HOW TO ACHIEVE AND ENHANCE TRACEABILITY

- A study about how traceability could be improved within manufacturing processes

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Master of Science Thesis
Stockholm, Sweden 2017
Abstract

The trends for manufacturing organizations are continuously increased customer expectations and demands, together with globalization of both markets and competition. As we are currently approaching the fourth industrial revolution and in order to stay competitive, companies need to adopt technological changes, differentiate themselves and improve their digital maturity. In line with this, Atlas Copco Secoroc, a Swedish manufacturing company of mining equipment and tools, has shared a divisional vision stating that they will embrace the Internet of Things and introduce some of the latest technological and digital trends. This in turn, sets some requirements on a functional traceability system. This research investigates how traceability could be improved throughout Atlas Copco Secoroc’s production chain and manufacturing processes.

This research is based on an empirical study consisting of observations and interviews, all conducted at the company Atlas Copco Secoroc in Fagersta, Sweden, as well as a coherent and iterative literature review.

The results emphasize the importance of understanding the overall need, clearly defining a traceability strategy and setting a suitable target level. It is vital to acquire knowledge regarding the subject and to first focus on securing the internal traceability and then expand to cover the entire supply chain. Furthermore, the findings highlight existing shortcomings, present material and recommendations that should be taken into consideration before advancing further and indicate the synergies with total quality management.

Moreover, the master thesis resulted in concrete actions regarding how Atlas Copco Secoroc can enhance traceability within their manufacturing processes. Due to confidential information these recommendations are shown to Atlas Copco only and are not included in the published master thesis.

Keywords: Traceability, traceability system, traceability method, traceability implementation, total quality management, manufacturing company, Industry 4.0
**Sammanfattning**


Detta examensarbete baseras på en empirisk studie utförd hos Atlas Copco Secoroc i Fagersta. Studien bestod av ingående observationer och intervjuer samt en kontinuerlig och iterativ litteraturstudie.

Resultaten betonar vikten av att förstå det övergripande behovet, tydligt definiera en spårbarhetsstrategi och sätta en lämplig spårbarhetsnivå. Det är viktigt att förvärva kunskap om ämnet och att först fokusera på att säkra den interna spårbarheten innan arbetet avser täcka hela försörjningskedjan. Vidare lyfter resultaten fram befintliga brister, material och rekommendationer som bör beaktas innan en vidareutveckling kan ske. Studien presenterar även synergierna till konceptet total kvalitetsledning.


**Nyckelord:** Spårbarhet, spårbarhetssystem, spårbarhetsmetod, spårbarhetsimplementering, total kvalitetsledning, tillverkande företag, Industri 4.0
Acknowledgements

This master thesis report marks a great milestone for the author. Several people have contributed with assistance and should be acknowledged for making this project possible.

First and foremost, I would like to thank Atlas Copco Secoroc for the opportunity to conduct this study. Special thanks to my company supervisor, Mattias Lejon, and his entire quality team who have provided valuable information and guidance.

Furthermore, I like to express gratitude to my interview candidates and all other Secoroc employees, especially the DTH-department personnel, for sharing information and patiently answering all my questions. Without your help I would not have been able to get such a good insight into the daily business.

I would also like to thank my supervisor Per Johansson at the department of Production Engineering and Management for your support.

Fagersta/Stockholm, Sweden
June 2017

Lisa Grunning
List of Abbreviations

COPQ  Cost of Poor Quality
DC    Distribution Center
DTH   Down the Hole
ERP   Enterprise Resource Planning
IoT   Internet of Things
MO    Manufacturing Order
PC    Product Company
PO    Purchase Order
RDT   Rock Drilling Tools
TQM   Total Quality Management
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1 Introduction

In this introductory chapter the background for this research will be presented together with the problem definition. It is followed by the studies purpose and corresponding research questions. Furthermore, project limitations are to be presented.

1.1 Background

In 2005, Baily et al., correctly wrote that the world partook in a fast-technological development and increased global competition. Today however, 12 years later, it is safe to state that industries observe an accelerated development and that change is faster than ever. The trends for manufacturing organizations are continuously increased customer expectations and demands together with globalization of both markets and competition. Thus, to stay competitive, companies need to adopt technology changes, differentiate themselves and improve their digital maturity.

Some might say that current technological and digital trends are recognized through buzzwords such as the Internet of Things (IoT), Big Data, Smart factory and Cloud solutions. But truthfully, these are not just buzzwords. We are currently approaching the fourth industrial revolution. Industry 4.0 will include a technical integration of Cyber-Physical-Systems throughout intelligent networks, which allows communication between humans, machines and products alike (Kagermann, et al., 2013). Consequently, very dependent on the trends and buzzwords previously mentioned.

Atlas Copco

In their 2015 annual report, Atlas Copco mention that it is more important than ever for mining companies to use machines that are productive, energy efficient and have a lower total cost of operations. The Rock Drilling Tools (RDT) division at Atlas Copco has announced a strategy where they aim to differentiate themselves by offering quality, safety and productivity, among other things (Internal document, 2016). This vision will be accomplished by embracing the IoT and introducing some of the latest technological and digital trends.

On this topic, the RDT-division currently has several on-going projects and prior to this study an internal investigation of a previously performed digital transformation project (DTP) was carried out. That project, from here on referred to as DTP 1.0, intended to differentiate Atlas Copco through quality assurance by creating a common quality platform. The concept, which is shown in Figure 1, was to connect Atlas Copco, suppliers and customers to a shared quality database, based on a cloud solution. The database would collect, visualize and allow easy access to quality data in real-time.
Another research project, called Consumable Management, which aims to increase knowledge and customer’s productivity can be described as the successor, hence DTP 2.0. While the predecessor focuses on collecting quality information from manufacturing and installation, DTP 2.0 intend to gather continuous process information from drill site. Evaluations and analysis are enabled by potentially connecting and comparing all information.

1.2 Problem definition
In order to operate according to the divisional strategy and achieve successful projects some prerequisites are needed. For instance, to utilize DTP 1.0 or 2.0 completely and be able to analyze one specific product operating at drill site, the products need to be individually traceable with related manufacturing data throughout the entire supply chain. This has now been recognized as a vital shortage by the company’s own quality department. For the reason that inadequate traceability currently has a negative impact on their performance and therefore raised a concern accordingly.

All mentioned projects are initiated at top management level and in reality the production control is far from where it needs to be in order to align the strategy. Mainly because the topic of traceability historically has been neglected. In fact, the company has actively decided that it is not important and therefore ignored it completely.

Thus, the problem is known but not yet to what extent. With this project the quality department therefore wish to highlight all existing shortcomings and explain the importance of traceability so that all management and personnel understand that it must be prioritized and in place before the divisional goals can be attained.

1.3 Objective
Given the background this study addresses the lacking traceability of products as its key fact. That the traceability level is insufficient is partly known but a comprehensive picture over the current state is missing. Thus, the overall objective of this research is to clarify all existing traceability inadequacies and provide recommendations for how the internal traceability could
be increased. This is done by investigating how a factory within the Atlas Copco Secoroc organization can minimize the existing traceability gap through the implementation of adequate actions and initiatives.

By shedding light on traceability and its importance, this study also aims to support future decisions regarding traceability improvements. This will be done by finding business- and market-oriented benefits and emphasizing the advantages of full traceability. Another aim is to identify to what extent and how the current traceability situation affects the quality department’s performance.

This thesis project will be carried out with the presence of the company divisional strategy and the outcome will acknowledge productivity.

