have a relation to plastic material, it is, therefore certain to say that what the plastic industry does, has an effect on the rest of the world not the less in terms of sustainability. In terms of the environmental aspect, studies have shown that if all plastic was recycled, 80% of the greenhouse gases could be reduced according to Gu et al. (2016). Gu et al. (2016) continue to state that if organisations were to take advantage of their defected products and scrap, they could contribute towards sustainable development. Dang (2014) explains all the different parameters that have to be set to operate a plastic injection moulding machine. These are delicate settings and many parameters have to be right to get the outcome that is expected by the production. With that in mind, it is understandable that these parameters sometimes not are set to their optimum levels. Especially since Dang (2014) also states that the way the machine is set is often based on the skill and knowledge of the operator itself, meaning that different operators have different knowledge, skill, and experience. That in its turn results in plastic injection moulding machines having different settings that are believed to be the optimum settings depending on what operator that is operating the machine. It is also understood that a defect is a result of an error, however, that error might not always generate a defected product at once, errors can be missed during quality inspections and could, therefore, result in a failure (Dhafr et al., 2006). Defects are inevitable when working with plastic injection moulding machines, it is a matter of holding the numbers of defect to its minimum and decide what to do with the defected parts once they are detected that can affect the sustainability performance of the company.

Melnyk et al. (2003) describe the advantages of having an EMS in an organisation, and that the impact of having a certified EMS is strong in terms of sustainable performance. The EMS is made possible by the ISO 14001, amongst many things it enables organisations to set an environmental policy that is suitable for the organisation and it also enables the company to monitor its processes to make sure that the policy is fulfilled. To be competitive in sustainability performance, and to create a standardised way of handling the defects produced in production, it could be argued that a certified EMS system could be decisive in terms of success. With regard to how Dhafr et al. (2006) described the effects of having defects in the production, reduction of defected parts will lead to several different improvements in terms of sustainability. Reduction of defects will lead to saved energy, less material used, equipment will wear out more slowly and it saves time. While also considering that 70 percent of today’s products have a correlation to plastic (Tang et al., 2007), it would have a great impact on the sustainable development if the plastic industry could lower the number of defects in its production.
5.2 Research question 2

*What are the most common defects in the processes and what are the causes behind?*

To be able to outline which are the most common defects in the production at the case company, the authors needed to both understand what is classified as a defected part at the case company and what the literature says about the topic. Defects are one of the seven wastes in lean methodology and are therefore something that companies should strive to reduce (Liker & Meier, 2006). The case company is fully aware of that eliminate defects within their production was not manageable and should be seen as a vision instead of a goal. Neuwirth (2019) describes a defect as a part or product that deviates from the normal distribution that is inconsistent with the quality requirements and the set specification. To then be able to identify the different defects could be harder than it seems to be (Ghosh, 2012). Through interviews with different employees at the case company and document studies, the definition of what literature describes defects as and what the case company sees as defects goes hand in hand. The case company had historical data about the number of defects and in what machines they had occurred. The historical data was a vital part of the study and its second research question to narrow the investigation down and to choose three out of the seven machines that were included in the studied area. Figure 4.2, presented in section 4.3, acts as a guideline for the authors to make a decision based on the three machines that account for the largest percentage of defects overall.

Why machine F, which do not have an automatic detection system, is chosen instead of machine C, which accounts for a higher percentage of defects then machine F, is because machine A-D uses an automated vision system to detect defects. There is also an interest from the case company to explore the difference between the manual and automated system.

