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The road to an automated truck maintenance workshop:opportunities and challenges

Master of Science Thesis
in the Supply Chain Management Programme

BARBARA MENSAH
WEI LIU

Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY
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BARBARA MENSAH
WEI LIU

Tutor, Chalmers: Frida Lind & Lisa Melander
Tutor, company: Maggie Tsang

Department of Technology Management and Economics
Division of Logistics and Transportation
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BARBARA MENSAH & WEI LIU

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Department of Technology Management and Economics
Division of Logistics and Transportation
Chalmers University of Technology
SE-412 96 Göteborg, Sweden
Telephone: + 46 (0)31-772 1000

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ABSTRACT

Automation is seen as a solution that many industries are adopting into their operations in order to meet the competitive market. Earlier researchers have shown that automation is a way for humans to extend the capability of tools and machines by using control systems and information technologies to relieve humans from heavy and dangerous work.

The aim of this thesis is to gain an understanding of automation technologies and its applications in three major industries. The thesis also discusses the industry maturity, benefits and challenges of the three industries. The project is part of the Volvo AB's project: Efficient Maintenance for Sustainable Transport Solutions (EMATS).

A qualitative research strategy, semi-structured interviews, unstructured interviews and participant observation are used to collect empirical data. Different sources and kinds of secondary data have been well collected.

This thesis proposes five levels of automation for the vehicle maintenance workshop. The first level is totally manual. At this level, the technician identifies and diagnoses a fault with his experience and fixes these faults using basic tools. The second level is vehicle diagnostics assistance. At this level, the technician uses a diagnostic tool to diagnose the fault and fixes these faults using flexible tools. The third level is partial automation. At this level, an automated system is used to fix the faults that were found in the vehicle diagnostics scenario. The fourth level is high automation. At this level, an automated system is used to diagnose, fix and verify the faults. This level is not fully matured to fix all faults in its knowledge base and requires a human presence at the workshop. The fifth level is totally automatic. This level can reliably identify all faults and correct them.

The main theoretical contribution of this thesis develops a framework to define the levels of an automated truck maintenance workshop and describes how the truck maintenance workshop will develop through the levels in the future. To succeed in the big change in the maintenance workshop, efficient change management strategies need to be implemented.

The analysis of the workshop classifies the execution of tasks in today's truck maintenance workshop as vehicle diagnostics assistance. Currently, the work involved in the workshop is not ergonomically friendly to the technician. Finally, a concluding discussion on the benefits and challenges of automated truck maintenance workshop is argued.

Keywords: level of automation, maintenance workshop, change management

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1 INTRODUCTION

The world is moving at a fast pace and we stand on the brink of a technological revolution that will transform the way we interact with one another. The buildup of the third industrial revolution which commenced in 1969 to create the fusion of technologies for the fourth industrial revolution has made many companies to research and redesign their value chain in order to meet the competitive market (World Economic Forum, 2016). And automation is seen as one solution that many industries are adopting into their operations in order to meet the competitive market.

Automation is a way for humans to extend the capability of their tools and machines by using control systems and information technologies to reduce the need for human work in the production of goods and services (Nof, 2009). Automation is rationalized by considering the technological and engineering aspects in the context of economic, social and managerial considerations, human factors and usability, organizational issues, environmental constraints, conservation of resources, energy and elimination of waste. On the other hand, as the economists Erik Brynjolfsson and Andrew McAfee have pointed out, the fourth industrial revolution could yield greater inequality particularly in its potential to disrupt labor markets (World Economic Forum, 2016). A 2013 University of Oxford–affiliated study found that 47 percent of U.S. jobs were at risk of disappearing due to technology (Frey and Osborne, 2013).

Today, automation is used in almost all industries such as the healthcare, warehouse management systems and agriculture to reduce cost and waste, increase efficiency and productivity. In the healthcare sector, advanced IT (Information Technology) systems are used to schedule a patient on appointment to see the doctor in the hospital. Likewise, in the automotive industry, trucks are scheduled for regular maintenance to see the technician in the workshop. This shows that, there are some similarities between the concept and technology applied in almost all these industries.

The future of this technology is also advancing. To improve a company's competitiveness, a modern automation system must make use of the advancements in technology to react to trends in the business world. To achieve the desired return, companies need to exploit all possibilities to further improve their production or services. This affects all automation levels from field to enterprise optimization, lifecycle stages from plant erection to dismantling and all value chain steps from procurement to service (Nof, 2009).

Accenture (2015) conducted a survey of more than 500 senior executives and managers in the world's leading automotive, construction and industrial equipment markets (Accenture.com, 2015). The results showed that 85 percent of the manufacturing executives expect to make the connected industrial workforce where human and machine work together to become widely used in their plant by 2020.The survey also showed that the automotive industry is leading in investing in the connected industrial workforce and the trend will continue in the next 5 years (Accenture.com, 2015). Adopting these emerging technologies allows companies to balance between current and future environmental, social and economic qualities.

A survey made by Barregard, Ehrenström, and Marcus (2002) showed hand-arm vibration syndrome (HAVS) is common among Swedish car mechanics. 62% of surveyed mechanics have symptoms such as white finger, persistent numbness or reduced grip force. With the incident rate of 3.2 claims in every 100 employees each year, automotive workshops have become one of the worst claim rates in the trade sector (Victorian WorkCover Authority, 2004). Manual handling injuries are the most common type of injuries in the motor vehicle workshop which accounts for 47% of all reported injuries. It can be caused by handling and lifting of heavy objects and sustaining prolonged awkward working postures. This is understandable since a large part of the work is done in the confined space under the vehicle which often leads to uncomfortable postures combined with heavy lifting.

According to American Truck Association, the technician shortage has become a critical issue in the truck industries and automation is seen as an alternative to face the future challenges (Bulktransporter.com, 2015). To succeed in this big change in the maintenance workshop, efficient change management strategies need to be implemented. All stakeholders need to understand the meaning of change and be part of the change process (Kotter and Cohen, 2002)

1.1 Description of focal company and research project

Volvo Group is one of the world's leading manufacturers of trucks, buses, and construction equipment, marine and industrial engines. Volvo Group also provides complete solutions for financing and servicing. They sell products in more than 190 markets and in 2014, VolvoGroup's sales amounted to around SEK 283 billion. Volvo Truck is a truck OEM (Original Equipment Manufacturer) which means Volvo Trucks are the original manufacturers of the truck. Advanced Technology and Research (ATR) is a department within Volvo Group Trucks Technology (GTT). The main assignment in ATR is to drive research, development and advanced engineering for the long term competitiveness of the Volvo Group. This project is aligned with the Volvo Group's vision to be the most desired and successful transport solution provider in the world.

This master's thesis is part of an ongoing joint research project which Volvo ATR together with Chalmers University of Technology, PostNord and ARHO AB are involved in. The project is targeting one of the most important challenges for the future sustainable transport solutions. In particular, this project deals with the role of maintenance in sustainable transport solutions. Therefore, the name of the ongoing project is Efficient Maintenance for sustainable Transport Solutions (EMATS). The EMATS project is co-financed by VINNOVA FFI (Fordonsstrategisk Forskning och innovation) and is running for three years, 2015 – 2018.

1.2 Purpose and research questions

The purpose of this master's thesis is to gain an understanding of automation technologies and its applications in three major industries. The thesis will analyze the current truck maintenance workshop, identify the benefits, opportunities and challenges that they are likely to face related to the automated maintenance workshop.

The thesis will also suggest innovative ideas about the future of automation technologies in the truck maintenance workshop. Change theories will be used to analyze different perspectives which will contribute to a successful automation project. Furthermore, the thesis will suggest tools to handle future challenges of automation technologies and discuss implications for the truck OEM (Original Equipment Manufacturer) in order to increase customer satisfaction by offering effective and efficient services and increase the employee satisfaction to achieve its goal of becoming the most desired and successful transport solution provider in the world.

In order to fulfill the purpose, four research questions have been formulated. The questions will serve as guidance along the way of suggesting future automation technologies to be implemented in the truck OEM's maintenance workshop. **The four research questions are the following:**

1. What are the automation technologies, benefits and challenges for the chosen industries of this study?
2. Where does today's truck workshop stand in the use of automation technologies?
3. What are the predicted future challenges for implementing an automated truck maintenance workshop and how can this be solved?
4. How can the change process be accomplished?

1.3 Limitations

Given the complexity of this project, this thesis will only focus on automation technologies in the healthcare, automation in dairy farms and warehouse management systems and relate the findings to truck maintenance workshop. The project is also limited to preventive maintenance. Due to time limitation, the project is geographically limited to Sweden.

1.4 Structure of the thesis

There are ten chapters in this thesis report. Chapter 1 introduces the thesis background, research purpose, research questions and limitations in this research. Chapter 2 describes the research strategy and methodology, data collection methods, data analysis methods and concludes with a discussion about the research quality of this study. Chapter 3 describes the theoretical background to automation including the definition of automation, implementation of automation and concerns of automation. Chapter 4 defines the theoretical framework used in this research study which starts by introducing two existing frameworks for level of automation in different areas. Following that is the levels of automation framework defined for an automated truck maintenance workshop which is proposed by the authors. The chosen change analysis framework, change diamond model, will also be introduced. Chapter 5 discusses automation technologies in the three chosen industries (Dairy, Healthcare and Warehouse system), industry majority, benefits, challenges and applications of future technologies. Chapter 6 describes the insight from the truck OEM and the phases of preventive maintenance in a real workshop. Chapter 7 analyzes the level of automation in the truck maintenance workshop including the current status and how to improve the levels of automation to a higher level. Chapter 8 uses the workshop change diamond model with four perspectives to analyze the workshop condition to make the automation project change more successful. Chapter 9 and chapter 10 discuss and conclude the research. Following figure1-1 shows the research steps in the thesis.

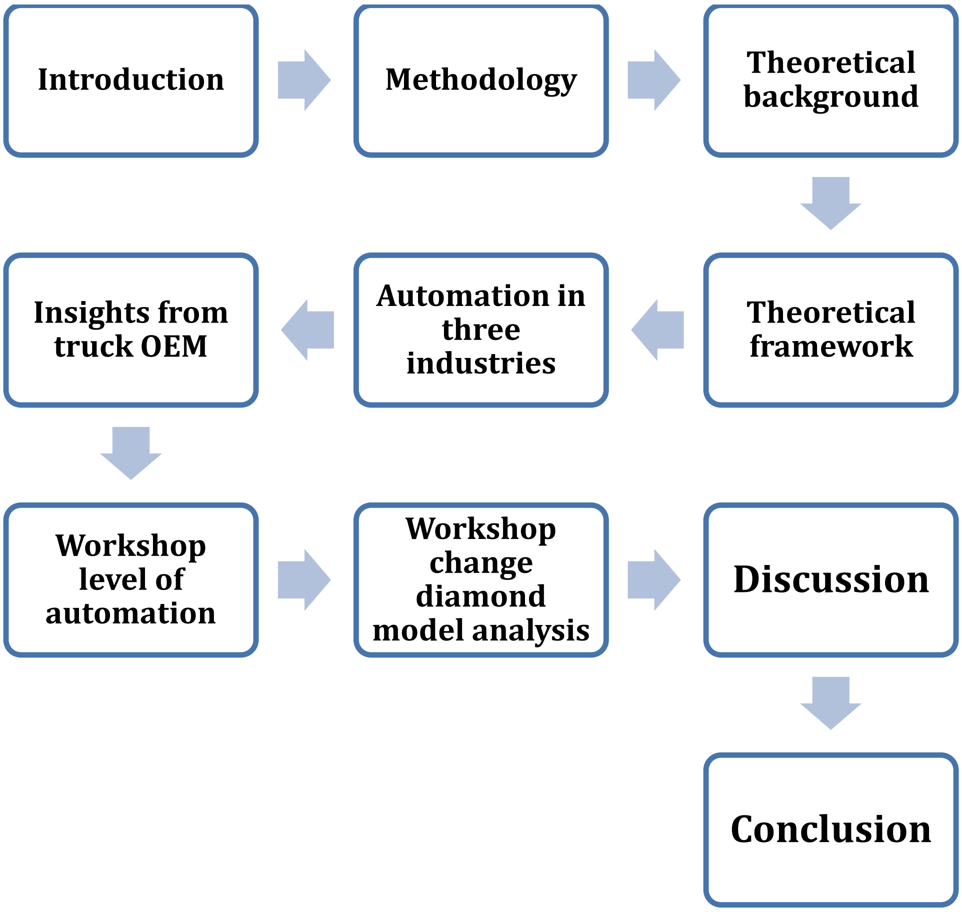

Figure 1-1: Master thesis structure

2 METHODOLOGY

This chapter describes the methodology and research approach used in this master thesis. The research strategy and research design will be introduced first, followed by an explanation of the data collection and data analysis methods. After that, the methods that were used to describe, explain, understand, criticize and analyze data will be explained. Finally, research quality and research limitations will be discussed to evaluate the meaning of the results and the validity and reliability of this research