### 1.4 Research question

The purpose of this study is fulfilled by answering the following main research question:

*How could the traceability be improved throughout Atlas Copco Secoroc’s production chain and manufacturing processes?*

The following subset of questions have been formulated in order to answer the main research question:

- **RQ1**: How is traceability defined and a traceability system designed?
- **RQ2**: Which are the main benefits a company can gain from enhanced traceability?
- **RQ3**: What is the current traceability situation at Atlas Copco Secoroc?
- **RQ4**: How is the current traceability affecting the overall quality assurance?

### 1.5 Limitations

In focus for this master thesis project lies traceability and mainly how it could be improved. Due to the broad research field, several limitations have been defined for this study. The research is limited to only investigate and observe the possibilities at one specific business case and therefore does not consider a general solution. The thesis is also limited to focus on how to possibly improve a current situation and does not consider either optimization or implementation of a traceability system.

The case study, through which this research’s main empirics are gathered, is moreover defined within the scope. The use of benchmarking or more quantitative methods could have been other ways to investigate the research questions further but were excluded to reach a manageable scope within the study’s limited time frame.

Furthermore, as the purpose is to investigate how the traceability *could* be increased, the author is aware of that the identified conclusions and implications may not be the only ones able to fulfill this research’s purpose. Most likely, there are more ways in which the traceability at Atlas Copco Secoroc could be increased.
2 Method

To fulfill the objective, this study carries out an empirical investigation at Atlas Copco Secoroc AB. This case study has been chosen as the main research method, consisting of observations and interviews. In addition, evaluation of existing internal documents and procedures has been done together with a corresponding literature review. Thus, both primary and secondary data collection methods are being used.

Initially, to acquire knowledge about the topic of traceability, and other theories related to the underlying research questions, a literature review was performed. A few introductory interviews were then conducted in order to understand the background as well as the company’s vision and strategies. Simultaneously, in the projects observation-phase, the current traceability was identified at the selected factory together with its impact on the company’s quality department. The process map in Figure 2 illustrates the research process and how the different activities relate and contribute to the research findings.

All observations from the activities taking place in the projects second phase were compiled, analyzed and presented as suggested improvements. The recommendations are divided into two categories; one directed towards top management covering more comprehensive areas, while the other presents detailed on-hands activities that more easily can be executed by the investigated factory.

The future state is marked with dashed lines since it is not yet defined. The same goes for the knowledge acquired during investigation of the RDT-vision since it is not directly related to the traceability concept. This activity only widen the perspective and presents the background and incitements for a potential future implementation. Therefore it only acts as an auxiliary input for the suggested improvements.
3 Industry 4.0

While the first three industrial revolutions came about as results of technical innovations such as steam power, electricity and PLC, experts foresee that the fourth and upcoming one will be triggered by the Internet, and its increased integration into the industrial value chain (Kagermann, et al., 2013; Brettel et al., 2014). Industry 4.0, also known as Smart industries, focuses on the establishment of intelligent products and production processes (Brettel et al., 2014). It involves the technical integration of Cyber-Physical-Systems (CPS), which combine physical systems and information communication technology. Thus, allowing communication between humans, products as well as machines throughout global intelligent networks (Kagermann, et al., 2013; Brettel et al., 2014; Segura Veladia et al., 2016).

Baur and Wee (2015) define Industry 4.0 as the next phase in the digitization of the manufacturing sector and it is mainly driven by four digital technologies. Namely: Big data, advanced analytics, human-machine interfaces and digital-to-physical transfer. In order to become smart, manufacturing companies need to employ new intelligent methods of production and target a marketplace in which real time information is exchanged between products and machine services (Segura Veladia et al., 2016). To get the most out of Industry 4.0 technologies and capture its potential, manufacturers should consider the following (Baur and Wee, 2015):

- Companies can gather more information and make better use of it.
- Strategists should take Industry 4.0 into account as they plan the company’s future directions.
- Prepare for a digital transformation.

Technology development and digitalization create enormous opportunities for companies to increase customer value by streamlining processes, increasing quality, creating new revenue streams, and reducing production costs. Despite all the possibilities, there are significant challenges. Digitalization of a business requires a systematical approach, changes in leadership style, and a completely new mind-set in the production chain.
4 Traceability according to literature

In order to be able to give recommendations for why and how to improve traceability at the case object, a number of key concepts on the subject of traceability must be clarified and understood. Thus, in the following chapter’s theories regarding definitions, concepts such as traceability system and methods, benefits and the implementation of traceability will be presented.

4.1 The concept of traceability and definition

Traceability is a widely used concept (Karlsen et al., 2012), it has been a part of manufacturing for the last few decades and it is used within many industries (Han et al., 2011). The automotive and food industries are said to be in the lead regarding the implementation (Nambiar, 2010; Dai et al., 2012), which also corresponds to the currently available research. Traceability is an interdisciplinary research field and various approaches within the traceability field have been studied during recent years (Karlsen et al., 2012). However, the research majority is related to the effects, benefits or implementation within the food or agricultural industry (Van der Vorst, 2005; Karlsen et al., 2012)

Through their conducted literature review, Karlsen et al. (2012) also argue that the term traceability has no common definition, nor theoretical framework for its implementation. This is also strengthened by authors such as Kvarnström (2010) and Olsen and Borit (2013). According to them current definitions of what traceability is leave room for interpretations, which result in principles that are neither precise nor consistent. Due to lack of a unanimous definition and a theoretical discussion concerning traceability within the scientific literature, Kvarnström (2010) explored the existing scientific literature, described how different traceability concepts are related and presented a theoretical framework for traceability from his point of view.

In his research the author defines traceability as:

“Traceability is the ability to track, trace, and predict the location of a lot, its sub-components, and raw materials through the supply chain.” (Kvarnström 2010, p.25)

Since the definition is general and covers all required aspects of traceability it will be used in this study. The definition is general in the way that it can be applied in industries producing few products consisting of many sub-components and/or raw materials, as well as for industries where various products are produced from few sub-components and/or raw materials. The definition was also chosen since it clearly denotes the importance of maintaining the link from, and between, the sub-components and/or raw materials to the finished product. In the definition created by Kvarnström (2010) it is clarified that a lot can indicate either a single item or several items. It is implied that the extent covers the entire supply chain, that tracking refers to the ability of following the location of a lot whereas tracing refers to locating its previous position. In other words, tracking denotes the identification of the lots containing components from a certain batch and tracing the identification of the lot history. Furthermore, the definition adds the level of prediction and thus allows the use of traceability for process optimization and control. This is also argued for by Jansen-Vullers et al. (2003).
Moreover, Moe (1998) refers to traceability as either chain traceability or internal traceability. Chain traceability is the ability to trace the information through the supply chain, and internal traceability is the ability to trace product and process information within a company. Chain traceability is dependent on all companies in a supply chain having full internal traceability (Moe, 1998; Opara and Mazaud, 2001; Karlsen and Senneset, 2006; Regattieri et al., 2007). Van der Vorst (2005) also states something similar.

Backward and forward traceability are two other terms mentioned within the literature. Jansen-Vullers et al. (2003) describe forward traceability as the ability to explore the where-used relations between lots and backward traceability as the ability to explore where-from. A comparison to Kvarnström’s (2010) definition allows backward traceability and trace to be seen as synonyms, while the same goes for forward traceability and tracking.

4.2 The need for traceability

The incentives for traceability may differ and different industries might have different objectives with their traceability implementation (Nambiar, 2010; Dai et al., 2012). Kvarnström (2010) argues that traceability and the target level of traceability can vary in importance in various processes and may differ between products. In order to determine a suitable target level, “the minimum number of items an organization wants to be able to uniquely separate in the process (namely the lot size)” (Kvarnström 2010, pp.26), that is, an organization first must identify the importance of traceability for an item.