The percentage of defects that the case company had registered is low, roughly 2%, however, interviews reveal that the percentage of defects in the investigated area is about 8-10%. Since the cycle-time for each machine is very low and the production is up and running 24/7, the difference between 2% in defects and 10% is extensive. They are using a non-renewable resource, and from a sustainability perspective, the impact of having 10% in defects instead of 2% will have an even more negative effect on the triple bottom line (Koplin et al., 2007). However, from interviews and observations, the case company has a solution for the defects. All defective parts and products are ground down into smaller pieces which are then resold to a customer who handles the recycling process of the material. This means that the case company contributes to the re-use of defects and scrap which is seen as a sustainable action that contributes to sustainable development (Gu et al., 2016). The registration of defects at the case company is poorly performed, and the historical data used to answer the second research question could be questioned in terms of reliability. The calculation below shows the probability of detecting at least one defect out of a sample of 30 items for the machines A, B, and F.
Machine A: \( P = 1 - P \left( \frac{615}{630} \right) \approx 52.3\% \)

Machine B: \( P = 1 - P \left( \frac{779}{791} \right) \approx 37.3\% \)

Machine F: \( P = 1 - P \left( \frac{785}{792} \right) \approx 23.8\% \)

By presenting these probabilities numbers, one can see that the probability of detecting a defect from the processes in machine A is quite high compared to machine F. However, detection of a defect from the processes in machine F is highly dependent on the operator because there is no other aid that could detect the defects.

When the choice of which machines should be further investigated, the types of defects are explored. The result of a deeper investigation of what different types of defects that are produced in the processes shows that the defect code “Cause cannot be found” appears to be the most common defect in the production, according to the historical data at the case company. This is also illustrated in Figure 4.3 in section 4.3. However, as mentioned in section 4.3, there are three different types of defect codes; “Cause cannot be found”, “Cause missing” and “Auto scrap”, that should be distributed among the other types of defects codes. This resulted in a further investigation to get the answer to the second research question. Through interviews with managers and operators, the defect code “Auto scrap” means that the vision-system has detected a flaw in the product that has a relation to the defect codes; “Product not filled”, “Colour” or ”IML”. The defect code “Auto scrap” should, therefore, be distributed to “Product not filled”, “Colour” or ”IML”. The defect code ”Cause cannot be found” and ”Cause missing” however can be distributed to all the different types of defect codes, except ”Auto scrap”. To get the best possible and most relevant result, these defects should be equally distributed among the other defect codes with regards to their percentage, which is illustrated in Figure 5.1.
The most common defect code is "Product not filled" which stands for 29,18% of the defects. It stands for almost one-third of the total number of defects. The defect codes "IML", "Palletising" and "Start-up" have almost the same percentage, roughly 17% each. Since "Start-up" defects are seen as a need-to-have defect, the focus has been placed on the other four most common defects in the production. The most common defects in the production are displayed in Table 5.1.

**Table 5.1 – Ranking of defect codes in percentage from high to low**

<table>
<thead>
<tr>
<th>Rank in occurrence</th>
<th>Defect code</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Product not filled</td>
<td>29,18</td>
</tr>
<tr>
<td>2</td>
<td>IML</td>
<td>17,70</td>
</tr>
<tr>
<td>3</td>
<td>Palletising</td>
<td>16,99</td>
</tr>
<tr>
<td>4</td>
<td>Colour</td>
<td>9,14</td>
</tr>
</tbody>
</table>

To explore the cause or causes behind a defect, a *cause-and-effect diagram* is an appropriate tool to start with. It is highly recommended to start with defining the main problem and then map out what is perceived to be the causes (Bergman & Klefsjö, 2010). This study will start with the main problem which is defects and then map out the different causes behind it. After that, the relation and connection to the most common defects will be presented with regard to the causes. This will be done to clarify the causes which Neuwirth (2019) describes as a vital part to perform corrections. Figure 5.2 illustrates the cause-and-effect diagram that is developed in regard to the research.
These causes, illustrated in Figure 5.2, are what Dhafr et al. (2006) describe as affecting variables that lead to some sort of an error that in turn could result in defects. These variables have been divided into five different main causes/variables; surroundings, operator, method, machine, and material. Each of the main causes/variables has then been broken down to further causes that can be seen in Figure 5.2.