2.1 Starting point of the thesis

The initial research idea about investigating how automation can be improved in the workshop was given as part of the EMATS project. Both rational thinking such as discussion, search for literatures, scanning the media and creative thinking such as keeping a notebook of ideas and brainstorming were used to generate the initial research ideas. Several inspiring discussions with supervisors, colleagues and relevant participants of the EMATS project were carried out to generate the possible research ideas. Based on the ideas from the discussions, several interesting topics were well noted such as the trend of the fourth industrial revolution, the meaning of automation, the development of automation in other industries, especially the healthcare and dairy industries, how to make the automation progress happen, the potential challenges and benefits, etc. Different literatures such as academic articles, industry reports, books and media such as websites, videos, newspapers, speeches were further investigated. Finally, a fruitful brainstorming among thesis students and supervisors was conducted to refine the research ideas to be analyzed in this thesis. In this thesis, we investigated the automation development in the three industries (the healthcare industry, dairy industry and warehouse system), the benefits of implementing automation in the three different industries, the industry maturity and challenges for each automation progress. The findings then became inspirations to find the road to an automated truck maintenance workshop.

2.2 Research strategy

The term “research” means using a systematic way to find out things in order to increase the knowledge about a certain area (Saunders, 2011). It emphasizes the importance of collecting data and interpreting data in a systematic way. It also requires researchers to have a clear goal and purpose to find things out.

The classification of the research purpose includes exploratory, descriptive and explanatory elements. It is very common to have more than one purpose in a single thesis and the purpose may change over time as well (Saunders, 2011). In this thesis, exploratory studies of the workshop were conducted to find out what is happening in the real workshop such as workshop visit and interviews with relevant people in the workshop. This is due to the fact that the students were not familiar with the real workshop and were willing to change the research direction when new data and new insights occurred. Based on the findings from three industries, we analyzed how these can guide the way to implement automation in the workshop. This can be considered as an exploratory study since the new findings in each industry influenced the research direction and results. The descriptive-explanatory studies as stated by Saunders (2011) means using description as a precursor to explain information. In this thesis, the authors observed preventative maintenance operations and consulted the workshop manager to get an insight of the preventive maintenance phases in order to have a clear picture of what kind of data needs to be collected further on. Explanatory studies such as applying change theories and levels of automation framework in the workshop condition were also carried out.

The choice of research method and strategy were guided by the research purpose and research questions. Defining clear research questions at the beginning is important to guide the research process since it is a good way to focus on the important problems and can help to avoid the overloaded work and too large amount of data. According to Bryman and Bell (2003), the qualitative research and quantitative research can be considered as two distinctive clusters of research strategy. Identifying the differences between the qualitative and quantitative research can help classify the proper methods used in the business research. According to Saunders (2011), quantitative research is more focused on generating, analyzing and utilizing the numerical data while qualitative research generates and analyzes non-numerical data such as words, videos, pictures, etc. In this master thesis, a qualitative research strategy was used to collect and analyze data and draw conclusions.

In summary, as shown in figure 2-1, a qualitative research strategy was chosen in this thesis, exploratory studies, descriptive-explanatory studies and explanatory studies were all conducted to make the data collection over-rounded.

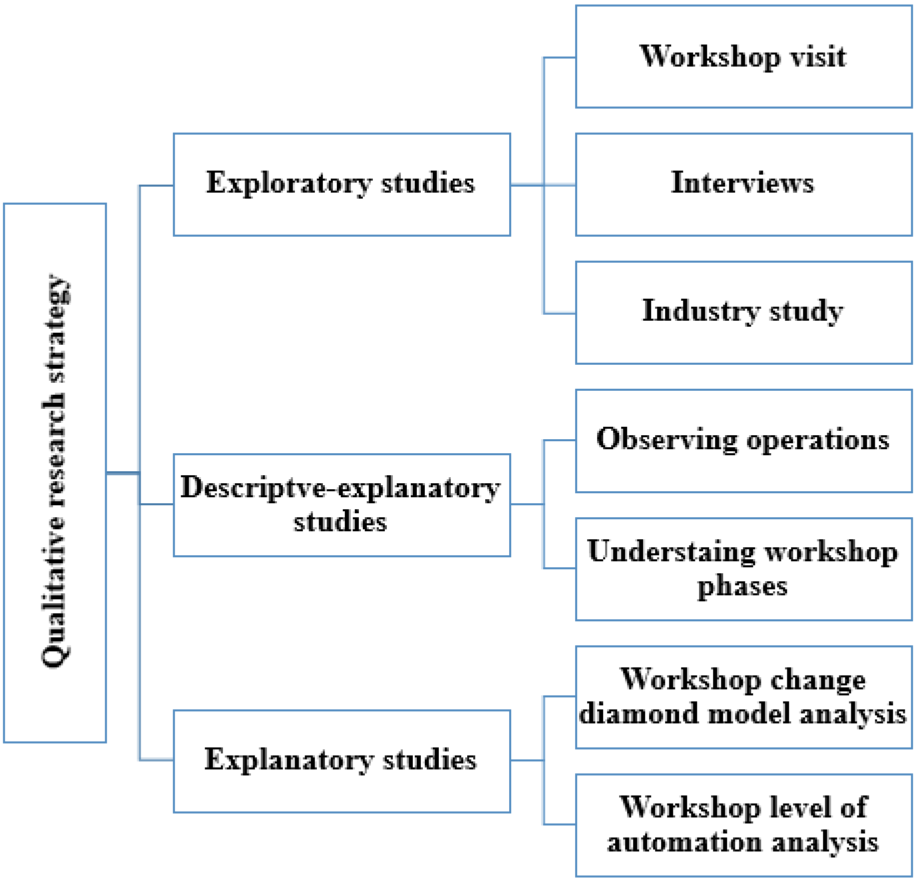

Figure 2-1: Summary of research strategy

2.3 Data collection

Data explains the facts of study object, the settings and background that they occur. Organizing the data collection structure and methods in a systematic way can improve the research quality (Saunders, 2011). In general, data can be divided into primary data and secondary data. The primary data means the data which is collected directly by the researchers to answer the research questions while the secondary data refers to the data that is collected for other purposes but also consists of information that are relevant to the research study (Holme, 1997). According to Ghauri and Grønhaug (2005), primary data can be collected through experiments, observation, interviews and questionnaires while secondary data can be gathered through literature studies. Secondary data is a good way to understand the research problems under cost and time limitation but at the same time can increase the research reliability.

In this thesis, both primary data and secondary data have been gathered in order to capture the whole picture of the complexity and high volume of data. The primary data were gathered through interviews and observations which were made based on the specific research purpose and were conducted by the thesis authors. Secondary data were gathered through an extensive literature study, including both written and unwritten documentaries such as organization's database, websites, journals, video recordings and voice recordings, etc.; multiple sources such as financial reports, books, journals, industry statistics and reports, etc.; surveys such as employee attitude surveys, labor market trends, organizations' surveys, academics' surveys, etc., as shown in the figure 2-2.

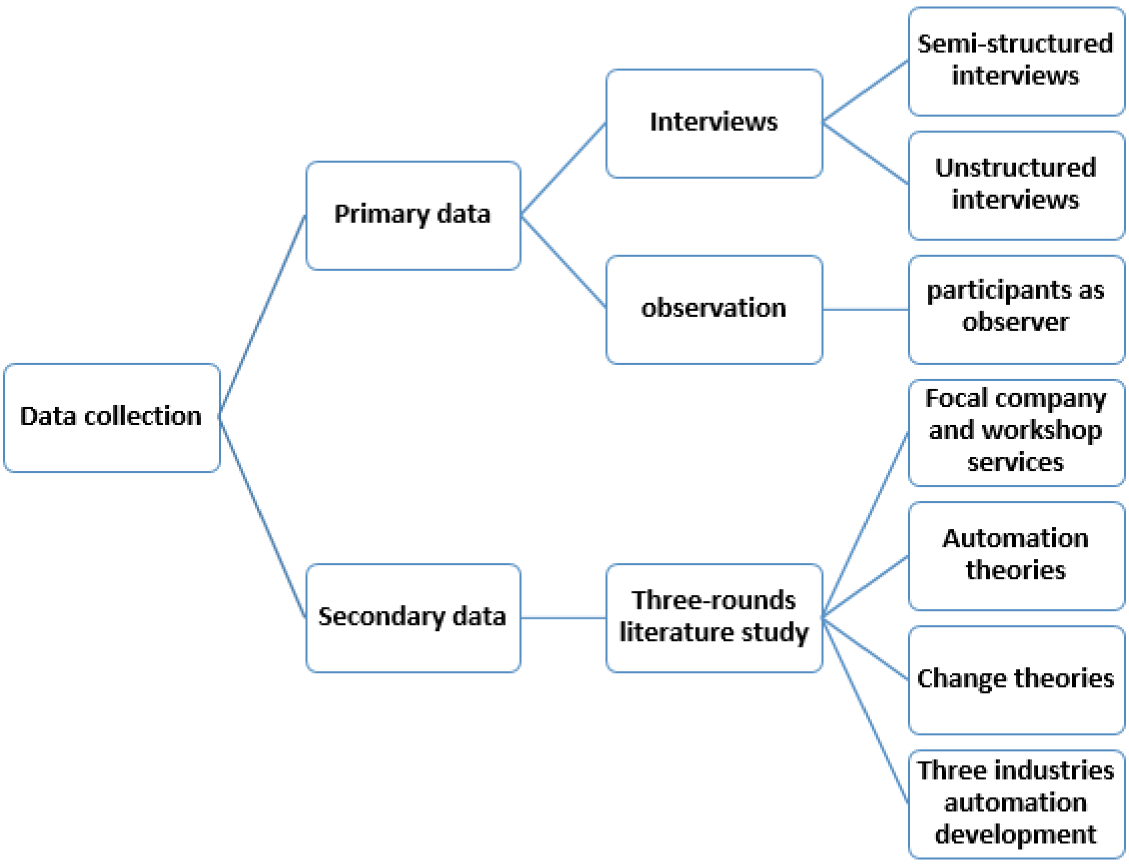

Figure 2-2: Summary of data collection

According to Saunders (2011), the data collection stages are always associated with ethical issues. In this thesis, the authors were responsible to make sure the data collection will not cause harm or intrude participant's privacy and the participants had the rights to withdraw participation. Confidentiality and anonymity were also considered as an important aspect in this thesis. So the collected data were checked and reconfigured with participants after each data collection.