Töyrylä (1999) has identified five factors that affect the need of traceability and, thus, the target level. The five factors can be described as the value of each item, the probability of an item failure and the consequences that it might have on its environment, the items lifetime, the replacement cost, and finally the external environment considering consumer concerns and the legal environment for the item. High importance implies a higher level of traceability and, consequently, requires a more detailed target level.

The possible advantages derived from traceability – why it is important

According to Cheng and Simmons (1994) traceability functions are vital, but are not directly value-adding. This might leave one questioning; why then, is it so important to embrace the concept of traceability? The answer is simple – traceability is a necessity for quality, hence very essential and an important ability for all manufacturers. The many advantages enabled through traceability are far more important than the shortcomings. Some of the main benefits found in literature are to be presented:

- **Quality and Process Improvements**: Traceability offers tools for identifying problems (Kendrick, 1994; Khabbazi et al, 2010) and is central for the identification of the root-cause behind a product deviation and thus vital to achieve a high and even product and process quality (Kvarnström, 2010; Nambiar, 2010). Through identification of root-causes future problems are reduced and prevented (Töyrylä, 1999).
Traceability also allows for process optimization and control. An organization may use traceability to identify issues affecting the efficiency of a manufacturing processes, which facilitates process improvement. As a result the organization can reduce costs (Olsen and Borit, 2013), increase productivity and achieve a higher quality (Jansen-Vullers et al., 2003). Another important advantage is that traceability makes it easier to distinguish effects of product changes (Kendrick, 1994).

- **Better-informed decision making:** Traceability gives access to more accurate information, real-time data, (Olsen and Borit, 2013) and increases the visibility and allowing for better-informed decisions to be taken (Fang et al., 2013) Reduced uncertainties within production plans and schedules allows organizations to stay competitive (Dai et al., 2012).

- **Product recall:** The use of traceability data can help locate products on the market and also make selective product recalls possible (Caplan, 1990). Hence, the information is important to minimize the extent and reduce negative impacts of undesired events (Töyrälä, 1999; Khabbazi, 2010). By recalling the non-conforming parts, the risk of product liability claims is reduced.

- **Part liability prevention:** In the event of a product liability claim, a company can use traceability data to provide evidence (Caplan, 1990).

- **Other advantages and necessities:** The usage of traceability is not restricted to the applications mentioned above. Traceability serves the needs within supply chain logistics, security, accounting and legal activities too (Khabazzi, 2010; Kvarnström, 2010). As well as for activities within quality-, information- and risk management, commercials and after-marketing (Töyrälä, 1999). Furthermore, it is argued that with the introduction of LEAN, traceability has never been more critical. Thus, traceability is essential for the implementation of continuous improvement activities (Sohal, 1997; Khabazzi, 2010). Also, many quality management systems require that organizations meet particular traceability demands (ISO 9001:2015). Hence, traceability is necessary for the fulfillment of external requirements. A final aspect to be mentioned is the proof of quality and origin. A company can gain competitive advantage through the ability to document and provide desirable product records that can be used to attain premiums or higher price products (Kendrick, 1994; Olsen and Borit, 2013; Khabbazi, 2010).

### 4.3 Achieving traceability – The implementation

As previously mentioned, it is stated that no common theoretical framework for the implementation of a traceability solution exists (Karlsen et al., 2012), possibly due to the fact that the objectives behind an implementation varies, as for the environments in which it is to be applied.
Nevertheless, Van der Vorst (2005) states that an organization needs to formulate a traceability strategy and argues that it exists three different takes on strategies. To implement traceability a company can choose to comply only with rules and regulations (compliance-oriented strategy), to achieve internal control by means of production integrated measures (process improvement-oriented strategy), or aim for full traceability within the supply chain (market-oriented strategy). Van der Vorst (2005) believes that the third strategy will help the company to achieve competitive advantages.

Kvarnström (2010) is of the opinion that an organization first must identify a suitable target level of traceability, e.g. by using Töyrylä’s five factor-concept, and then the organization needs to create the possibilities to reach the required traceability level. When implementing a traceability solution the three concepts of traceability, traceability methods and traceability systems are helpful to take into consideration (Kvarnström and Oghazi, 2008).

The relationship between these terms are shown in Figure 3 and are described as “the precision of traceability in a process is dependent on the traceability system, which in turn relies on the models created by the traceability method.” (Kvarnström & Oghazi, 2008: p. 4)

![Figure 3 – An illustration of the correlation between a traceability system and traceability method(s), and how they together creates traceability.](image)

There is continues interchange of data and information between the system and methods. The traceability achievement is dependent on both these measures and will not be fulfilled without one of them. A logical map distinguishing the different terms for traceability is presented in Appendix 1. The traceability gate map gives a structured model view of how a company can proceed to reach a sufficient level of traceability in a production process.

**Traceability system**

A traceability system can be described as required to provide the means of traceability (Moe, 1998; Furness & Osman, 2003). Hence, the traceability system is the infrastructure that enables traceability within a process step. Similar to the concept of traceability, the system is not limited to an organization but to the complete supply chain.
“A traceability system is required to provide an unambiguous, uninterrupted means of traceability for a physical lot, its sub-components, and raw materials within the supply chain.” (Kvarnström, 2010; p.28)

To successfully establish a traceability system that connects the required data with each product, thus implementing traceability, a few techniques and requirements should be considered. Steele (1995), Töyrylä (1999), and Jansen-Vullers et al. (2003) claim when designing a system the precision needs to be determined and that the resolution of a system is the minimum number of items that can be individually separated during the process. Moreover, data collection is needed, including ways of capturing the required data. Added to this is the need of product identification, which enables the linkage between product and process data. Lastly, retrieval of data from the system must be considered. This is also referred to as reporting and the actual use of the system (ibid).

**Traceability methods**

While the system is seen as the setup that enables traceability, the method can be described as the key that enables the linkage between product and process data. Kvarnström (2010) explains it as:

“The method provides the means for a traceability system to connect the correct process data to a physical lot through the whole or part of the supply chain.” (Kvarnström, 2010; p.31)

Accordingly, it is important to identify and choose the most suitable product identifier. There is a variety of different technologies available to achieve traceability (Hodgson et al., 2010; Han et al., 2011). The most common data carriers, such as barcodes and RFID, are found within the category *Auto identification*. Unique product identification can also be attained by engraving directly onto the product. This method however, does not carry any direct data. Van Dorp (2002) claims that in order for traceability to be successful, unique product identification is essential.
5 Total Quality Management

The concept of quality is closely related to the production and supply of products, and customer satisfaction. During recent years the concept however has taken on a much wider approach and now incorporates the entire organization and all internal processes (Sandholm, 2000; Sörqvist, 2001). This phenomenon is referred to as total quality management, TQM. The differences between the two perspectives on quality is explained in the Figure 4 below.

<table>
<thead>
<tr>
<th>Element</th>
<th>Quality</th>
<th>Total quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regarding………</td>
<td>Products supplied (goods or services)</td>
<td>Products supplied and everything that can come with the products (supplementary services)</td>
</tr>
<tr>
<td>Related to………</td>
<td>External customers</td>
<td>External and internal customers</td>
</tr>
<tr>
<td>Includes…………</td>
<td>Processes directly related to products supplied</td>
<td>All processes</td>
</tr>
<tr>
<td>Engages…………</td>
<td>Some people in the organisation</td>
<td>All people in the organisation</td>
</tr>
<tr>
<td>The work with quality aims at……….</td>
<td>A certain part or function of the organisation</td>
<td>All parts or functions of the organisation</td>
</tr>
<tr>
<td>The training aims at…….</td>
<td>The quality department</td>
<td>Everyone in the organisation</td>
</tr>
</tbody>
</table>

Figure 4 – Product quality versus total quality. An explanation of the different perspectives on quality.
Source: Sandholm, 2000

Sandholm (2000) argues the importance of human performance in quality. He mentions that it is generally believed that most quality problems are caused on the part of the individual and its lack of interest and attention. Quality would be better if the person’s behavior could be influenced. However, not all the blame can be laid on the individual. There are often a variety of different factors which the individuals cannot influence. For example, quality problems are often caused due to the lack of proper conditions such as inadequate instructions and neglected training.