Table 5.2 illustrates the connection between the most common defects in the case company and the possible causes behind it. If there is a possible connection between the defect, presented on the x-axis, and the cause, presented at the y-axis, that column has been marked. The defect "Product not filled" has the most possible causes behind and the defect "IML" represents the lowest possible causes behind.

<table>
<thead>
<tr>
<th>Type of defect Causes</th>
<th>Product not filled</th>
<th>IML</th>
<th>Palletising</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleanliness</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Colour mixed</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>Contamination</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cooling of mould</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle-time variation</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign particles</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequate operations</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequate storage</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequate transport</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inconsistency in feed of material</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of experience</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of maintenance</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of standards</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Low skill level</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Low standard</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method variation</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Motivation</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Parts are ware-out</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorly trained</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Process variation</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supervision</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Tidy workplace</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Variation in density</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analysis

| Variation in humidity |  | x |  |
| Variation in injection pressure | x |  |  |
| Variation in operations |  |  | x |
| Variation in temperature | x |  |  |
| Workplace structure |  |  | x |
| Sum | 12 | 5 | 6 | 8 |

5.3 Research question 3

*How can the processes be improved in order to decrease the number of defects?*

What became evident during the interviews is that all respondents had their view of why the processes of operators checking for defected parts were different. When interviewing employees responsible for quality controls at the company, they all provided the answers that the operators do not follow the set standards for quality checks. However, they both had different views of why that is the case. One of them has the theory that people do not follow the set standards because of the way new employees are trained. After interviewing an operator that has the responsibility of training new employees, it became evident that the company during the recent years has decreased the number of training days from 10 to 5. Unused creativity is one of the wastes mentioned in lean literature, by not utilising the skills from the employees, resources will be lost in form of skills and improvements (Liker & Meier, 2006). When interviewing another employee responsible for the quality, the employee gives the answers that the standards for operators performing quality controls are set but not followed. However, the employee does not say why, that is simply how the employee thinks is the case. The answer given was that the standards are not followed by all operators. During observations of the operators, it is seen that very few attempts to check the quality of the products is made. Since the company has two types of system in their machines, one system where no control system is used, instead totally reliable on the operator’s skill and knowledge to detect any defected parts. The other system used is a system with the help of cameras sort out the defected products, helping the operators so that they only have to do a final check once the products are on the pallet. Jidoka is a tool that is used for creating smarter machines, a system that helps operators by removing or eliminating, certain tasks that before the Jidoka system required human assistance (Liker, 2004). The vision-system used at the company is a type of Jidoka, it gives the operator more time and removes the uncertainty of products that are defected going on a pallet. The problem that is detected during the observations is that not all machines utilise the built-in vision-system, and the reasons behind are many. Either the system is malfunctioning, or it is not compatible with the products that are produced. This would give the operators more work since the machine has to be treated like a machine that does not have a vision-system built in, which requires more quality controls by the operators. The other problem generated by the vision-system is that in one of the machines, a robotic arm is pulling the finished products out from the machine.
that always produces two at the time. That robotic arm does not know if one or both products are defected and therefore is programmed to put both products on a conveyor belt as defected products. This type of process requires the operator to either scrap both products as defects, or they must look at both pieces to identify whether it is a defect or not. When observing the pieces that are labelled as defects by the machines, it is very hard to see what products that are defective and who is not. This creates waste in the form of over-production, if the good products are thrown away, or over-processing, if an operator must check if the products are good or not. When comparing this to the other system where the machines did not utilise any vision-system, that requires the operators to be a lot more patient and spend more time on visually checking for defected products which takes times of other tasks. In this type of process, it is during observation hardly seen any attempts of checking for defects, even though it is supposed to be done 4 times per pallet. It is more common, that the first time the products are checked is at the end of the line where the products were on a pallet, where it is very difficult to spot any defects. And if a defect is found, the whole pallet needs to be looked through, whereas potentially many pieces might be defective because it had not been discovered earlier. By detecting defective products, measures can be taken for the machine to produce correct parts again. Dang (2014) describes how parameters on the plastic injection moulding machines are set by an operator which is determined by his or her own skill and knowledge, therefore, it is hard to set a standard for how the machines are supposed to be set, even though the company sets the machine to what they believe is the optimum settings. However, that is constantly changing. The processes such as checking for defected products should always be the same if taking the definition of a process that is mentioned in the theoretical framework where a process is continuous and does not change from time to time. Liker and Meier (2006) describe the result of having defect products in the production, whereas defects lead to rework, and would it reach the final customer it could damage the image of the company. Therefore, improving the processes regarding discovering defects to prevent the defects to grow in number would be a suggestion. This also means that all quality control has to take place at the machines and should not have to be performed once the products are on the pallet. For the machines with the vision-system, it is very important that the system is optimised correctly, and that the system is used as much as possible to gain as much efficiency as possible from the system.