2.3.1 Secondary data collection

The secondary data consists of an important part of the qualitative data used in this thesis. Different sources and types of secondary data have been collected. In order to deepen the understanding of the research questions, applications and theories for similar research areas were collected through a comprehensive literature study. The literature study can be categorized into four parts, which includes the literature study of the focal company and workshop services, automation theories, change theories, and three industries (dairy, healthcare, warehouse system) automation development.

Academic articles and books were accessed through the library database in Chalmers University of Technology and search engine such as Google scholar, industry statics web portal, and the printed literatures from Chalmers University of Technology library. The internal documents provided by Volvo Trucks and workshop, materials gathered during the interviews and workshop visit are important parts of the secondary data. Continuous and regular surveys such as the labor market trends, employee attitude surveys, automation development survey, organizations' surveys and academics' surveys were also accessed. Other types of data such as voice recordings and video recordings from the internet were also included as part of gathering secondary data. The data collected forms part of chapter 3 (theoretical background), chapter 4 (theoretical framework), chapter 5 (automation in three industries) and chapter 6 (insights from the truck OEM).

The secondary data collection was structured in three phases. The first round search for literature began in a broad scope and mainly focused on searching for the informative literature reviews, the keywords used were for example: automation theory, the history and development of automation, human factors in automation, level of automation, change theories, leading change, change models, automation in dairy industry, automation in healthcare industry, automation in warehouse system, etc. The findings helped us gain a basic understanding of the whole subject, research questions and gain more insights about certain areas and knowledge.

Findings from the first round data that were collected served as guidance for conducting and collecting the second round data. Based on the interesting points and important information summarized from the first round data that were collected, a more in-depth learning was performed. In addition, resources such as videos, web pages and industry reports were scanned, categorized and summarized for future analysis. In the second round data collection, more understanding about the development of automation in the three industries were required. The challenges, benefits and industry maturity information were gathered. Among the various literatures, best real-life practices and case studies were collected to get more inspirations. At the same time, the theoretical background for levels of automation and change management were gathered, options such as the models and framework for level of automation and change theories were well analyzed and documented.

The third round of data collection was conducted together with the analysis and discussions. This is due to the fact that the research process in this thesis was not a line structure; instead it was an iterative process. The understanding of the theories developed together with the thesis progress and more data were gathered to deepen the understanding of the research questions and support the analysis (Dubois and Gadde, 2002).

2.3.2 Primary data collection through interviews

An interview is a data collection method to gather thoughts and opinions through a purposeful discussion among the participants, knowledge about person's experience, values and opinions collected (Saunders, 2011). Due to the inquisitive nature of the interviews, valid and reliable data which are relevant to the research purpose and research questions can be gathered (Saunders, 2011). According to Dubois and Gadde (2002), both passive data such as the data which is intended to acquire, and active data such as new findings from the interviews are interesting and inspiring and can be gathered through interviews. The interviews can be either highly structured and use standardized question or informal and unstructured discussions. Based on the level of formality and structure, three types of interviews can be categorized. These are structured interviews, semi-structured interviews, and unstructured interviews.

It is believed that the most efficient method to understand a specific topic in the short time span such as in this thesis is to discuss it with the experts in the certain areas. The main methods used in this thesis were qualitative research interviews as defined by King (2004). This includes both semi-structured and unstructured interviews. According to Saunders (2011), the qualitative interviews are suitable for the researches where the authors want to investigate the participants' role, attitude and opinions. As in this thesis, the purpose of interviews was to understand the current status of certain topic and the opinions and experience of the participants to contribute to future analysis.

The participants and aim for the semi-structured interviews are listed in the Table 2-1. Volvo GTT Employee A has made a previous study about time waste in the workshop. Interview with workshop manager and technician, Volvo Trucks technical director, Director of aftermarket, Director of service sales, Director of service operations, Volvo GTT employee B and Director of sales in ARHO are involved in the EMATS project. The unstructured interviews include the interviews and discussions with thesis supervisors and EMATS project manager. All interviews were conducted as face-to-face interviews and recordings were made after asking the permission of the participants. The interviews were arranged to have enough time space between the two adjacent interviews in order to transcribe and analyze the interviews.

Table 2-1: Summary of interviews

Participants	**Date**	**Aim**
Semi-structured interviews		

Workshop manager	2016/03/11	To understand the current condition of the workshop, workshop layout, working phases of performing preventive maintenance and the KPIs used in the workshop. To know their opinion about automation, potential areas in the workshop that can be automated as well as potential challenges.
Technician	2016/03/11	To understand the current preventive maintenance in the workshop and technician's opinion about their daily work, investigate what can be improved and their opinion about automation.
Volvo Trucks: Technical director, Aftermarket director, Service sales director, Service operations director	2016/03/24	To gather different opinions about the automation in the workshop from Volvo Trucks aftermarket department perspective and understand the dealership management.
Volvo GTT employee B	2016/04/14	To understand what actions Volvo Trucks take to maximize truck uptime, understand the interpretation of automation in EMATS projects and the desired automated progress phases.
Director of sales in ARHO	2016/05/04	To understand the technical perspectives of automated tools and process such as the function, human role in automation and the potential challenges.
Unstructured interviews		
Volvo GTT employee A	2016/03/07	To get a general idea of the current status of the workshop and what are the waste service in the workshop.

EMATS project manager	2016/04/20	To understand the definition of automation and levels of automation in EMATS project, the progress of this project and what are the desired status of automation in the workshop.

In the unstructured interviews, there was no predetermined list of questions but the authors had a major topic to be explored which was relevant to the research purpose. The interviewees' perceptions guided the direction of the interviews. New ideas and more in depth of the topic was explored which was beneficial for the research.

In semi-structured interviews, the interview guidelines were made based on the specific themes and purpose before each interview which contained a list of topic and interview questions and can be found in the Appendix. The interview guidelines were modified based on the specific organizational context and the participant's experiences which were related to the research purpose. Brainstorming was used to generate interview topics by authors based on the aim of data collection. The research questions were grouped and categorized as high priority, medium priority and low priority due to the time limit of each interview. During the semi-structured interviews, the sequences of questions were changed due to the specific discussion and interview progress. Additional questions were also added to gain more understanding of certain statements or new ideas given by the participants.

In this thesis, interviews' recordings were transcribed after interviews immediately. This helps reduce the future workload, strengthen the understanding of each interview and avoid missing the important information. Both verbal communication and nonverbal communication were noted down. As an example, during the interview with the technician, when asked his opinion about automation, the facial expression and the pause showed his concerns about automation which was noted by the interviewees. During the transcription, not only the answers were noted down but also the questions were well listed to each answer which made the further analysis easier. The interviews' transcriptions were saved in separate word-files with an easy to recognize name.

2.3.3 Primary data collection through observation

Observation is a systematic way to observe record, describe, analyze and interpret a certain human behavior in order to understand the participants' behavior for a certain purpose (Bryman and Bell, 2003). There are two types of observation. These are participant observation and structured observation. Participant observation is a qualitative observation method which aims to explore the meaning of participants' behavior. While structured observation is a quantitative observation method which aims to analyze the frequency of their actions (Saunders, 2011). It has been recommended by Saunders (2011) that using both participant observation and structured observation can help to gain more understanding of the certain behavior. In this thesis, due to the time limitation and the fact that the authors were only able to visit one workshop, a participant observation was used.

According to Saunders (2011), the different types of observation can be categorized based on the role of participant and whether they will reveal their identity during the observation. There are four types of participant observation. These are complete participant, complete observer, observer as participant and participant as observer as shown in the figure 2-3 below.

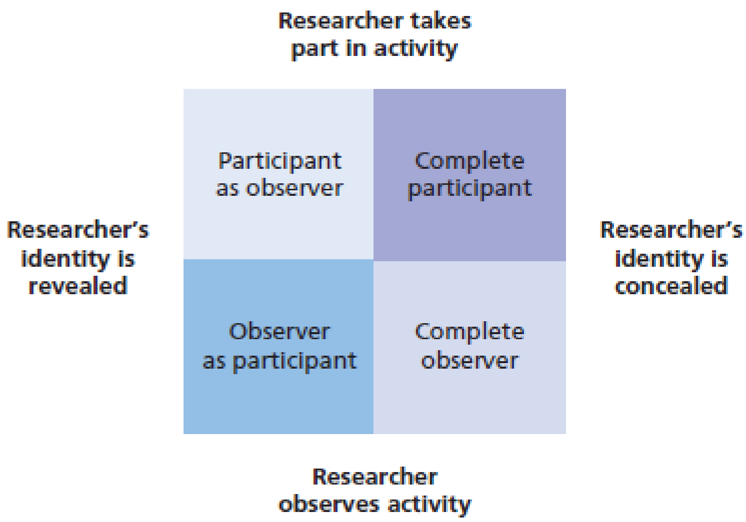

Figure 2-3: Typology of participant observation researcher roles
Source: Saunders (2011) Page 324

In order to reduce the ethical problem and gain trust of the group, participant as observer was chosen during the workshop observation. The author's purpose of observation and the subject to be observed were well informed to the participants who were observed. This was also beneficial for the observers to ask future questions to enhance their understanding. The voice and video recordings were made after seeking the permission of the participant. All data that was collected from the observation were well documented directly after the observation.

According to Delbridge and Kirkpatrick (1994), three types of data can be gathered by implementing participant observation. These are primary observations, secondary observation and experiential data. During the workshop observation, primary observation data were gathered. The authors noted down what happened in the workshop such as how technicians change engine oil, the real layout in the workshop, discussions and communications. Secondary observations were also carried out when observers need to interpret the work done. The feelings of observing were also noted down as the experiential data. This includes how the feelings and knowledge changed along the observing process. In order to avoid misunderstanding and make the process of compiling the notes easy, video and voice recordings were made after getting the permission of the participants. This was done in a way that didn't disturb their actions and behavior.

2.4 Data analysis

The nature of data collection and analysis in this thesis are interactive. This nature provided the opportunity for the authors to adjust the direction of research processes and data collection (Corbin and Strauss, 2008). According to Corbin and Strauss (2008), data can be categorized as quantitative data and qualitative data. Quantitative data is based on the meaning of numbers while qualitative data is expressed through words. Qualitative data analysis begins at the start of data collection and continues after collecting data (Corbin and Strauss, 2008). Qualitative data was collected in this thesis. Due to the non-standardized and complex nature of qualitative data, the data were summarized, categorized, grouped and restructured for following analysis.

Both primary and secondary data are used in this thesis. As stated earlier, the collection of secondary data was performed from three rounds. The data was summarized and the long sentences were compressed into brief statements. After the first round of secondary data collection, a summary of automation theories and change theories was made. After the second round of data collection, a summary of more specific subjects such as stakeholder management, change diamond model, level of automation framework, different perspectives of automation (benefits, concerns, challenges, etc.) and the automation development in the three industries was made. After the third round, more specific and detailed summary for the selected subject was made according to the needs of new information during the analysis phases.

The data was then categorized under the research purpose and research questions. This was grouped into different segments under different titles such as automation, change, dairy industry, healthcare industry, warehouse industry, insight from the workshop, etc. The grouped data was then reorganized based on more detailed categorizations such as the definition of automation, industry maturity, challenges of automation and stakeholder management, etc., which was further developed into subtitles in each chapter. Besides that, the title and content of each data group was checked regularly and changed based on the context.

2.5 Quality of the research findings

One of the main issues of conducting a qualitative research is evaluating the credibility of the research findings. In order to reduce the possibility of making wrong research findings, reliability and validity need to be evaluated and put into high priority in the research design. Reliability emphasizes whether the research results are repeatable (Bell and Bryman, 2007). It means to what extent the data collection technique and analysis process can produce the consistent findings. According to Colin (2002), the subject or participant error, subject or participant bias, observer error and observe bias are the four threats to reliability. Validity concerns whether the research results are really about what they appear to be (Saunders, 2011). According to Colin (2002), there are five threats to the validity of research findings. These are history, testing, instrumentation, mortality and maturation.