Furthermore, the author continues by listing a few basic prerequisites needed to attain good results and stresses the importance of a genuine action plan and that the quality required must be clearly and unambiguously stated. Sandholm (2000) then emphasizes the need for the manager to take on the role as a quality leader and states that how well a company succeeds depends on the leader’s ability to operate the quality related activities. A few guiding principles for the quality leader are mentioned. Among these one can find: (Sandholm, 2000; p.227)

- Instruct personnel in how tasks are to be performed in order to achieve the right quality. Including information about the consequences in the case of a failure or defect, both internally at the next operation and for customers.
- Follow up the work to ensure that it is performed in the right way.
- Set goal for quality and guide quality activities towards them. These goals should be derived from the company quality policy, declared by the top management.
- Ensure that equipment and other tools are in good condition.
- Monitor quality trends.
- Ensure that quality problems are dealt with.

5.1 Quality system - ISO 9000

A management system is a way of defining an organization’s operations to help it meet its objectives. Thus, a quality management system (QMS) is a way of defining how an organization can meet the requirements of its customers and other stakeholders affected by its work. A quality system embraces all activities that influence quality and shows their relationship towards one another. (Sandholm, 2000; ISO 9001:2015)

ISO 9000 is the international series of standards for quality systems. These standards help organizations to develop and introduce procedures for their own quality activities by setting out the requirements for a quality management system. ISO 9001 is one standard within the series and broadest in its scope. It helps businesses and organizations be more efficient and improve customer satisfaction (ISO, 2015-1).

The seven principles

ISO 9001 can help bring financial benefits by improving customer experience, and increasing productivity and efficiency, thus lowering the costs and increasing an organization’s sales and income (ISO, 2015-1). The ISO 9001 standard builds on seven quality management principles. The seven quality management principles are: (ISO, 2015-2)

QMP 1 – Customer focus
QMP 2 – Leadership
QMP 3 – Engagement of people
QMP 4 – Process approach
QMP 5 – Improvement
QMP 6 – Evidence-based decision making
QMP 7 – Relationship management

See appendix 2 for more details regarding each of the seven principles. The importance of these principles are also emphasized by Höglund & Olsson, (2015).

5.2 Cost of poor quality

When working with business development a common deployed tool is the theory called Cost of Poor Quality (COPQ). This tool helps an organization to identify their problem areas by acquiring knowledge about where the costs for poor quality exist (Sörqvist, 2001). The total cost of poor quality can correspond to about 10-40% of a company’s total revenue (Swerea IVF, 2008).

The costs for poor quality are divided into three categories:

- Appraisal cost – costs for verifying that required quality are delivered in all process steps. E.g., control, inspection, surveillance and internal revision.
- **Internal failure cost** – losses caused by deviations from required quality level, detected before delivery to external customer. E.g., re-work, scrap, wait, delays, inefficiency, re-control.

- **External failure cost** – losses caused by deviations from required quality level, detected after delivery to external customer. E.g., claim, warranty, recall, fine, discount, lost revenue and badwill.

Due to the difficulty of measuring all the costs they can be categorized in five levels. These are, traditional COPQ, hidden COPQ, lost revenue, customer expenditure and socio-economic costs. Figure 5 represents a common perspective of the costs of poor quality. Demonstrated by the iceberg the biggest costs are not visible, they are the hidden ones. To estimate all the hidden costs an organization must have knowledge regarding what is unnecessary expenses.

![Costs of Poor Quality Diagram](image)

*Figure 5 – A common and representative view of the costs of poor quality. The top represents about 10-40 % of all costs emerged due to poor quality.*

The visible costs correspond to approximately 10-40% of all COPQ, whereas 60-90% normally go unseen (Sörqvist, 2001). Costs that are usually associated with visible and traditional costs are related to re-work, scrap, warranty, recall, lacking efficiency, and claim among others. These are costs that many companies measure since they are direct and easy to identify (Swerea IVF, 2008).
6 Industrial investigation

In order to give the reader full understanding of the context, this chapter will shortly describe the company and its offerings, together with the business case’s limitations. The context, in which the study took place, will be described by presenting the product, followed by the current traceability situation at Atlas Copco Secoroc, which will be presented with regards to the theoretical background. Likewise, the quality department’s reality are to be explained before the main findings are summarized.

6.1 Rock Drilling Tools – Atlas Copco Secoroc AB

Atlas Copco Secoroc AB, also known as Rock Drilling Tools (RDT), is a division within the Atlas Copco Group and operates in the business area of Mining and Rock Excavation Technique. The business area has a leading market position globally in most of its operations and the target customers are within surface and underground mining, infrastructure, civil works, well drilling and geotechnical applications (Atlas Copco’s Annual Report, 2015).

The Atlas Copco Group’s vision to become and remain “First in Mind—First in Choice” is well-communicated throughout the organization, which is based on the principle of decentralized responsibilities and authorities. Due to the managerial decentralization, the different business areas are autonomously managed and consequently responsible for their continued development. The divisions in turn, are separate operational units and are independently accountable to perform according to strategies and objectives communicated within the business area. Furthermore, a division can have one or more product companies and several customer centers dedicated or shared with other divisions. Product companies are units responsible for product development, manufacturing and product marketing, and customer centers can be described as units responsible for customer relations, sales and service (Atlas Copco’s Annual Report, 2015).

Based on customer needs, the RDT-division offers innovative products and an extensive product portfolio for several market segments and a wide range of application areas. As for the business area, the division is a global supplier and holds a market leading position for some of their market segments. To mention some, they provide rotary and exploration bits, hammers, handheld tools and bolts for underground support (Internal document, 2016). A selection is displayed in the Figure 6 below.

![Figure 6 – A selection of products provided by the Rock Drilling Tools division (Internal source).](image-url)
This research has been conducted at the production unit in Fagersta, Sweden. The plant is one of 13 product companies within the RDT-division, and is specialized in top- and down-the-hole hammers, bits, inserts, drilling tubes and rods, which all are developed, manufactured, marketed, sold and serviced at the production plant in Fagersta.

6.2 Limitations of business case

Here follows information regarding the business case’s limitations. The information also explains and places the study in its context.

6.2.1 Supply chain

As previously mentioned, a traceability solution should cover the complete supply chain in order to reach full potential. However, due to the limited time frame, this project has been delimited to not focus on the entire supply chain process. Figure 7 illustrates a generalized representation of the RDT-division’s supply chain, as for a more detailed view on how a product company might be structured.

![Figure 7 – The general RDT-supply chain. Including insights to how the selected product company is structured.](image)

As presented in Figure 7, a product moves through four different chain steps before it reaches the final customer. This study has focused on one Product Company, and more specifically the internal traceability within one of its five departments. This is demonstrated with the red continuous lines. The blue dotted lines capture an extended part of the supply chain to allow a more holistic and deliberated view for the projects recommendations.