The plastic injection moulding machines suck the material and colour into the machine, where material and colour mix. The material comes from pipes from the roof, and the colour comes from a smaller container standing next to the machines, these containers vary in quality. Some containers look brand new and are completely sealed, while some are much older and are completely open with the colour being exposed to anything that can fall into the container. When the production of a product is finished, a change of material and colour is most likely required for the next product. When observing this change of colour, the operator starts with cleaning the compartment where the colour ends up from being sucked into the machine. While doing this, a lot of colour end up on the floor, mainly because of the design of the compartment. This results in a big amount of colour granulate on the floor and on the machine. Besides from being dangerous to fall on, it also increases the chance of the wrong colour ending up in one of the older, open containers which holds a different colour. While discussing this with employees working around the machine, it became evident that one little colour granulate has a big effect on the outcome of the machine. One colour granulate creates a discoloration for a period of time, if the operator is not aware, it could easily end up
on the pallet and might not even be discovered. A successful 5s project could help in this situation, it does not only create a safer working area (Myerson, 2012), but also reduces the chance of wrong colour granulate ending up in the wrong container. In this case, it might be a requirement to also only use the containers that are completely sealed, since that would eliminate the change of wrong colour granulate falling down in the wrong container.

When the products are finished, they are put on a conveyor belt and automatically put on a pallet by two robots. While talking to the employees of the company, they said that there had been issues with the process of palletising as the products occasionally fell off the pallet, creating a stop in the automated packaging system and generating a lot of scrap since the products that had been on the floor must be seen as a defect. However, the employees at the company argue that the problem has been to some extent fixed but when looking at the numbers of defects it can be seen that palletising has a rather high number of defects. When discussing this further with employees, they said that lately it has been exclusively operators’ fault when operators bring the pallet down from the automated packaging system or they make a too sharp of a turn, making the products falling. Liker and Meier (2006) describe how unused creativity is one of the wastes mentioned in the lean literature, this can also be seen as a lack of skill from the employees. Knowing this, it could be argued that more focus should be put on training employees on how to handle the pallet once it is taken down from the automated packaging system. If products fall from the pallet it generates both rework and waste in the form of defects that must be scrapped. There is also no inspection of the pallets used in the automated packaging system, potentially leading to bad pallets also generating products to fall from the pallet.

The IML process is another process that causes defective products. These labels ads another variable to the many variables there already are in the production. The IML is placed in the compartment in the machine, while there, the machine picks up the IML with the help of a vacuum and then places it in the machine. During this process, if the IML is not entirely flat it can cause the IML to be placed wrong in the machine, which in terms results in a defected product. What causes the IML folding is humidity in the air according to the employees. What enhances this problem is that there is not a really good process of storing the IML that has returned from the production to the storage space. Because the IML is not sealed perfectly, it gets exposed to more humidity which decreases the quality of the IML. This causes the company to either produce products with the bad IML that results in defective products, or they have to throw away IML because it cannot be used in the production. Either way, this results in waste of material. A possible solution to this problem is to standardise the way IML both are handled when not in production, but also to standardise the way the IML are inspected before going into the production. Since the IML also varied in quality based on supplier, a benchmark could be made to classify the suppliers.