2.5.1 Validity and reliability of the literature study

To ensure the validity and reliability of the secondary data used in this thesis, the authors chose to collect data from trustworthy sources (scientific journals, internal reports and documents) in this thesis. The majority of the data was found through the database provided by the library of Chalmers University of Technology which can be considered as credible resources. When data was gathered from other sources than acknowledged scientific databases, the information was examined carefully to make sure that the authors do not provide a biased viewpoint. According to Dochartaigh (2002), survey data from large and well known organizations are likely to be reliable and trustworthy. Such as the Boston Consulting Group (BCG), Deloitte, IBM etc., which were part of the resource to know the real industries practices. Documents and reports from Volvo Trucks and the relevant dealers used in this thesis can also be considered as credible.

Literature reviews were used to get a better understanding of certain subject. Resources from Business source premier, Scopus, Cambridge journals online, ScienceDirect, Emerald, SpringerLink and Summon Chalmers etc., can be considered as reliable sources. In order to narrow down the research scope and find reliable resources, lecture materials and open courses from Chalmers University of Technology, Massachusetts Institute of Technology and Harvard University were also searched by the authors. The understanding of certain subject such as robotics, automation and change management were well understood from the literature study. Recommended readings was also searched for such as Springer handbook of automation (Nof, 2009) and well known professors in change theories such as Dr. John P. Kotter. Also, institutions and projects such as IBM Making Change Work (Www-935.ibm.com, 2016), Kotter International (International and International, 2016), Prosci Inc (Prosci.com, 2016), etc. with high reputation were also researched. The change diamond model used in this thesis can also be considered as reliable since it was based on a survey made by IBM in 2008 which investigated more than 1,500 real-life project participants in 21 different industries worldwide including project leaders, project managers, sponsors, change managers etc.

2.5.2 Validity and reliability in the interviews and observation

One of the biggest threats to the reliability of observation results is the observer bias which can't be avoided but can be reduced by increasing the awareness of its bad effect (Saunders, 2011). According to Saunders (2011), the quality issues such as reliability, forms of bias, validity and generalizability are related to using semi-structured or unstructured interviews. The concerns about the reliability are related to the issues of bias such as interviewer bias (Silverman, 2007) which will cause the less trust of the interviewee and will limit the information to be given from interviewee. In an unstructured interview or semi-structured interview, the participant might be sensitive to the unstructured exploration of certain themes and may not be willing to discuss with the interviewers.

For the interviews and observation conducted, the validity and reliability were ensured mostly through the agreement among participants. The knowledge about the participant's background and the organizational and situational context were searched through website or school library database. The credibility was improved through the supplement of relevant information to participants beforehand (Saunders, 2011). For example, before each interview, the interview guidelines were sent to the participants to check if there was any information that they were not willing to share. The questions were brainstormed by the authors and checked by supervisors to make sure they are understandable to avoid many theoretical concepts. This can also help participants have enough time to prepare for the necessary information to be discussed. During the interview, the questions were phrased clearly to make the interviewee understand the questions and feel comfortable to answer.

Voice recordings and video recordings were made after getting the approval of the participants. Notes were also written as the interview and observation progressed. According to Colin (2002), it is a good way to show interviewees that the information they shared was important for the thesis writing which encourage them to share more good information. After each interview or observation, a specific time period was set aside by the authors to transcribe the recordings and evaluate information received.

2.5.3 Validity and reliability in analysis

The analysis of data was conducted through summarizing, categorizing, grouping and restructuring. As analyzed in section 2.4.1 and section 2.4.2 the source of data can be considered as reliable. The primary data collected from interviews and observations were structured in a systematic way to make sure the meaning of data won't interpret in a different way. The secondary data collected from literature studies were noted down and summarized and the references were also noted down to make sure the important points can be traced.

The level of automation for the operations was analyzed using the framework developed by the authors. The framework was inspired by SAE (Society of Automotive Engineers) International's levels of driving automation for On-Road Vehicle (Society of Automotive Engineers (SAE) standard J3016, 2015) and Levels of automation for computerized and mechanized tasks within manufacturing (Frohm, 2008). Truck maintenance workshop conditions such as operations and tools were taking into consideration which contributed to a more adaptable framework. Suggestions of which technologies can be implemented into the workshop were defined based on the comparison of workshop and the chosen three industries.

The change management theories were carried out based on the change diamond model which as analyzed before, can be considered as a reliable source and framework. The learning's from the chosen three industries were discussed and brainstormed among master thesis authors and supervisors. Reliable secondary data were summarized, grouped and categorized under each element in the change diamond model. The data collected from interviews of the potential obstacles were also combined into the analysis which made the suggestions more reliable and adaptable to the truck maintenance workshop condition.

3 THEORETICAL BACKGROUND TO AUTOMATION

This chapter aims to provide the theoretical background of the study and starts by providing definitions of automation. Subsequently, it describes the differences between human and machine capabilities, implementation of automation and concludes with the concerns of automation.

3.1 Automation

Zeithaml, Parasuraman, and Malhotra (2000) defined automation as a grey scale with partial or full automation: "Automation refers to the full or partial replacement of a function previously carried out by the human operator". Automation can be considered as a way to extend humans' capability of doing things, which is according to Nof (2009), automation is a major method to gain and sustain the productivity advantages.

Encyclopedia Britannica (2016) defines automation as the application of machines to tasks once performed by human beings or, increasingly, to tasks that would otherwise be impossible. Dictionary.com (2016) also defines automation as "The technique, method or system of operating or controlling, is a process by highly automatic means as by electronic devices reducing human intervention to a minimum."

In general terms, automation is a technology that is used to perform a process by means of programmed commands with automatic feedback control to ensure that there is proper execution of the instructions. Automation can also offer solutions when human operations is proved to be inefficient or in time critical situations when there is not enough time for human operators to respond and take appropriate actions (Zeithaml., Parasuraman, and Malhotra, 2000).

3.1.1 Human and machine capabilities

The question to design automation is not about how to design the best system but also about how to optimize the task between humans and machines (Frohm, 2008). The first step in the human system design process is to analyze the task (Sheridan 2002) and break it down into its respective task and elements. Further, each overall task must be broken down into respective elements. Then the task and the specification of how these elements relate to one another in space, time and function must be analyzed.

Hoffman et al. (2002) illustrates the task allocation of both humans and machines and where the performance of one category exceeds that of the other as shown in the table 3-1 below.

Table 3-1: Fitts' list on human and machine capabilities
Source: Frohm (2008), page 145

HUMANS SURPASS MACHINES IN THE:	**MACHINES SURPASS HUMANS IN THE:**
Ability to detecting small amounts of visual or acoustic energy	Ability to respond quickly to control signals, and to apply great force smoothly and precisely
Ability to perceiving patterns of light	Ability to perform repetitive, routine

or sound	tasks
Ability to improvise and use flexible procedures	Ability to store information briefly and then erase it completely
Ability to store very large amounts of information for long periods and to recall relevant facts at the appropriate time	Ability to reason deductively, including computational ability
Ability to reason inductively	Ability to handle highly complex operations, i.e. to do many different things at the same once
Ability to exercise judgment	

There have been many criticisms regarding to the applicability of Fitts' list in systems engineering. According to Jordan (1963), machines can only do the operations which are predefined, so the idea of comparing the abilities between human and machine is not realistic. However, system designers can keep in mind that the human and machine is a complementary system. The different advantages and abilities of human and machine can benefit for a well-structured human-machine system (Nof, 2009) such as the speed of response, breadth of comprehension, range of vision, physical strength which might limit the human operators to perform certain tasks (Williams, 1999).

Researchers have shown that disturbance related to machine and automated equipment is common in industries (Ingemansson and Bolmsjö, 2004). It can happen when there are no pre-defined solutions for machines to perform task that is out of their action scope, according to Säfsten., Winroth, and Stahre (2007). This will cause losing control of the equipment and system which may cause future damage. Many tasks require human innovation and cannot be automated with the available technologies and facilities. Human operators need to get involved in the whole system and get to know the technical advancements of machines in order to tackle the unforeseen and accident situations (Frohm, Karsvall and Hassnert, 2003). Consequently, both advanced technical systems and skilled human workers need to work together and collaboratively to achieve flexibility and efficiency. Making an automated system as robust and flexible as possible is not only a question of how to assign the right task to the right element of the system. It is also a question of how human and automated components can support and collaborate with each other during different level of automation.

3.1.2 Implementation of automation

According to Frohm (2008), unrealistic or undefined objectives are one of the main reasons why automation projects end in failure. So more time need to take to define the goals and requirements of automation before the actual implementation (Frohm, 2008). The challenge with automation is to identify the optimal parts which are to be automated and to understand the correct amount of automation for both short and long term (Fasth, Stahre, and Dencker, 2008). This depends on searching, selecting, analyzing, acquiring and properly implementing the right type and level of automation in relation to the company's needs, goals and prerequisites. This in turn puts great demands on a company's way of working since the process not only requires that the actual automation development and its adherent processes are well structured and supported, but also puts large demands on the structure, control and understanding of the operations to be automated.

Before investing in automation it is first important to structure the system in which the automation should be included and make sure that it is well integrated with other systems and adjusted to current needs (Groover, 2007). It is also important to be well aware of the parameters affecting your system as well as what requirements there are on the system and the future automated solution (Groover, 2007). Further, the selection of equipment is an important strategic part of designing and developing internal logistics systems (Chung and Tanchoco, 2009).

Formal and appropriate process automation development models can direct the way of progressing automation which can increase the success of automation project (Bellgran and Säfsten, 2010). A good dialogue between both internal and external stakeholders involved in the automation progress is important, especially crucial to agree on the requirements, goals, expectations, and concerns and clarify the responsibility for each stakeholder.

3.1.3 Concerns of automation

As when introducing any type of improvements, there is a risk of disruption and service level failings during the implementation and start-up of an automated system before the benefits are achieved (Baker and Halim, 2007). However, the risk and level of disruption depends on several aspects such as the extent of the change or implementation, the experiences of dealing with similar projects and technology and perhaps foremost the degree of preparations and planning.

One of the most common arguments against automated equipment is that it is generally considered inflexible. However, this depends on the type of automation. Based on the prerequisites and intended area of use, the suitability of the different types varies. Mital and Pennathur (2004), conclude that inefficiencies in highly automated systems in addition to the lack of adequate maintenance and the difficulty of re-configuring the systems often depend on inappropriate selection of system types.

According to Baker and Halim (2007), other potential obstacles to implementing automated equipment not connected with the automation technology are related to the lack of commitment from top management, issues concerning change in culture, internal politics and also worker acceptance of automation from manual to automated procedure.

Automation does not simply eliminate tasks once performed by the operator. It changes the task structure and creates new tasks that need to be supported, thereby opening the door to new types of error. Contrary to the expectations of a technology-centered approach to automation design, introducing automation makes it more rather than less important to consider the operators' tasks and role.