One of the departments was excluded for the reason of geographical convenience, it has a different location than the other four factories. The same reasoning goes for the customer centers and end customers that are located all across the globe.

Worth mentioning for the sake of comprehension of the entire picture, all five departments manage a different number of manufacturing processes. These processes in turn, are functionally structured and cover various interrelated product flows.
6.2.2 DTH-hammer and bit

This study has been limited to focus on the down-the-hole (DTH) hammers and bits. This selection was made due to the fact that these two products represent the selected department’s main product offerings. They were also selected on account of their complexity. In this case complexity refers to the number of components and their dimensional requirements, in comparison to other products produced at the plant.

Figure 8 shows an exploded view of a complete hammer. The bit is represented by number 1, whilst the rest of the components are assembled into the actual hammer.

![DTH-hammer exploded view](image)

Components that are important to the products functionality have been central in the study. These components are bit (1), chuck (2), casing (7), piston (8), control tube (10) and backhead (21).

In common for these components is that they are manufactured in-house and they are machined by turning and milling, among other, before they are heat treated and painted. However, some are purchased as semi-finished goods, others as raw material. Some are only manufactured in-house, whilst some are produced both by Atlas Copco Secoroc and sub-contractors. Additionally, components such as springs (18), lock- and O-rings (3, 5, 9) are called commodities and bought directly as finished components.

6.2.3 Process chain and information flow

As mentioned, main focus has been towards production and the manufacturing of components. Thus, little work has been addressed to the identification of traceability within the company’s different functions. However, some administrational processes have been examined, but only briefly. These are information flows directly related to the production processes under investigation and will be included in presented findings.
Moreover, manufacturing and control processes at the suppliers and sub-contractors has been excluded. The investigation only includes the information interfaces between them and the case object.

**6.3 Current situation**

The following sections are structured in accordance to the presented literature review. First the present traceability situation and its limitations are described. It is followed with a presentation of the current quality assurance, where the effects from a lacking traceability solution are central. The information described in this chapter is obtained through first-hand observations and interviews, and via analysis of existing internal documents.

All findings in this project are confidential material and therefore only presented to the company. Consequently, the information presented from here on only represents mere reflections of the reality. Also, only the main finding areas are to be highlighted.

**6.3.1 Traceability at Secoroc**

Early on it became relatively clear that a unified, defined and communicated traceability solution is missing. The existing traceability situation are to be presented:

**The Need**

The necessity of traceability is not yet defined. Not for the organization at large, nor for the different products. Secoroc’s product offerings primarily fall into the mining industry’s category of consumables with a fairly short life expectancy. The consequences in the case of a failure are big, not in a legal sense but from a customer’s productivity loss perspective. The product value and complexity vary between products at the product company and so also the importance of traceability. Remember, nothing of this has previously been defined or assessed by the organization.

In comparison to the food industry, for example, Atlas Copco Secoroc is not exposed to any traceability requirements from customers or legislations. The only external requirement comes from their Quality Management System (QMS) and ISO-certification. They are currently certified with ISO 9001:2008 and plan a transition towards the latest ISO 9001:2015 standard during 2017. Even though the customers do not demand traceability the need for evidence has been observed in the case of a customer complaint. Consequently, it has been identified that current objectives for an implementation are completely created by the company itself. Referring to the management and divisional vision (DTP 2.0) and the quality department’s desire for process optimization, their wish for the ability to predict that is.

Similar to what is mentioned concerning the traceability requirements, the same goes for general product and quality requirements too. Secoroc delivers products where all requirements are specified by them. In other words, no communicated demands to fulfill from customers. Obviously they still have expectations that must be met.

Concerning a traceability strategy, it is notable by its absence. As for everything already mentioned. In fact, up until now, the organization has not been aware of the need of a strategy.
Perhaps because of the simple reason that they have not clearly stated that traceability is something they wish to achieve. However, given the background (previous initiatives, company vision) it can be assumed that the organization aims to reach full supply chain traceability. They hope to gain competitive advantages through a market-oriented strategy - without even knowing so. And far more importantly, without understanding its basic fundamentals. Moreover, the quality department is aware that a traceability solution must be in place before any advantages from for instance DTP 2.0 can be gained and they have communicated their desire for adopting a process improvement-oriented strategy. Which in a way is incorporated into the market-oriented strategy since chain traceability is dependent on full internal traceability at all process steps in the supply chain.

Once again it is important to stress that a strategy from the company’s viewpoint is missing. According to scholars a system and method(s) are needed after the identification of a suitable target level. The details about the current situation regarding these two subjects are to be covered in the next chapter, *The Ability*.

*The Ability*

In the case of deviations and/or recalls it is important to be able to trace and track products throughout the entire supply chain. Figure 9 illustrates Product-A, which is a product extracted from Lot-A containing of $n$ parts. After manufacturing at the product company, Lot-A is stored at the distribution center before packed and delivered to an unknown number of customers (see Figure 7 for a reminder of the supply chain logistics). Product-A consists of four essential elements:

*Input data* – Product requirements such as drawings, process specifications and bill of material (BOM).

*Material* – External and/or internal suppliers of raw material, semi-finished goods and/or components.

*Processing* – Machining (turning, milling, honing, drilling etc.), heat treatment, metallurgical control, assembling, painting and packaging performed in-house and/or by sub-contractors.

*Delivery* – Receiving and storage management of Product A (or Lot-A) at the distribution center. Packaging and delivery of customer order to customer center.

The “Proof of Quality”-box represents all information of interest and from where it is supplied. This box is just a representation and does not exist, the reasons for it will be explained in continuation.
Dashed lines represents possible connections. For instance, same raw material could be used for manufacturing of other products, either in the same lot-A or Product B. Also, a process deviation could possibly have affected other MO’s and products during the given time of failure.

According to the scientific literature and the definition chosen for this project, traceability should enable three scenarios, the ability to:

**Scenario 1: Track – Identify where a product is being used.**
Imagen that the raw material supplier sends a notification of a defected charge delivery, possibly included in different purchase orders and so received multiple times. This scenario is illustrated with color red in Figure 9 and is initiated at (1). Today there is no easy way to find all products produced by that specific charge. The charge number is not searchable. In the company’s ERP-system (M3) it is possible to find a connection between purchase-, manufacturing- and customer orders but since the material is not allocated to a specific manufacturing order, MO, (neither is the MO designated to a specific customer) the information is not bullet-proof. Assumptions can be made in M3 based on transaction history, but it is not easy to access and identify all MO’s and products deriving from that faulty charge, nor reassuring.

Other matters affecting the ability to track down the exact location of a product is the lack of standardized procedures for goods receiving control and stock management. In fact, some of the products are handled with a replenishment system and the break point between two orders is difficult, sometime even impossible, to identify. This means that traceability is lost at the distribution center (DC). The same procedure is used for some of the components used to assembly a hammer.
Scenario 2: Trace – Identify the history of a product and where it is from.
This scenario, which is a case that relies heavily on traceability and requires access to a large set of data, is illustrated by the entire figure. It begins with a customer complaint (2) and it is important to know what product it is, from which lot it originates, what raw materials it contains, and when and how it was produced. This is necessary information in order to determine the correct root-cause and to be able to identify possibly other affected products. At this point, depending on the outcome, a trace scenario turns into a track scenario. The ability to trace back the history emphasizes the importance of identifiers, and thus traceability methods. What is the unique identification carrier has not been decided by the company, and therefore not standardized. When tracing information the MO-number tends to be the common denominator and it is usually engraved directly onto the product. Regarding marking approximately 90% of products are marked but roughly 10% according to drawings and specifications. The engraving techniques differ and so the quality. Also it has been identified a difference in marking on products that can be produced internally and by sub-contractor. For products marked with engraving it is important to understand the applications corrosive environment. The bit for example, which crushes rocks are subject for excessive wear and almost not recognizable after use. Etiquettes are used for products that lack ID-marking. This solution also fails to secure traceability since it similar to the bit either wares off or are thrown away. In some cases the etiquette is even attached on the thread cover, which is removed by customer prior to use.