In the production there are many different processes constantly working, a tool that deals with the processes in an in more depth approach is the fault tree analysis (FTA). By using this tool, it enables the company to highlight a negative event that needs to be minimised (Makajic-Nikolic et al., 2016). By performing an FTA, the company could gain a clear view of the processes that have to be improved and with which process to start with. When choosing what process to start with, the causes closest to the defect should be started with, and appropriate actions shall be taken. After that, working its
way down the chain of processes until the desired result is reached. The positive aspect of this tool is that it is applicable to all processes mentioned in the report and is also possible to conduct in all industries.

By lowering the number of defects in the production, the sustainable performance of the organisation will increase. Not only does it save money, it also saves time and energy amongst others (Dhafr et al., 2006).
6 Discussion
In this section the research questions are discussed, the author also presents to what extent they believe the research questions have been answered.

6.1 Discussion of research question 1

The first research question was aiming to provide clarity in the concept of sustainability and how it is related to defected products and parts within manufacturing companies. To be able to answer the research question, a literature review is made where relevant studies are assessed. In the analysis section, the literature found are compared with each other. The section starts with describing to what extent plastic is present in products produced and research shows that it accounts for 70% of all products. The text then continues to state what negative effect plastic and its defective produced parts have on the environment, to create an understanding for the reader. In relation to this, the text describes how organisations, in general, can contribute to sustainable development. In terms of plastic injection moulding, which is a common way of producing plastic products, the text describes the many parameters that must be set right to produce products that meet the required standards. In addition, these parameters do not have a standard value, rather than the parameters are set by individuals who, by their skill and knowledge, decide what the optimal parameters are. Through this, a conclusion is made that it is impossible to have a production that produces zero defects because of the many parameters that must be set.

When defects occur, it is not certain that they are detected at once. In that case, it results in more defects and possibly a failure in the machinery. This has a negative impact on the entire triple bottom line. It is also understood that it is impossible to have a plastic production that produces zero defective products. Therefore, it is concluded that it is important that the defective products are handled correctly when they occur to improve the sustainable performance of an organisation. Once this is concluded, the positive effect of having an ISO 14001 certification is described to be vital for developing an EMS. The EMS in its turn is described as an important factor for being competitive in sustainable performance towards the market. The section continues by describing the different advantages that will be gained from reducing defects in the production. The authors consider that through this literature review, a clear relation between sustainability and its implications on sustainable performance has been made. The authors, therefore, consider the first research question to be answered.

6.2 Discussion of research question 2

The aim of the second research question is to clarify which defects can be found in a production and what causes that underlies the defected products. To be able to succeed with the aim, multiple methods are used. The methods used are interviews, observations, secondary data collection as well as a questionnaire.

The section starts with analysing what a defect are and concludes that defects is something that must be reduced. The vision should be to reach zero defects, while the goal is to reduce defects. It was also important that the case company had the same view of what a defective product is as the literature has, which made it possible to identify
defects in the production. The connection to the 7 wastes in lean are also established to easily define what the consequences are from having defects in the production.

The secondary data regarding the defected parts and products from the case company is an important part of the thesis. That data made it possible to get an indication of what the current state is at the company in terms of defected products. It is mentioned in the analysis that the secondary data are not completely trustworthy due to the inability of the operators to register defected products. This is taken into consideration, and even though it does not tell the entire truth, it still provides the thesis with a solid indication of the current state at the company. By analysing the data on defected products, it is possible to select machines of interest. The choice of machines is made based on the percentage of defected products produced in a certain machine, but also whether the machines had a built-in vision system or not. This resulted in choosing two machines that are using a vision system and one that did not. Besides the percentage of defects, the use or non-use of a vision system is interesting because of the difference in processes required in both cases.