A study by Hofmann and Orr (2005) on the adoption of advanced manufacturing equipment showed that more middle management over other business levels were worried about the workers' acceptance of the new technology, while the process workers were more worried about interruptions during the installation. Since the use of automation can improve efficiency, it often leads to a reduced number of staff. One danger of this is the risk of losing important information exchange needed to uphold tacit working skills and knowledge (Frohm, 2008). Increasing the level of automated equipment might also change the demands on the skills and knowledge of the staff to properly operate the equipment. The operator's role as problem solver or decision maker might also increase. As a result, the need for competent professionals might increase when automating (Frohm, Karsvall and Hassnert, 2003)

Product are becoming more customized, which according to Shapira, Youtie and Urmanbetova (2004) resulted in increasingly complex operating systems as well as an increased level and extent of automation (Sheridan, 2002). Automation may not lead to the expected results, and too high levels of automation may result in poor system performance (Zeithaml, Parasuraman, and Malhotra, 2000), as shown in the figure 3-1. Merchant and Weinberger (2000) also noted that technology will only perform at its full potential if the utilization of the system's human resources is fully optimized which shows the importance of human operator's' role in the human-machine system. A key problem is therefore to establish and maintain an appropriate level of automation to realize the full potential of automation and reduce or avoid the negative effect of automation (Harlin et al. 2006).

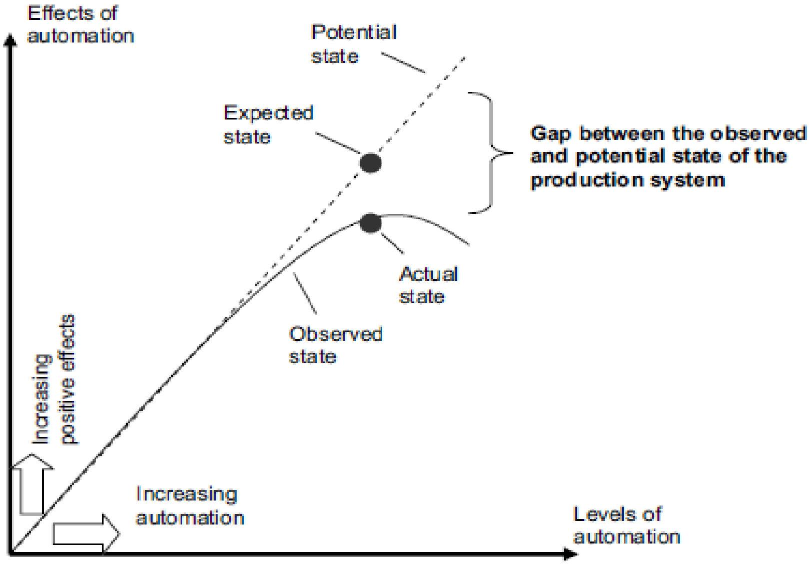

Figure 3-1: Hypothetical effects on varying the level of automation
Source (Frohm, 2008), page 49

4 THEORETICAL FRAMEWORK

4.1 Levels of automation

The introduction of automation in industry has aided in consistent product quality, reduce human error while performing repetitive tasks and improve process availability and production efficiency. Due to this there has been a high availability of automated systems because of the advancements in computer and information technology (Wei, Macwan, and Wieringa, 1998). This implies that to achieve efficient production or operations there is the need to decide which aspects of a process should be done manually and which should be done by a computer with the right flexibility.

Frohm (2008) describes the task in a manufacturing company as a mix of both mechanized (physical) and computerized (cognitive) tasks (Frohm, 2008). Computerized (cognitive) task is to help the human to monitor situations by providing decision support and to speed up information flow. Physical task involves activities such as replacement or support of human muscle power (Frohm, 2008). But manufacturing processes are not only limited to physical task but also of cognitive support for carrying out control and information task.

The level of automation is related to what is automated and what is performed manually (Nof, 2009). According to Frohm (2008), automation can be used to several different levels which refers to the fraction of automated functions out of the overall functions in a system. The concept of the level of automation is defined as "The allocation of physical and cognitive tasks between humans and technology, described as a continuum ranging from totally manual to totally automatic" (Frohm, 2008). The level of automation for cognitive activities is called information level of automation while the level of automation for physical support is called Mechanical Level of automation (Frohm, 2008). Most tasks involve a mix of both computerized and mechanized and companies needs to consider both when automating their system.

4.1.1 Various levels of automation

There are various definitions for various levels of automation. The SAE (Society of Automotive Engineers) international define 6 levels of automation for their autonomous driving vehicles as shown in the table 4-1.

Table 4-1 Levels of automation for autonomous driving vehicle
Source: (Society of Automotive Engineers (SAE) standard J3016, 2015)

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

The SAE level of automation considers automation only in the domain of driving and as pointed out by Frohm (2008), automation levels designed for specific predefined tasks such as driving may have limited significance to other sectors like manufacturing etc. The SAE model can be compared to that developed by Milgram, Rastogi, and Grodski (1995) and Swartz (1997) in the context of tele robotics and tele operations of satellite, where they consider the different roles a human operator can play in controlling a system, where the human serves as a control agent mostly.

Also Frohm (2008) also defines various levels of automation based on production systems. The model developed by Frohm (2008) breaks down activities into cognitive and physical while still acknowledging the co-operation between humans and machines, thus producing two kinds of levels of automation as described in the table 4-2.

Table 4-2: Levels of automation for computerized and mechanized tasks within manufacturing
Source: (Frohm, 2008), page 161

Levels	Mechanical and Equipment	Information and control
1	Totally manual - Totally manual work, no tools are used, only the user's own muscle power. E.g. The user's own muscle power	Totally manual - The user creates his/her own understanding of the situation and develops his/her course of action based on his/her earlier experience and knowledge. E.g. The user's earlier experience and knowledge
2	Static hand tool - Manual work with support of a static tool. E.g. Screwdriver	Decision giving - The user gets information about what to do or a proposal for how the task can be achieved. E.g. Work order
3	Flexible hand tool - Manual work with the support of a flexible tool. E.g. Adjustable spanner	Teaching - The user gets instruction about how the task can be achieved. E.g. Checklists, manuals
4	Automated hand tool - Manual work with the support of an automated tool. E.g. Hydraulic bolt driver	Questioning - The technology questions the execution, if the execution deviates from what the technology considers suitable. E.g. Verification before action
5	Static machine/workstation - Automatic work by a machine that is designed for a specific task. E.g. Lathe	Supervision - The technology calls for the users' attention, and directs it to the present task. E.g. Alarms
6	Flexible machine/workstation - Automatic work by a machine that can be reconfigured for different tasks. E.g. CNC machine	Intervene - The technology takes over and corrects the action, if the executions deviate from what the technology considers suitable. E.g. Thermostat
7	Totally automatic - Totally automatic work. The machine solves all deviations or problems that occur by itself. E.g. Autonomous systems	Totally automatic - All information and control are handled by the technology. The user is never involved. E.g. Autonomous systems

What is common from the above definitions is the fact that both vehicle driving and production system levels of automation has a bandwidth of zero to full (0 – 100 %) with different mapping and names given to different ranges of this bandwidth. This implies that a mapping of the level of automation in the workshop needs to be defined so as to suit the work carried out within the workshop environment.

4.1.2 Levels of automation in the workshop

The workshop environment is similar to the manufacturing environment in that there is a mix of both mechanization and computerization which implies that the observed tasks and operations can be divided into mechanized and computerized activities. For example, to operate a cutting machine, tasks such as controlling the cutting tool (computerized activity) as well as handling the work pieces and performing the cutting (mechanized activity) are involved (Frohm 2008).

Because the maintenance workshop is similar to the manufacturing environment, it is easy to tailor that to the workshop environment. In addition to that, the SAE model also inspires each level with a name. The level of automation for the workshop is a combination of Frohm (2008) and SAE, as shown in table 4-3.

Table 4-3: Levels of automation in the truck maintenance workshop

Workshop level	Name	Narrative Definition
1	Totally manual	The technician creates his own understanding of the work based on his or her own knowledge and experience. The technician will do the work with basic tools that require man power. E.g. Screw driver.
2	Vehicle diagnostics assistance	The technician gets information about what to do from a diagnostic scan tool and how the task can be achieved from checklist, manuals, etc. The technician will do the work with the support of a flexible tool.
3	Partial automation	The technology performs the task but will need verification from the user. The user can step in or perform the task with an automated tool. The job is done by technology; the verification is done by the user
4	High automation	The technology will perform the task but will call for the attention of the user only in situations when there is a mismatch with status information like alarms, etc.

		The user can step in to reconfigure or do the job with a highly automated tool.
5	Totally automatic	All information and control are handled by the technology. The user is never involved. E.g. Autonomous systems

(1) Totally Manual

This is the first level of automation in the workshop. Here the technician uses his past experience in solving similar problems to identify and diagnose a fault and fixes these faults with basic tools such as screw drivers which require much muscle power. The technician receives no help cognitively from any manual or computer and also uses much muscle power. The cognitive aspect here requires somewhat detailed training and may take many years to acquire and perfect. Due to this, workshops which are totally manual basically base their success largely on the experience of their best technicians.

(2) Vehicle diagnostics assistance

With the advancement of technology, most modern vehicles have onboard diagnostics software that monitors almost all operations and conditions of the vehicles and report faults to the dashboard. Also this software is able to keep some form of maintenance journal which it activates at predetermined time so the vehicle can be taken for preventive maintenance. With this, a computer can be connected to the vehicle to read the status of this onboard software to determine exactly what needs to be done on the vehicle to fix or optimize its operation. This reduces the cognitive burden on the technician since he does not have to rely on his personal experience to diagnose the fault of the vehicle. The technician then goes ahead and corrects the problems found by this computer using some form of flexible tool like automated screw drivers etc. The technician uses less cognitive power by way of reading manual on how to fix the faults reported as well as uses less muscles power in terms of using flexible tools.

(3) Partial automation

Automated systems are becoming more advanced and taking more complex tasks in the working environment. With the technological advancement, an automated system can be fed with the diagnosis from the vehicle diagnostics tool and carry out the work needed to be done by a human to fix or correct the faults found. This eliminates the muscle power that the technician must use to fix the problems in the vehicle diagnostics assistance scenario. Here the main task of the technician is to verify the work done by the automated system as such the automated system or technology identifies and fixes the problems but the verification is the task of the technician. With this there is little cognitive burden and almost no muscle power burden on the technician.

(4) High automation

In this scenario, the technology identifies, fixes and verifies all faults but calls on a technician when the technology is not able to match the fault with any of the faults in its knowledge base. If the fault is known to the technology, the technician plays no role as the technology does everything and the system is basically full automation. But because the system is probably not fully matured in terms of identifying all faults, a technician must be onsite to ensure that there is continuity when the technology fails.

(5) Totally automatic

This is the scenario where the high automation scenario is fully matured and there is completely no need for a technician on site since the technology can reliably identify all fault with a vehicle. This requires a comprehensive database of knowledge for the technology.

4.2 Change theories

In today's changing world, many drivers can lead organizations to changes such as the involvement of new technology, government rules, policy changes, globalization, and customer base. As customer’s demand and preferences change all the time, the organizations need to change at the same time or even at a faster speed to satisfy customer’s need and sustain the development. As stated by Baker and Halim (2007), lack of commitment from top management, issues concerning changes in culture, internal politics and the worker acceptance of the automaton are crucial obstacles to progress automation. Which is also aligned with Hofmann and Orr (2005), different stakeholders have different concerns and acceptance level regarding a new technology. All these imply the importance of managing change in the automation process.

The change can be a simple process change or a system change. To what degree the change is depends on the organization’s goal and needs. According to Alvesson (2002), there are over 770 million references on the internet about organizational changes. This is due to the fact that people want to seek solutions to their problems which require new management roles and decision making to make the change happen.