As for the variety of marking methods, no standardized solution for its linkage to accurate process data exist. More explicitly, a traceability system is missing. For all daily operations a number of different systems, databases and servers are used. They are all explained in the Table 1 - Databases and systems used at the production plant.
Table 1 – Databases and systems used at the production plant.

<table>
<thead>
<tr>
<th>System/Database</th>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>M3 ERP-system. Used for inventory management, shipping, product planning, manufacturing, finance, and more. Allows for some linkage between PO, MO and CO. Holds information regarding products BOM-structures. Also, a very limited amount of quality information can be extracted from M3.</td>
<td></td>
</tr>
<tr>
<td>Axxos OEE-system. A software solution for day-to-day production monitoring used to improve manufacturing productivity.</td>
<td></td>
</tr>
<tr>
<td>ProTherm System used for monitoring of furnaces in the heat treatment process. System logs and stores process data on database where program access is required.</td>
<td></td>
</tr>
<tr>
<td>PDM-link A system containing all product drawings. Mainly used by the R&amp;D-department.</td>
<td></td>
</tr>
<tr>
<td>Lotus Notes The IMS - Integrated Management System is managed through Lotus Notes. All work and control instructions are stored on this database. Lotus Notes is currently being changed to the cloud solution based software SharePoint. Lotus Notes is also used for managing deviation reports. All product and process specification are found here.</td>
<td></td>
</tr>
<tr>
<td>The Portal Same as Lotus but allows a web-based interfaces. This is where operators found their instructions and routines, etc. (Only accepts reading, no editing.)</td>
<td></td>
</tr>
<tr>
<td>SharePoint Currently only used for managing claims since it holds the claim process. Will shortly be the forum where the IMS can be found.</td>
<td></td>
</tr>
<tr>
<td>QlikView and Click &amp; Decide Report analysis tools. These two programs facilitate the reading of data and makes it visual. Information mainly gathered from M3 but QlikView allows the reports to collect information from different databases.</td>
<td></td>
</tr>
<tr>
<td>Extend A scanning software used at the DC for order-picking. Based on the barcode technology. Can be seen as an add-on to M3.</td>
<td></td>
</tr>
<tr>
<td>AC-server Local network file server. Each department has their own folder containing complementary information that cannot be found in the IMS. Note that machine drawings can be found here while the final product drawing is in PDM-link. This file server also stores most quality information, such as measuring protocols and material analyses.</td>
<td></td>
</tr>
</tbody>
</table>

Information Description:

<table>
<thead>
<tr>
<th>Information</th>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process data Information mainly stored locally in the machines own computer. Usually accessible at the PC but at times machine suppliers need to be contacted in order to access records. Some process information, such as controls, are kept as paper copies.</td>
<td></td>
</tr>
<tr>
<td>Quality data Very little quality information (proof) is stored. The data that do exist (material analyses and measuring protocols) are stored on the AC-server or individual computers.</td>
<td></td>
</tr>
<tr>
<td>Paper copies An inexplicable amount of information is still stored as paper copies. E.g. process information, quality and measuring protocols. The information is created by both AC and suppliers/sub-contractors.</td>
<td></td>
</tr>
</tbody>
</table>

The current situation of data handling does not facilitate tracing. In order to gather all information regarding a specific product or MO, one most access all the different system listed in the table (since each and every one contains parameters of interest). Information is not searchable and cannot be easily retrieved through one single system. This results in a highly non-transparent environment. Appendix 3 – “Lack of transparency: quality information and process data” illustrates the lack of transparency and gives a holistic overview of the current situation.
Not only has the lack of transparency a poor impact on a case of scenario 2 investigation. More notably, the information is not reliable and complicates the identification of root-causes. For example, it is impossible to determine what raw material has been used in Product A since Lot-A possibly can be produced from more than one charges. This reduces the possibilities to do a selective product recall. Another aspect, of equal importance, is the absence of an adjustment routine. A product can be sent for adjustment or re-work without the deviation being reported, which makes it impossible to determine what process step actually caused the failure. The manual reporting of numbers and connections in M3, together with hand typed etiquettes and markings does not aid the reliability.

**Scenario 3: Predict**

With the scenario 1 and 2 in mind there is barely no need to explain that the third scenario to predict the lots manufacturing flow and optimize the upcoming processes also falls short. Worth mentioning is that as long as a MO is in the production plant it is possible to track its theoretical location through M3 and Axxos. For instance, that it is being manufactured or queued in a specific machine. However, the information in M3 and Axxos is dependent on the registrations made by personnel and therefore the actual location of the pallet(s) may well differ. Information is not in real-time and thus only used reactively.

### 6.3.2 Quality at Secoroc

As mentioned, traceability is a necessity for quality and the work with improvements. Traceability offers tools for identifying problems and is central for the identification of the root-cause behind a product deviation. Through identification of root-causes future problems can be reduced and prevented. In a perfect world traceability also allows for better-informed decision making through access to accurate information. Due to the earlier described inadequacies this is not the reality for Secoroc and its quality department.

**Insufficient traceability affecting the quality department’s results and procedures**

The quality department is a support function assisting the entire product company. Today the personnel mainly work reactively with investigations of non-conformance and internal deviation reports. As a result of the situation displayed in Appendix 3 – “Lack of transparency: quality information and process data” and also explained in relation to Table 1, these investigations are seriously implicated. In fact, more than 50% of the quality departments total working hours are put into the investigation of internal quality deviations. The problems reoccur and only a fraction results in sustainable solutions, leaving them handling emergencies instead of focusing on continued development.

*Figure 10 – How the deficient traceability currently affects the quality department, SHEQ, and its management of quality.*

Figure 10 shows the negative consequences attained from lacking traceability. The implications are displayed to the far right and take form as inefficiency, insufficient accuracy and low development rate.
The illustration represents the flow for how the shortages are created throughout a product's lifecycle and in the end take expression by affecting the overall quality management. At the moment the quality department mainly work with investigations of internal deviations (B) and identifying root-causes. They also support the marketing department when customer claims are examined due to a technical problem, so called Non-conformance reports (C). However, due to the deficient traceability, the handling of these tasks results in extended lead times and decisions being made based on mistaken information, leaving the personnel without time for continued development. Figure 10 indicates that the deficiencies are generated in the production, as well as by the R&D- and purchase departments. For example the R&D-department lacks a well-functioning routine for the industrialization of new products, nor is the responsibilities regarding change process clearly defined. The production on the other hand barely stores any data, making the available information incomplete.

**TQM**

Another critical observation made is that the department lacks quality goals, vision and mission. None of these elementary pillars have been formulated by the divisional management. This shortage in managerial engagement affects the organization top-down. Some affected areas are to be emphasized in continuation.

**Scrap**

The entire plant, all factories that is and without distinction between departments, has a communicated quality goal of 1.5% scrap. Not only is the scrap percentage currently unrealistic but it also hides costs, which results in incorrectly used resources and misleading priorities. For instance, at the investigated factory the scrap percentage are presented and discussed on an overall factory level. This does not give a good representation of the reality since the factory on average has a yearly scrap level of approximately 2.8%, while some components are as high as 8.5%.