To illustrate and better understand the current situation, a statistical calculation is made. Given that the numbers from that calculation generated a rather high chance of having defects in the production, it also provides an argument for having good quality controls in the production. What must be taken into consideration is that the statistical calculation is based on numbers that are not 100% correct, therefore the statistical calculation must also be seen as an indication more than truth.

From the selection of machines, it is concluded that machine F that does not possess a Jidoka system (vision) needs a lot more attention from operators than the other machines that have a Jidoka system does. By acknowledging this, it would be possible to put resources where it is most needed.

The company has different defect codes that categorise what is wrong with each defected product. Three of these codes that are used do not specify what is wrong with the products. These three defect codes are spread out evenly across the other defect codes to create a more correct table, this made it possible to easier see what type of defects that are most occurring.

One of the defect codes, “start-up”, is explained to the authors as a necessary defect. If the machine has stood still for a while, then the machine had to get up in temperature and pressure rather slowly to not damage the tool. This resulted in defected parts, however, the authors decide to not pay attention to this type of defect because there are other types of defects that are not necessary defects. When the unnecessary defects have been taken care of, it would make sense to investigate the start-up defects.

In the end, this section results in a table that shows the types of defects in relation to what causes them in the production. The table gives a good picture together with the table of the number of defects. Together they make it possible to fulfil the aim of the research question and give the case company an overview of the defects in their production. With this overview, they will have the chance to make an informed decision about what types of defects to try to minimise first.
6.3 Discussion of research question 3

The analysis of the third research question starts with discussing the result of the interviews and observations made regarding quality control at the company. Two out of three quality inspectors are interviewed. The quality inspector that is not interviewed is not available for interviewer's when this observation was made, however, from the two quality inspectors that are interviewed, similar answers are received. These answers provided the authors with a clear view of to which extent quality controls are made by the operators. These answers are also confirmed by the observation made where almost no attempts of quality controls were made by the operators. This became one of the improvement areas that the authors decide to look deeper into.

One of the answers provided by the quality inspectors is that the training of new employees is a problem due to the limited time given to training. From that, an employee in charge of training new employees are interviewed. The answers received from that interview provided knowledge that is of big importance because the training of employees affects how all future processes are performed. Lack of training new employees can also be connected to the concept of waste described in lean literature. It also became evident that the process of detecting defects needed to be improved because of the number of defected parts and products that are produced before it is stopped. What also made this clearer, is the fact that the machines are connected to an automated packaging system, meaning that all defects that are not discovered before it ends up on a pallet will be difficult to discover and worst case even reach the customers. The lean tool Jidoka is present in the form of a vision system in the production and that is analysed as a good help for the operators. However, the system is in need of improvement work, what this process does when picking out defected products is that it is also generating a lot of rework. The authors thought this fact was important to bring up, mainly because when using a system to perform better, it should not add problems. The other issue regarding the vision system is that it is not built into all machines. Three of the seven machines did not have this system, which results in that two different processes were treated as the same. The process of working at a machine that utilises a vision system should require less time spent by the operator at the machine, however, that also means that operators should spend more time looking for defects at the machine that does not have a vision system. This is not the case and it reveals that the operators do not prioritise the machines depending on if there is a vision system working or not.

In the investigated area, four machines had a vision system built-in, however, quite often these vision systems were not used. The answer to why that is the case is a bit unclear, but if there is a vision system in place, the system should be operating as much as it is possible to make sure to minimise the number of defects.

The containers in which the granulate material is stored before it is sucked into the machines were found to vary a lot in quality. Some containers are brand new and is completely sealed, while others look old and completely exposing the material for anything to fall in the material. This is found to be one of the causes behind the defects related to the defect code “colour”, meaning that the colour of the product is not correct. By only using the sealed containers, the variable of any other colour to fall in would be eliminated. This is mostly described as a problem when the type of product or the colour of products currently being produced are switched. The machines are poorly cleaned
between the shift of material and colour, which resulted in a lot of material in granulate form ending up on the floor. It creates a dangerous workplace and increases the risk for the material to end up in a container which it is not supposed to be in. Here the tool 5s was proposed as a possible solution.