Change management is an approach to shift or transit individuals, teams and organizations from current state to a desired future state. The change management methodology is an instrument to realize the goals both internally and externally. It can help diagnose the associated problems and potential risks before they become a crisis. The factors and methods created by the change management methods will help deal with opposition or any other problems that may happen during or after the change processes (Tcs.com, 2016). According to the best practices in change management survey, a structured change management approach benefits for moving organizations away from merely resistance to change to a solid organization with engaged and mobilized employee (Prosci.com, 2016),

A study published by PricewaterhouseCoopers (PwC) in 2012 reveals the important correlation between project performance, maturity level and change management (PwC, 2012). It is very common among the best performing and most mature organizations to apply change management to their projects which highlights the need for alignment of change management and project management practices. In 2010, Change First Limited conducted a study including over 2,500 people who occupied change management roles across 120 organizations. The study found that, six to nine months after project launch, projects with change management input delivered significant performance improvements, financial results and behavioral change. A majority of the respondents believe that over 20 percent of the success can be directly related to effective change management. Implementing automation in the truck maintenance workshop will have influences on the existing system, changes from manual procedure to automated assistance will influence worker's acceptance, the high investment requires the commitment from top management, the concerns of changes in organizational culture will cause other stakeholders' resistance etc. All of these factors imply the importance of a systematic change management.

4.2.1 Leading change

How resistant the organization is to change will influence the most effective method for the organization. The biggest risk of initiating change is the acceptance by the stakeholders which needs to be classified as the top most priority. These risks include top management commitment, employee's acceptance and other people or organization participants in this change process (Tcs.com, 2016). Realizing different ways people prefer to deal with change can help manage and lead people through any type of change project successfully.

A survey made by IBM (2008) investigated 1,532 real-life experiences of change project practitioners. The results showed the factors that influence the success of change process can be categorized as soft factors and hard factors as show in figure 4-1 below (Making Change Work, 2008). The top six answers all belong to the soft factors such as leadership, employee engagement and honest communication, behavioral and cultural. The study shows soft factors are prerequisites for a successful change project and they are harder to address than the hard factors such as structure, performance measures and incentives.

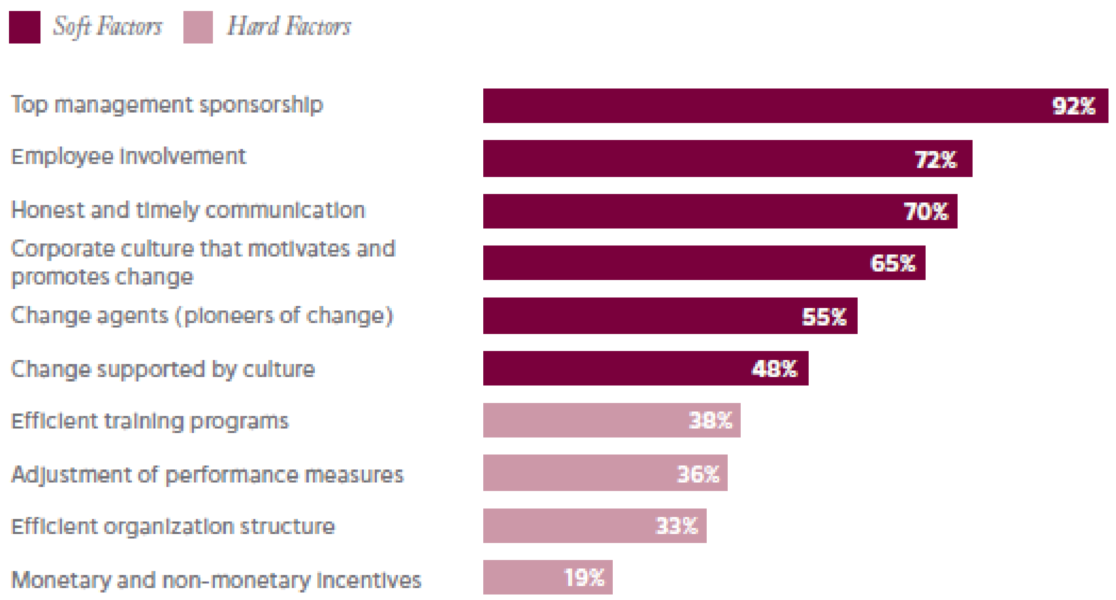

Figure 4-1: Factors influencing the success of change project
Source: (Making Change Work, 2008) Page 12

Managing organizational change starts with understanding how to manage change with a single person (Creasey, 2007). When defining change management objectives and activities, it is very important to coordinate closely with the ones who are involved by identifying their responsibility for change. The owners can be project manager, business manager or HR department. They are the people who are responsible for identifying change agents, who will define the re-training plan and what will be the impact on changing job descriptions and employment contracts. Knowing who is responsible and how things are organized will help define the change management scope.

Communicate change means to overcome the fears and concerns resulted from a change (Kotter, 2008). People are often worried about how the bad effect of the change will have on them. Uncertainty in a working environment will reduce the productivity so it is important to communicate what is changing, how and why. Communication is an ongoing process. As the change progresses, people will gain a better understanding and knowledge about change effects and they will have new questions and new ideas about the change process. In order to reduce the concerns of people, a feedback process needs to be built up to make sure the communication can meet its objectives and goals. The current state and future state of change need to be updated and well informed by the people who are involved in and their questions should be answered immediately with enough necessary information.

According to Mckinsey (2015), about 70 percent of change programs fail to achieve their goals (McKinsey & Company, 2015). There are various factors which result in the failure of the change process. When the organization is not clear about the reasons for change and the overall objectives, it often leads to failure of the change process. Lack of a systematic and structured change approach and methods that are not suitable for the organization's real situation also lead to poor performance of the change project. Making sure the organization is prepared for the change project and a realistic goal for change is important for a successful project. Failures of transformation of the leadership will influence the efficiency of managing people, which might also lead to the failure of the change project. Sometimes the organization fails to move quickly from a speech which will mix message and create resistance to a better focus. (Kotter, 2007).

Effective leadership is one of the most important factors to improve the overall organizational performance and change. The intelligent leaders are those who have the skills and knowledge to manage daily tasks effectively and efficiently (Deal and Kennedy, 2000). Leaders in the organization should be willing to change their leadership styles based on the different situations and have a positive influence on the staffs during the change progress. To enhance more team work spirit and efficiency in situations, leaders can take more development programs and teamwork trainings for specific situations to have a better influence on the people.

Using diagnostic tools to identify why and where the resistance is taking place and making corrective actions to reduce the resistance can contribute to a successful change project. During the entire project, advanced planning and stakeholder management is important to aggravate resistance and inconsistency (Mackinson et.al, 2011).

4.2.2 Stakeholder management

Stakeholder engagement is crucial to the whole process of effective change. Through understanding, prioritizing and mobilizing stakeholders, change managers can gain and sustain the momentum for change (Miller and Oliver, 2015). When leading a large engagement collaboratively, certain agreements can be written to prevent ambiguity and clarify decisions and responsibilities. A list of all stakeholders can help to clarify the change management efforts. The lists can include positions of stakeholders, prioritization of stakeholders, the approaches and mechanisms to engage stakeholders and the measurement of effectiveness (Kotter, 2001).

According to Miller and Oliver (2015), stakeholder's identification is a continuous practice where new stakeholders will emerge during the change process while old ones may fade away. There are a number of methods to identify stakeholders such as rapid listing, group brainstorming and mind mapping. As the change continues, the priorities of managing certain stakeholders will change. Some stakeholders will increase their importance of the change success while others' influence may reduce or even disappear. Based on the size of stakeholder group, different analysis techniques can be taken to segment the subgroups. Personas and empathy maps are appropriate for large, broadly homogeneous groups whereas power maps are more appropriate for small key groups of individuals.

The stakeholders' characteristics such as influence, power, position, interest, attitude, potential wins and losses, resistance and concerns to change also influence the different strategies to move them from current position to the target position. According to Kotter and Cohen (2002), connecting stakeholders with the meaning of a change, building emotional connection between stakeholders and change project can help motivate stakeholders sufficiently to a good change.

It can happen that change managers are not the most effective people to influence particular stakeholders. This may be as a result of lack of personal chemistry with that stakeholder or lack of position, shared history or recognized credentials in the eyes of the stakeholder. Some stakeholders are influenced by other stakeholders such as the one who is more respected by other stakeholders or have worked for a long time in the organization. One of the most powerful influencing strategies is firstly ask the influencing person's interests, needs and concerns with immerse efforts to make them accept the change. Early wins have big influence on stakeholders' engagement. The early demonstration of progress or success can be a powerful tool to persuade and convince other skeptical stakeholders (Kotter, 2008).

4.2.3 Change diamond model

The Making Change Work study (2008) conducted by IBM investigated how surveyed organizations manage change and how to identify strategies that is most efficient to improving project outcomes. The Making Change Work study involved 1,532 practitioners who have real-life experiences of change projects worldwide from organizations of all sizes across 21 different industries. The goals of these diverse projects includes to improve customer satisfaction, increase sales and revenue, reduce cost, improve process innovation, introduce and implement new technology, enter new market and prepare for the organizational change. The study results showed that achieving project success does not only depend on technology but also depends largely on people and organizational culture. Based on the survey results, change diamond model was established and it has been considered as a useful framework to guide organizations in the real-life change practices. The four common factors in the Change Diamond Model can contribute a synergistic benefit to the project success, help practitioners to prepare for the potential risks and address challenges during the project as shown in figure 4-2 and figure 4-3 below (Making Change Work, 2008).

Figure 4-2: Change diamond model
Source: (Making Change Work, 2008). Page 15

❖ **Real Insights, Real Actions** Strive for a full, realistic awareness and understanding of the upcoming challenges and complexities, then follow with actions to address them.
❖ **Solid Methods, Solid Benefits** Use a systematic approach to change that is focused on outcomes and closely aligned with formal project management methodology.
❖ **Better Skills, Better Change** Leverage resources appropriately to demonstrate top management sponsorship, assign dedicated change managers and empower employees to enact change.
❖ **Right Investment, Right Impact** Allocate the right amount for change management by understanding which types of investments can offer the best returns, in terms of greater project success

Figure 4-3: Details of change diamond model
Source: (Making Change Work, 2008). Page 15

Improving the levels of automation in the workshop will make a big impact on the existing workshop system. In order to move the current condition to the desired future status successfully, a structured change management need to be conducted from the very beginning and along the whole project process. As one of the aims to improve automation in the truck maintenance workshop is to level up customer satisfaction, improve workshop efficiency, cutting cost and improving employee working environment etc., which aligns with the objectives of surveyed organizations in the making change work study, the change diamond model can be considered as a proper change theory framework in this thesis. It is well adapted to the workshop environment to analyze what aspects need to be considered when implementing automated systems in the workshop.

5 AUTOMATION IN THREE INDUSTRIES

In this section, the automation development in the chosen three industries: dairy farm, healthcare industry and warehouse system will be described. The applications in each industry will be further introduced. In robotic milking on dairy farms, more emphasis is placed on the physical activities. In robotic surgery, the operation requires both physical and cognitive activities. However, more emphasis is placed on the physical activities as the doctor uses their knowledge to operate the robotic arms. In the Warehouse management system, both physical and cognitive activities will be discussed. The benefits, challenges and industry maturity in each industry will also be discussed.

5.1 Robotic milking on dairy farms

Milking cows is a complex task in animal husbandry due to the combination of variable biological components (under simulated, milk secretion), physics (control of the milking unit, teat treatment) and the risk of infecting the udder with pathogen microbes (Ordolff, 2001). Traditionally, cows are housed and milked in stanchion (Hansen, 2010). The milking process is done using muscle power and human skills as shown in figure 5-1. The farmer uses a clean towel to wipe the teats to prevent infection. A bucket is then placed underneath the udder in good position. The farmer then wraps his hands around the teats of the cow and begins to squeeze the base of the teats to push out the milk whiles still maintaining a firm grip on the base of the teats to prevent the milk from flowing back into the udder until it’s completely milked out (Cowseatgrass.com, 2016).