**Cost of poor quality, COPQ**

It was discovered that the only data available today showing the costs of poor quality is related to scrap volumes. Thus, most costs are still hidden and go unseen. The concept of First Time Through (FTT) is not widely known within the organization, nor measured. This means that
adjustments and re-work are not registered and go unseen. The pre-conditions to register re-work exists in already existing systems, which leaves this to be a matter of leadership.

Also, the control costs are difficult to estimate. This goes for both planned control costs as for unplanned. Planned control frequencies are documented but guidelines for unplanned controls and exception routines does not exist. For example; during normal production a certain manufacturing order should be measured in the coordinate measuring machine between two and ten times, depending on the result and number of shift changes. A search on one of the articles MO’s resulted in over 100 hits. Are the increased number of controls accepted as planned since they might be preordered or are they seen as excess? How this cost should be labeled and accounted for is unclear. Neither is it possible to find historical logs on the decision made to perform an increased number of controls, if it actually was made.

*Quality Control and Documentation*

Operator routines and instructions are not followed. The operator controls are not performed according to communicated and agreed frequencies. Only a fraction of the controls are performed and these deviated behaviors, the lack of engagement, are accepted. Furthermore, it is notable that only the quality controls performed in measuring machines are documented. Meaning that measurements done by operators are not registered.

Moreover, as shown in Appendix 3 – “Lack of transparency: quality information and process data”, the information majority is stored in formats that does not allow analysis. Obviously, this also adds to the shortages presented in Figure 10.
6.3.3 Summary of main findings

Below follows a summarized list on the most apparent observations and critical shortcomings identified through the current state analysis:

- Ignorance towards the traceability concept.
  - The need is unknown and a strategy missing.
  - Quality department is aware but lacks mandate and resources to act upon it.

- Low quality engagement.
  - Ignorance towards Total Quality Management.
  - Cost of Poor Quality is not visible or measured.
  - Standardizations are missing.
  - It is accepted to deviate from existing routines and instructions, leaving the organization with limited quality and process control.

- Very limited possibilities for a root-cause identification and thus decisions are made based on incorrect information.

- The organization suffers from not having standardized procedures regarding:
  - Product management, storage management, purchase and planning processes, goods reception and relationship management.

- The available information may be inadequate and lack transparency. The same can be said about the organization and its departments too. Due to decentralized responsibilities there is no collaboration between company functions, nor their processes.

- Every action within the organization is a reactive countermeasure. They do not advocate a proactive mindset and use of information.

- Consistently inadequate leadership and unclear allocation of responsibilities.

- The company strategy and digital vision are communicated with a top-down approach where there exists a disconnect to the operations with little understanding of its reality and therefore the gaps that the vision creates.
7 Recommendations

Given the information presented in the previous chapters, this section aims to present recommendations for how Atlas Copco Secoroc AB could enhance their traceability. The findings are confidential material and thus presented in more detail to the company only, found in Appendix 4 - Suggested improvements. Consequently, this section only provides the reader with an indication of what areas the suggested improvements cover.

As pointed out in the industrial investigation the company lacks a defined and integrated traceability system and so they have a long way to go before they proudly can present a fully enabled solution. The following are some recommended measures that must be considered in order to be able to improve the traceability level. When they are accounted for, the current traceability situation most likely will be enhanced, as for the company’s quality assurance procedures.

7.1 Acknowledge the importance of traceability

The lack of a unanimous theoretical framework and a handbook for best practice implementations may perhaps make the concept of traceability confusing and difficult to comprehend. This, however, does not mean the subject should be ignored. It is time for the divisional management to make a deliberate decision concerning traceability, agree on its importance and communicate it to the entire business. The organization must overcome the ignorance and acquire knowledge regarding the subject.

For this purpose, I would like to remind the reader of the traceability definition stated by Kvarnström (2010):

“Traceability is the ability to track, trace, and predict the location of a lot, its sub-components, and raw materials through the supply chain” (p.25)

This definition was chosen because it covers everything and allows Atlas Copco Secoroc to become best in what they do. It gives the company the right context and all insights needed to remember all aspects of this usually comprehensive and confusing concept.

Do it for all the right reasons

After a change of attitude towards the traceability concept the organization must understand why they are in need of an improvement. This cannot be stressed enough. Especially not now, with all the ongoing projects and initiatives. Even though the literature mostly disagrees, the scholars agree on one thing: the fact that a chain traceability is dependent on all companies in a supply chain having full internal traceability (Moe, 1998; Opara and Mazaud, 2001; Karlsen and Senneset, 2006; Van der Vorst, 2005; Regattieri et al., 2007). This means that for the company to succeed with digital transformation projects such as DTP 1.0 and 2.0, and to fully benefit from their respective investments, they must understand the need for full internal traceability within their own production processes and appoint the necessary resources accordingly. Hence, focus firstly on securing the internal traceability and then expand to cover the entire chain. Remember to have the future development plans in mind when designing the system.
In line with this argument comes the necessity of a clearly defined strategy (Van der Vorst, 2005). As for the need of well-defined objectives and incentives behind the implementation (Khabbazi et al. 2010; Namibiar, 2010; Dai et al., 2012). Before the actual implementation can be planned and executed the target level must be agreed upon. Use the five-factor-method by Töyrylä (1999) to define the level of traceability needed. And remember, the company’s biggest difficulty lies in the agreement on what is an adequate level of traceability.

**Understand the concepts of traceability system and methods**

When preparing for a traceability implementation it is essential to know the concepts all building blocks. After the suitable traceability level is determined it is time to create the possibilities to reach that level. Build the infrastructure and select the most appropriate methods. Understand the linkage between these perceptions and what role they play in the overall solution. To prevent systematic information loss, which is a reoccurring problem, the product should be assigned unique identifiers that systematically records data and information [Karlsen et al., 2012]. Furthermore, to minimize the possibility for human error, consider implementing the Extend system, or similar, up the supply chain. And, aim for transparency. By referring to Appendix 3 - Lack of transparency, I would like to stress the need for a more transparent environment. The company will benefit greatly from a system implementation that allows transparency. It will most definitely, but not only, aid the quality department in their daily work.

Consequently, a first step in the direction to acknowledge the importance of traceability is to assign a dedicated and diverse team. Allow them to understand and break down the traceability concepts into its finest components. Align the acquired knowledge with the company vision and from there, identify the traceability strategy and the necessary target level. Decide what information is desired to have in the traceability system and outline a roadmap from there. Trust and allow the team to act upon initiatives that are in the best interest of the company.

**7.2 Redefine the Quality Management System**

As presented in the industrial investigation the overall organizational quality engagement is very low and beneath contempt. The next recommendation therefore goes out to the top management and can be summarized as; stop, rewind, and restart all the work related to the existing quality management system. The organization needs to embrace and focus on total quality management. A clear quality strategy must be formulated, as well as its goals and context identified. The organization would benefit greatly if they only focused on the seven quality management principles outlined by ISO. The fact that they also facilitate the implementation of a traceability system is not a disadvantage.

I see a great opportunity to recreate the company wide quality strategy as the new implementation of ISO 9001:2015 is planned later this year. If the organization redefines their QMS and truly strives to work accordingly, the company will soon realize that certain quality management systems require that organizations meet particular traceability demands (ISO 9001:2015). The necessity of traceability will become more evident by redefining the quality management system and focusing on the seven principles.
Change is necessary to stay competitive and profitable

The first step towards quality and process improvements does not come from the implementation of a traceability system and methods. Less complex and much cheaper measures can be put in effect to improve the quality. For instance, the wide-ranging quality goal of 1.5% scrap must be altered. These types of goals must be broken down into more specific and realistic targets in order to visualize the real problem areas. By acting on a simple measure like the one presented above, other benefits will derive from it too, such as higher employee engagement and involvement. If the organization adopts a process approach, as mentioned in one of the 7 principles, making sure everyone understands their part and how it is connected to others and impacts the entire system, and at the same time emphasizes the importance of continues improvements, it will drive higher engagement and better results.