Besides from the defect code colour, palletising is another defect code found to also have a high number of defects. Interviews reveal that most of the palletising defects came from operators not driving carefully enough with the forklifts when lifting the pallet from the automated packaging system, which results in the products to fall of the pallet. This is referred to as an issue of a low level of skill which could be fixed with more training of the employees.

The defect code IML is then analysed since it also had a rather high number of defects. The IML is found to be sensitive to humidity since that made the IML not stay flat, the corners raised which meant that it ends up wrong in the machine which in turn results in a defected product. Even though there are sprinklers in the roof that controls the humidity, it is still not enough for the IML. Based on interviews, this is because old IML that had been in the production before is being used again, and during that time decreased the quality of the IML. During the interviews, it is found out that IML came from different companies which varied in quality. To decrease the number of defects it is proposed by the authors to develop a standardised way of inspecting and storing the IML when not in production. Also, to benchmark suppliers to purchase the IML with the highest quality.

A cause-and-effect diagram is made, it helps to map and structure the events that in the end leads to a defect in this case. The tool fault tree analysis is also discussed in this research question. The authors have had the intention to perform a fault tree analysis but understood that it would be a more suitable continuing for the company to create, because the company would have the chance to choose the types of defects they would like to continue with. The cause-and-effect diagram is a good start and could make the next step of a fault tree analysis easier.

The final part of this section also concluded that from a sustainability aspect, by lowering the number of defects in the production, organisations can contribute towards more sustainable development. The authors also believe the third research question is answered and that the aim of the question is fulfilled.

6.4 Discussion of method
In this section, the methods chosen for this study are discussed. The aim is to criticise the methods chosen and why they were chosen. The discussion is regarding a single case study that was carried out on the case company where empirical data was compared with already existing literature.

6.4.1 Case study

By conducting this study in the form of a case study, it enabled the authors to connect theories from literature with the empirical data at the case company. Theories can be compared with the empirical data gathered at the case company, which results in an abductive approach. The risk of using an abductive approach is that the authors can find themselves looking at situations where they already have experience from, instead of
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looking at where the problem actually lies. However, it does also provide the opportunity to get a new theoretical ground from the study and at the same time confirm the result with theory from the literature. The use of a single case study does limit the reliability of the study, however, it gives the opportunity to go more in-depth when studying a problem. What could be argued by using this method is that the chosen case company can represent the majority of the industry. The authors consider that the case company can represent the majority of the industry because of the chosen production methods in the production, such as plastic injection moulding which is one of the most occurring operations to produce plastic products.

6.4.2 Interviews

The interviews are an important part of the study since it gave the authors information that cannot be discovered through the numerical data. The interviews are carried out in a mix of semi-structured and unstructured interviews. The unstructured interviews are important since it generated easy conversations with employees which does not put any pressure on them. These unstructured interviews are also carried out while the operators are working, this made it possible for the authors to get into depth with questions around problems they see in the production. The risk of having unstructured interviews is that the purpose of the interviews could get lost. The semi-structured interviews are used on managers which generated validity for the study.

6.4.3 Observations

Observations are used for the authors need to see where the problems are and to get a good understanding of the current state at the case company. The authors comes into the case company with different eyes than those who work there on a daily basis and can see things that the employees would never mention as issues. By doing frequent observations, the authors can determine what is being frequent issues at the case company and what is an onetime happening. Observations also strengthened or confirmed what was said in the interviews by the employees. Even though the interviews are conducted at the case company, the authors consider the answers to be generalised to the rest of the industry.

6.4.4 Document studies

The document studies outlined a big part of the study, the document studies consisted of numerical data which shows the number of defects in the production. These numbers are rather quickly understood to not be 100 percent correct, this has to be taken into consideration when assessing the documents. With the document studies, the most frequent types of defects can be determined which in turn gave the authors a good indication of how to progress with the study.