Figure 5-1: Traditional way of milking cows
Source: (Cowseatgrass.com, 2016)

The advent of technology led to an improvement in stanchion barns where a wheeled cart is used to move the teat dips and milkers from cow to cow. The milkers were then attached to a pipeline that runs the length of the barn and are moved from coupler to coupler as the milker moves down the line of the cows (Hansen, 2010). This technology was not favorable to the farmer due to bending and crouching to attach the milkers and affected their knees and hips over the years.

This led to an improvement in technology with the use of milking parlors either built new in a separate building or retrofitted into an old barn (Hansen, 2010). This technology had the people and the milking equipment stationary. The process for milking includes automatic teat cup detaching and detection of end of milk (Ordolff, 2001). The concept of robotic milking is shown in figure 5-2.

Figure 5-2: Concept of robotic milking
Source: (Lely.com, 2016)

In order to detect end of milk, inductive, capacitive and optical sensors can be used (Ordolff, 2001). To locate the teats and control it in real time, a charge- coupled device camera (CCD), ultrasonic sensors and a laser are used to adapt to spacing, variation in teat positions, shape and motions of the cow during teat attachment.

The robot arm is attached with fine-position sensors using arrays of light beams. With RFID tags on the cow which is used to identify and obtain relevant data from the cow, an online milk analysis is performed to check the udder condition and milk quality. The teat can be cleaned using rollers, brushes, separate teat cup like cleaning devices and systems for cleaning the complete system (cleaning with boiling water, circulation cleaning, cluster flushing) (de Koning, 2004). During milking, health measurements such as respiration rate and leg health are measured (de Koning, 2004). At the exits of the milking parlor, the health of the cow leg is measured by measuring the dynamic load or weight of each leg while the cows are weighed on scales.

There is currently a new technology for milking animals known as the mobile milking robots. This automatic milking system follows the cows to the pasture and solves the problem of long distances between the immobile automatic milk system in the barn and grazing the cow (Milkproduction.com, 2011).

5.1.1 Industry majority of robotic milking

Robotic Milking was first introduced on commercial farms in 1992 (University Printing Service Sydney, 2011) to provide an increase in milk yield by improving the quality of milk and increasing the frequency of milking (Nof, 2009).

The adoption of automatic milking systems went slowly after its introduction until the end of the nineties. This is shown in figure 5-3. The technology then became accepted in the 2000´s in the Netherlands, European countries, Japan and North America with more than 90% of the world's automated milking systems farms located in North-Western Europe (milkproduction.com, 2011).

However, the greatest adoption of automatic milking systems can be found in the Scandinavian countries with up to 25% of the dairy farms are using Automatic milking systems. By the late 2010, more than 10,000 commercial farms used one or more automatic milking systems to milk these cows. Currently, automatic milking is used fairly in areas of dairy production (Milkproduction.com, 2011).

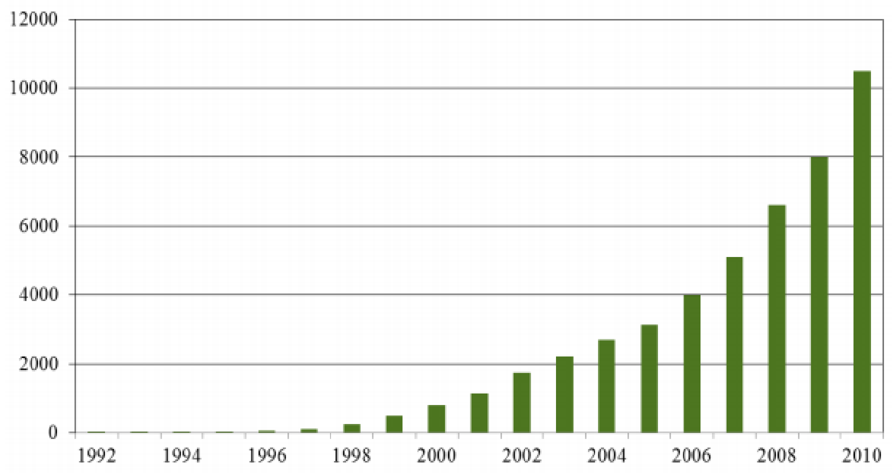

Figure 5-3: Development of the number of AM-farms world-wide since first introduction in 1992
Source: (Milkproduction.com, 2011).

5.1.2 Benefits of robotic milking

Below are the main advantages of robotic milking on dairy farms.

(1) Improved lifestyle

Robotic milking systems on dairy farms have improved the lifestyle of dairymen. Dairy producers have control over their daily routines and can choose to attend to other than farm related activities whiles the robot is milking the cows which is a huge attraction. Activities such as cropping on the farm do not need to come to a halt since the milking is being done by the robot while the diary producer is off planting or harvesting crops (Geleynse, 2003).

The work involved to milk a cow is so tedious that, a lot of dairymen are always looking for another way to pass the job on to someone else. Unfortunately, labor is scarce and expensive to perform milking chores. This has made machines that will take the drudgery of milking cows very attractive (Geleynse, 2003).

(2) Low stress cow environment

Dairy farms with robotic milking have reduced the stress on dairy men. The cows are in charge of when to eat, lay down and when to be milked. The diary man is now relaxed and the atmosphere is very restful. The low stress environment is a positive benefit of robotic milking (Geleynse, 2003).

(3) Consistent and repeatable routines

Robots are not affected by mood swings or the time of the day. A properly functioning robot will milk every cow the same way on every single. There is consistency and the direct benefits of this are hard to quantify. The more consistent and predictable and predictable the routine is, the more consistent the milk letdown reflex will be (Geleynse, 2003).

(4) Improved management

The difference between conventional milking regimens and robotic milking systems lies in the fact in the robotic milking center; the cows voluntarily go to the robots to be milked. On the other hand, the diary operator physically intervenes in a cow's daily routine at specified times to force her to the milking center. The success of a robotic milking center is dependent on the cow’s voluntary ability to attend to the milking robot. Therefore, it is very important that all of the factors that contribute to a cow’s contentment be well understood and heeded. Any aspect of the cow’s life that will hinder it from attending the robot whether it relates to ventilation, nutrition, etc. must be well addressed. Fewer visits to the robot will translate to less milk harvested and a less profitable animal. As dairymen improved the level required for a successful robotic installation, their efforts have paid back through improved milk production, low veterinary cost, etc. (Geleynse, 2003).

5.1.3 Challenges of robotic milking

Below are some major challenges why robots have not seen a broad based acceptance.

(1) Capital cost

The price for an average robotic milking stall is a quarter of a million dollar which is very expensive for most dairymen to afford the technology. This price tag on the milking robotic system is the major stumbling block to a broader acceptance of robotic milking (Rodenburg, 2002).

(2) Technical support

Robotic milking systems consist of components that are very complex and technologically advanced. The technology requires local or technical support to operate the machine which is beyond the scope of most traditional dairy equipment (Geleynse, 2003).

(3) Regulations

The European Union has regulations guiding the manufacturing of machines for the production of Grade A (pasteurized milk and milk based products such as cheese, yoghurt and fluid milk) milk products. This is the Commission Directive 89/362/EEC (1989). The regulation requires that, milking robots meet the requirements of the commission directives before they are accepted to be used in the society. The main challenges with these regulations relate to the preparation of teats prior to the attachment of the teat cups, the inspection of the foremilk, the diversion of unacceptable milk, the detection of abnormalities and the separation of milk or wash from the animal housing area. This is a primary challenge because there are no humans present during the milking and the robots must have the capability to automatically detect and separate abnormal milk. As it is very difficult for an operator to effectively clean the teats of a dirty cow when it enters the milking parlor, it is even worse in a robotic facility (Geleynse, 2003).

(4) Milk Quality and Udder Health

The challenge concerning the quality of the milk and udder health continues to be an issue for robotic industry. There is no evidence that supports the improvement in these two areas comparing a conventional diary to a robotic milking facility (Geleynse, 2003).

5.1.4 Summary of robotic milking

In the early eighties when robotic milking systems was introduced, the critical challenges were getting the cows to the robot, locating and cleaning the teats, attaching teat cups due to the variable shaped udders, testing for any illness, removing the teats cups and disinfecting it and finally getting the cows to leave the robot after milking. Twenty years later, teat inspection and cleaning is routine, robots are reliable, milk quality sensing has improved, etc. The current benefits, challenges and summary of the technology is shown in table 5-1.

Table 5-1: Summary of robotic milking technology, benefits and challenges

Summary of technology	Benefits	Challenges
Milking Parlor Sort gates Robotic milking	Improved lifestyle Low stress cow environment Consistent and repeatable routines	High capital cost Technical support (skilled humans are still needed) Regulations
Electronic feeding station Scale weigh heads	Improved management	Milk quality and udder health

5.2 Robotic surgery in healthcare

Before the ninetieth century, surgery was performed using basic tools such as the bullet extractor and amputation knife. In the mid 1985 a robot was used to place a needle for surgery. This technology provided greater precision but had poor ultrasound imaging capabilities. (Allaboutroboticsurgery.com, 2016).

This led to the development of a robot with image guided, model based with simulation and online video monitoring. As technology kept improving by the years due to the increasing demand for minimally invasive surgeries, a new robot was developed to provide surgeons with an alternative to both traditional open surgery and conventional laparoscopy. The system was a state of the art technology in the robotic platform that virtually extended the surgeons eyes and hands into the surgical field. The most complex and delicate procedures through very small incision were performed with this advanced surgical robot. (Allaboutroboticsurgery.com. 2016). This is shown in figure 5-4.

Figure 5-4: da Vinci advanced robotic system
Source: (Allaboutroboticsurgery.com, 2016).

5.2.1 Industry maturity of robotic surgery

Approximately four million minimally invasive procedures are performed worldwide on candidates using robots. In 2000, there were only 1000 robotic surgeries worldwide. This number increased to 360,000 in 2011 and 450,000 in 2012. (Pinkerton, 2016). In 2011, the estimated market for surgical robot was $2.4 billion. This is anticipated to reach $8.5 billion by 2018 due to the developments of next generation devices, systems and instruments (SPARC, 2015).

The market for surgical robots is mainly in the United States with about 70% robots installed. Only a handful of European companies have shown interest in the field with about 20% robots installed. The remaining 10% of surgical robots can be found in the near and Middle East regions (SPARC, 2015).

5.2.2 Benefits of robotic surgery

Robotic surgery offers many benefits to the surgeon and the patient compared to traditional open surgery (Pinkerton, 2016). Amongst the benefits to the patient are less risk of infection and blood loss. This is due to the robotic arms making tiny incisions. The patient also spends shorter days at the hospital and is less reliance on postoperative pain. The patient is left with no big scar due to the small incisions. Lastly, on the average, most surgery are performed near sensitive organs, tissues or nerves and the surgeon needs to be remove the abnormality without affecting surrounding organs. This is easier to be accomplished with the robotic instruments (Center, 2016).

The surgeon can sit comfortably in front of a screen with a magnified 3D view of the surgical field while controlling the robotic arms (Pinkerton, 2016). He or she can access hard to reach places to treat more conditions with robotic surgery due to the enhanced flexibility and precision of the robot (Center, 2016). With the robotic arms, the surgeon can rotate a full 360 degrees to operate which exceeds the dexterity and range of motion of the human hand (Center, 2016). Lastly, the 3D high definition camera provides the surgeon with a magnified view leasing to a more precise surgery (Center, 2016).

5.2.3 Challenges of robotic surgery

Despite the use of robotic systems in several surgical subspecialties, some surgeons are not willing to adopt robotic-assisted surgery. In general, Health Care professionals and physicians especially are very slow in adopting a new technology. Common factors to their slow adoption to new technologies have been identified amongst others as important to the acceptance of healthcare technology. Some relevant factors that have been identified for the slow adoption of robotic systems are in the following.