Another recommendation is to start identifying the true costs of poor quality. It is a common saying that visible problems and costs only reflects a fraction of the actual value – that they only represent the tip of the ice berg. Knowing the price tag on the tip of this organizations ice berg, I can say no more than it is about time to focus on quality and that I see nothing but great potential.

7.3 Focus on the issues closest to you

As the technical setting impacts the application of traceability data, the organizational setting affects the overall success and acceptance of the traceability system. Literature stresses the importance of user acceptance, and that motivation and training is important for implementing traceability and achieving quality. Related to the topic of motivation, a few necessary organizational prerequisites have been identified as critical deficiencies, which the company must overcome prior to any future system implementation.

- Leadership
- Quality engagement
- Governance
- Responsibility
- Comprehension
- Monitoring
- Feedback
- Requirements
- Demand
- Standardization
- Appliance to routines and instructions

When presented fundamental requisites are in place and functioning smoothly within the organization it is time to continue with the traceability implementation. Thus, the organization must further investigate and standardize the following inadequacies:

- Reception and handling of internal and external documentation
- Linkage between products and information
- Minimizing manual labor
- Implementation of a digital measuring system
- Relationship management – Suppliers and sub-contractors
- Purchasing and planning procedures
- Reception of incoming material and products
- Management and updates of instructions and drawings
- ERP Ownership and support (M3)
- Storage management
- ID-marking
- Adjustment routines

Mentioned areas are associated with the entire product company and therefore directed to managers at the top level. All topics should be considered and handled as part of the future project in order to take the traceability implementation to the next level.

In the same way, some department specific activities have been identified and recommended to the production management team:

- Demand quality and appliance to existing routines
- Document measurements
- Standardize work instructions and its management
- Standardize and create a list of names, abbreviations and translations
- Introduce goods-reception control
- Standardize the administration and planning process
- Create a routine for M3 reporting
- Create a new scrap code for re-work
- Bit: Create routine for how to assure material traceability
- Hammer: Improve ID-marking


8 Discussion

I would like to finish this work by stating that the Rock Drilling Tools division at Atlas Copco has the right intention when they talk about digital innovation in their divisional strategy. That they aim to differentiate themselves by offering quality, safety and productivity through digital solutions. That they wish to accomplish this vision by embracing the Internet of Things and introducing some of the latest technological and digital trends. They are unquestionably on the right track since digitalization is just that, a strategy of adopting recent technologies in IT to make the most of the digital resources available in the enterprise, with benefits such as developed business models, improved customer experience, more productivity and automation.

However, I fear that Secoroc’s on-going initiatives within this field are too focused on the external environment and its customers, and that they forget the importance of assuring their own internal digital maturity. To achieve their digitalization strategy, they first and foremost must digitize their business and its processes before they bring digital products to market.

This brings us back to the topic of traceability. A solid traceability solution must be in place before the division can gain any competitive advantages from the other innovative solutions. This research has identified various areas that must be improved before the division can achieve a total traceability solution. It will take time to clearly define, design and implement it all, but it cannot be overlooked any longer. Traceability is a necessity for quality, hence very essential and an important ability for all manufacturers.

It can be discussed to what extent this thesis project fulfills its purpose on describing how the case object can improve the traceability since it entails few details regarding how an implementation could be carried out. Neither does the study investigate the possibilities of using certain methods. The organization, in its current setting, is not mature to successfully carry out a project in this caliber. It was therefore a deliberated decision to not evaluate suitable traceability methods, nor dig into specific details about system architectures and so on. Hence, the focus was directed towards what was identified as the most critical shortcomings: the absence of traceability objectives and strategy, the ignorance towards the concept and organizational requisites.

With this in mind, I would like to state that the objective of this research project is fulfilled. It emphasizes, in a general outlook, the why and how by presenting clear recommendations. Considered a pre-study it successfully identifies all existing inadequacies, explains the importance of traceability and presents material that must be taken into consideration before advancing further. Thus, the results presented in this thesis will support future decisions regarding traceability improvements. I am of the opinion that instead of “quick-fixing” the traceability gap, a more stable, thorough and future-proof way is achieved by accepting the findings and continue to define a traceability improvement strategy.

Furthermore, by focusing on traceability I believe the organization will find great positive effects on their overall quality performance. Through the application of all suggested improvements the company will reach a long way on taking back the production and quality control and
visualizing the real problems. The suggested improvements will lead to a transparent environment where production take on more responsibility and thus, in the long run, this will minimize scrap volumes and reduce associated costs.

Since industries change over time, the tracing system has to adapt in order to fulfill the changed requirements. To stay competitive, it is a continuous process that needs continuous improvements. As for everything within today’s industry. To conclude, I am confident that Atlas Copco Secoroc will manage to implement a traceability solution at the investigated plant. It will take time, be extremely comprehensive and require organizational structure and clear definitions of responsibilities, and thus demand patient. As mentioned, Atlas Copco has the right pre-conditions to make this a reality. Not to mention the industrial benefits with relatively few components, a low development rate, known customers, a standard product portfolio and no external demand. If companies acting within the automotive and food industry can have full traceability, so can this organization. And remember, traceability equals quality and that is a good enough incentive to make the topic of traceability a priority.
References


Appendix 1 – The traceability map for logical outcome

The traceability gate map gives a structured model view of how a company can proceed to reach a sufficient level of traceability in a production process. Moreover, the map presents a clear representation of the relation between the different terms for traceability, used in this study (Kvarnström and Oghazi, 2008), as presented in Figure 3.
Appendix 2 – The seven quality management principles

1. **Customer focus.** Meeting – and exceeding – customer needs is the primary focus of quality management and will contribute to the long-term success of your enterprise. It is important to not only attract but also retain the confidence of your customers, so adapting to their future needs is key.

2. **Leadership.** Having a unified direction or mission that comes from strong leadership is essential to ensure that everyone in the organization understands what you are trying to achieve.

3. **Engagement of people.** Creating value for your customers will be easier if you have competent, empowered and engaged people at all levels of your business or organization.

4. **Process approach.** Understanding activities as processes that link together and function as a system helps achieve more consistent and predictable results. People, teams and processes do not exist in a vacuum and ensuring everyone is familiar with the organization’s activities and how they fit together will ultimately improve efficiency.

5. **Improvement.** Successful organizations have an ongoing focus on improvement. Reacting to changes in the internal and external environment is necessary if you want to continue to deliver value for your customers. This is of paramount importance today when conditions evolve so quickly.

6. **Evidence-based decision making.** Making decisions is never easy and naturally involves a degree of uncertainty, but ensuring your decisions are based on the analysis and evaluation of data is more likely to produce the desired result.

7. **Relationship management.** Today’s businesses and organizations do not work in a vacuum. Identifying the important relationships you have with interested parties such as your suppliers – and setting out a plan to manage them – will drive sustained success.

The list is directly cited from ISO 9001:2015 – How to use it.
Appendix 3 – Illustration of the current situation from a transparency perspective

Lack of transparency with regards to quality information and process data.
Appendix 4 – Suggested improvements

Appendix 4 – Suggested improvements is based on confidential material regarding internal production processes and product specifications, and thus only attached to the report presented to Atlas Copco. The appendix contains a detailed description of the current traceability situation, financial numbers, quality information and suggested improvements.