6.4.5 Questionnaire

A questionnaire is made to get information on how the general opinion of the operator is regarding the handling of defected products. Why this information is chosen to be presented in the form of a questionnaire is because the employees worked different shifts. The authors can only be present at the case company during the daytime on
weekdays, a questionnaire enables the authors to get answers from employees working both on the nights and the weekends as well. The validity of the questionnaire can be questioned since the numbers of respondents are lower than what is hoped for. Out of 10 possible answers, 6 are received. However, the answers collected gives an indication that is helpful in developing a current state view of the case company.

6.4.6 Validity and reliability

To increase the validity of the report, different operators are observed. This generated a better picture of what different operators do as well as what they do differently. Also, employees with special knowledge regarding things of interest are interviewd to gain the most accurate answers.

The reliability of the study is increased by the many observations done, they ensured that what is observed is the reality of the day to day operations and not onetime events. The reliability is also increased by the fact that answers from interviews are double-checked with the respondents so that the answers are given and understood correctly.

6.5 Limitations

Only one company are being studied, if more companies are studied, a stronger result can be presented. At the case company, only the production area surrounding the automated packaging system is studied due to interest from the company. Later this area of investigation is limited even more to three machines in that area to be able to get more in-depth with the study. With more time, a greater number of machines are possible to study. All limitations that have been set have been necessary to keep the time frame of the study as well as the scope of the study. With those two aspects in mind, the authors consider the limitations that are set to have been correct.

6.6 Conclusions

To conclude the research, it is possible to affirm that by lowering the number of defects in production, companies can contribute towards more sustainable development. The answer to question one is also answered by the fact that it is impossible to have zero defects in the production, it is therefore important what the companies do with the defected products once they are discovered. To reuse material from defected products instead of throwing it away will also contribute towards more sustainable development.

It can be concluded that the most occurring types of defects are “product not filled”, “IML”, “palletising” and “colour”. The second research question can be considered as confirmed by the cause-and-effect diagram and a table where it clearly shows what types of defects and what causes that leads to them.

It is possible to affirm that the discovering of defective products in an early stage would lead to a reduction of defects. It is also possible to affirm that standardised processes for checking for defective parts and products will lead to reduction of defects.

The skill level of the employees, especially newly employed, has a clear connection to time spent on training and can be concluded that increased training time for new employees can reduce the number of defects.
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By using a Jidoka system, no defective parts and products will end up in the next process. It can therefore be concluded that it will increase the possibility of operators to see when a machine is producing many defective products and result in that the operator can stop the process and correct it to reduce the number of defects.

The reduction of the defect code IML can be reduced by improving the handling of IML when not in production.

It is possible to conclude that increased standards of equipment and implementation of a 5s work could reduce the number of defects.

6.7 Recommendation

- It is suggested for the case company to create a fault tree analysis described in the thesis to map and choose what processes to improve to decrease the number of defects.
- It is suggested that the case company should focus on discovering defected products earlier in the production.
- By increasing the time spent on training new employees, a more long-term view is taken.
- It is also suggested to maximise the use of the vision system in the machines at the case company.
- The standardised processes for checking for defected parts are not followed, therefore it would be suggested to work out a new process that will be able for the operators to follow.
- A benchmark is suggested to be made by the case company to select the suppliers that produce the IML with the highest quality.
- The defect code Palletising can be decreased by better training of the employees in driving the forklifts and are therefore a recommendation for the case company to perform.
- The defect code colour can be decreased by increasing the standards of the containers holding the colour before it reaches the machine, this in combination with a 5s would clean up and generate a structure to the workplace. This will create a safer and more productive working area.

6.8 Continued research

This research provides suggestions on how to decrease the number of defects in production. This research was carried out as a single case study, the study was performed at one company in a specific part of the production area. For further research, it would be interesting to see if the same result would occur at other companies. It would also be interesting to study other areas in the same factory since this study is only limited to one area in the production. Further research can also be made after the suggested improvements are implemented to see the positive effect it has on the number of defects register in the production.
References