(1) Self – governance

The perception of a technology to a physician is the most important factor for its voluntary use. The physician provides specialized services and the adoption of a technology to this industry is highly self-governed (Chau and Hu, 2002).

(2) Long training requirements

People fail to accept a new technology due to challenges of coping with new devices, learning new operative maneuvers and adapting new kinds of instrumentation (Schurr, Arezzo and Buess, 1999). These challenges will interrupt the practice of surgeons to attend educational programs, training sessions and seminars. According to BenMessaoud, Kharrazi and MacDorman (2011), hospitals are lacking uniform training standards for devices like surgical robots.

(3) Lack of clear benefits

A previous research in general surgery found out that, the application of robotic technology has not translated into improved patient outcomes (Marescaux and Rubino, 2005). Some surgeons still believe that, traditional practices are still sufficient to treat patients.

Robotic system is bulky and suffers incompatibilities with conventional laparoscopic instruments. It lacks force feedback and tactile (Talamini and Hanly, 2005; Gomez, 2004).

It gives the surgeon less control over patient safety (Finan and Rocconi, 2010) and has the risk of failure or malfunction (Finan and Rocconi 2010). In addition, it has the risk associated with port placement (von Gruenigen. et. al., 2009), less availability of parts (Nguyen et al., 2004) and requires surgeons to troubleshooting sometimes ((Finan and Rocconi, 2010).

Due to the amount of setup time involved, robotic procedures take longer than laparoscopic instruments (Marescaux and Rubino. 2005). The cost for surgical robot is also expensive compared to other techniques as a result of the fixed cost of the robotic system, on average $1.5 million) (Van, 2007). Robotic assisted surgery also requires higher maintenance and support costs (Lowenfels, 2004) with expensive equipment upgrades.

5.2.4 Summary of robotic surgery

Table 5-2 summarizes robotic surgery technology, its benefits and challenges to the healthcare and patients.

Table 5-2: Summary of robotic surgery technology, benefits and challenges

Summary of technology	Benefits	Challenges
Magnified vision system	More precise surgery	Self-governance
Surgeon console	Less risk of infection and blood loss	Long training requirements
Patient side cart	Shorter hospitalization	Lack of clear benefits (bulky, high cost, etc.)
Detachable instruments	Less pain and shorter recovery	
	Access to hard to reach places	
	Superior dexterity	
	An enhanced visual field	

5.3 Applications of IT systems in hospitals and healthcare

Healthcare IT systems are grouped depending on the location and functions they perform. The following describes some applications of IT systems in the healthcare.

(1) Patient access

Patient access systems are used to organize the way a patient interacts with healthcare systems. Various systems are available to find a suitable time and location for the patient. This is classified into location management and scheduling. Scheduling is considered as complex in healthcare. However, it is the key for efficient operation in healthcare systems. Simple scheduling systems are used to allocate a time slot and make reservations for a patient based on available resources and services. Enterprise scheduling systems are used to plan caring for a patient at multiple locations. Additionally, enterprise scheduling systems are used to schedule patients with complex situations in an appropriate sequence in two different locations at the same time. Location management functions are commonly called admission/transfer/discharge or patient administration message (ADT). This system is used to track the location of a patient in the hospital and store basic demographic information of a patient (Nof, 2009).

(2) Health care billing

Healthcare billing systems are used to generate charges based on the supplies consumed and services delivered. Invoices are generated and issued to the responsible persons for payment after a service or supply is consumed. Both the capture of charges and billing systems are classified as very complex in healthcare systems. Charges comprise of institutional/facility fee and professional fee. When an advanced IT system is used, this provides higher level decision support where the doctor’s clinical documentation is reviewed in order to provide the appropriate level of billing for a given service. To address revenue cycle, billing systems are made of accounting and billing management systems. Cost accounting is used to optimize productivity and understand the cost structure of the institution. Cost accounting is also used to track the cost of specific care actions and the cost for performing basic operations. For billing and revenue tracking, it’s a bit complicated since reimbursement comes from multiple sources such as insurance companies, government and patients. Hospital patients are responsible for all charges issued to them by the hospital. Often these charges are taken care by third parties who demand additional clinical documentation to justify the charges. This increases the complexity of the billing system and causes delays to patient who is dealing with severe illness and looming additional expenses (Nof, 2009).

(3) Healthcare administration

Healthcare administration systems provide an overview of the operations in the hospital. This includes reports and financial dashboard which displays the financial operations of the healthcare including bed management and patient census in the hospital. Additionally, healthcare administration systems are used to manage resources not limited to order communication (system that communicates order request within a hospital) and nurses on duty and their responsibilities. The system helps to identify redundant or inefficient processes and enable the health care to streamline their operations to improve both profitability and provider and patient satisfaction. Healthcare administration systems are seen as a major dependent on clinical care. This makes it difficult to get the details of the healthcare processes especially at the point of care since the point of care is mostly the least digitized. Once the point of care becomes digitized, administrators can understand the healthcare delivery systems such as decision flow, cost and workflow management of the operations (Nof, 2009).

(4) Clinical care

Another area in healthcare where impressive progress has been made is the use of diagnostic test systems. Diagnostic test systems are used to accelerate the process of performing tests, reviewing and managing the distribution of patients test results. This system allows simultaneous access where clinicians and the entire care team can access multiple data of the patient's status from anywhere at any time. Most hospitals today use laboratory information systems to manage the task, workflow and aggregation of data for all the patients' test that is performed in the laboratory. An equally significant aspect is the use of picture archiving and communications systems (PACS) and radiologists to view images and provide diagnostics reports. To improve on the quality of the patient care, computerized provider order entry (CPOE) and clinical documentation are used. CPOE is used to ensure that orders from the physician are consistently and legibly communicated. This provides the opportunity to use decision support to validate the appropriateness of the order that is being carried out.

According to Nof (2009), it is very uncommon for one provider to have all the knowledge to care for a single patient. However, interdisciplinary documentation allows cross functional teams contribute to the documentation of medical records in an orchestrated manner, leveraging and collaborating on shared documents that are created by others.

5.3.1 Industry maturity of IT systems in hospitals and healthcare

According to Nof (2009), health care lags behind almost all other industries in the use of information technology though the exchange of accurate information of a patient can literally be a matter of life and death (Nof, 2009). In many other industries, the benefit of information management has been enough to drive the adoption of the technology. But this is not the case in healthcare. Currently in US, only a few of the largest healthcare institutions implement expert information technology systems. Most of the medical records, prescriptions and receipts are still kept on papers (especially in the US) (Nof, 2009).

5.3.2 Benefits of IT systems in hospitals and healthcare

With today's complex healthcare environment where there are not enough health practitioners to continuously monitor and check on large patient population, then automated equipment is a must have in healthcare sectors. At every encounter with a health care system, patients are asked to provide their basic information such as name and date of birth. Each time this information is written provide an opportunity for transcription errors. With automatic check in kiosks, patients are able to access their data and review or make any changes to their demographic data eliminating the annoyance it creates to repeat the same information over and over (Nof, 2009).

Electronic records used in healthcare permit laboratory results to be available online as soon as it is completed and can be assessed by all members of the care team simultaneously without having to wait for it to be passed on from one clinician to another. Physicians can stay at home or in their office and regularly check on their hospitalized patients anytime and add new orders based on their demands without having to wait for their daily rounds. Again, nurses spend lots of time on administrative task and charting. With electronic records in place, nurses reduce the amount of time they spend on documentation and invest those hours to take care of a patient and chart data that has changed over the last entry. Finally, clinicians can copy and paste a patient's information from one part of the system to another without having to re- enter it every time (Nof, 2009).

Without properly kept medical records, clinicians may mistakenly perform surgery at the wrong site, prescribe medication to which the patient may be allergic to or cannot be taken with another medication prescribed by different practitioner. Automated tools that are used in healthcare are order entry, medical records and decision support that remind clinicians to fill missing data such as which side of the body is to be operated on or allergy information to result in reduction of complications, cost and deaths (Wall, 2000).

As medication ordering process is automated, hazards that arise as a result of unclear handwriting are eliminated. Additionally, it saves time between when the drug is ordered and the time it is issued. Clinicians are assigned to higher functioning roles by which they have been trained for. In the case where advanced tools are used, based on the patient's weight, age and medical history, the system is able to suggest appropriate medication based on the patient's current and past history (Wall, 2000).

In healthcare sectors where a closed loop management is used, this automates both the administration and dispensing of drugs to ensure that the right patient is getting the right dosage of the right drug at the right place at the right time. On a hospital's patient's wristband, nurses are able to scan the barcodes on each unit dose of medication and if there is any error or mismatch, the system generates an alert (Wall, 2000).

Automation helps to reduce cost that is associated with chronic diseases, such as diabetes, asthma and cardiovascular diseases. Electronic systems used in healthcare sectors are used to generate reminders and alerts that can help to ensure that patients receive preventive care for health examination review. If these conditions are managed properly, patients live long with few emergencies. In circumstances where advanced electronic records systems are used, it is easier to perform an outcome analysis on patients with the same condition to know the treatments that are more effective than others within a certain population (Wall, 2000).

5.3.3 Challenges of IT systems in hospitals and healthcare

Earlier research has shown that, the healthcare sector has been particularly slow to adopt IT systems and its lagging behind that of major industries by as much as 10-15 years (Goldschmidt, 2005). The challenge to the resistance of the technology ranges from the healthcare setting, technology itself, system users and the regulatory environment. In the US, the barriers faced by healthcare information technology are perceived lack of return on investments, low adoption rates by doctors and hospitals due to associated costs, use issues and concerns of privacy and security (Blumenthal, and Tavenner, 2010). End user resistance to the system is also a major challenge as well as lack of dedicated practitioner (Ngafeeson, 2014). Physicians and other healthcare personnel influence the resistance of implementing the technology due to the fact that they view the system from an entirely different paradigm than IT personnel or managers (Lin, Lin and Roan, 2011).

5.3.4 Summary of IT systems, benefits and challenges in hospitals and healthcare

Table 5-3: Summary of IT system in healthcare

Applications of IT systems in hospitals and healthcare	Benefits	Challenges
Patient access	Increased efficiency and accuracy	High capital cost

Healthcare billing	Patient safety	Perceived lack of return investment
Healthcare administration	Consistency of care	Privacy and security End user resistance Lack of dedicated practitioner

5.4 Warehouse system automation

According to Rowley (2000), Warehouse automation can be defined as "The direct control of handling equipment producing movement and storage of loads without the need for operators or drivers" (Rowley, 2000). The term warehouse automation includes equipment such as automated storage and retrieval systems (AS/RS), automated guided vehicles (AGVs), and conveyorised sortation systems, and also includes technologies where warehouse operators are still necessary such as supporting warehouse management systems, order picking systems etc.

Warehouse system is a crucial part of most supply chain systems, especially for realizing the customer satisfaction (Frazelle, 2001). The cost related to operations in the warehouse represents approximately 20% of total logistics costs. When warehouses are used as distribution centers, it significantly influences the customer satisfaction since they are often the final point in the supply chain for the order assembly, value adding services and dispatch to the customers (Ecorys et.al, 2015).

The five main processes in warehouse are receiving, storage, picking, consolidation and shipping. Transportation systems connect the whole processes in the warehouse such as conveyor systems and internal transport vehicles, etc. The storage process is responsible for placing received products into storage areas. The products are kept in storage until they are needed. When customer orders are received, the picking process is triggered. Products are retrieved from the storage area and placed in a special order container such as totes. The order containers will then be collected, consolidated and combined into the shipping containers such as pallets and finally shipped to the customers.

Order picking activities are the activities where certain goods will be extracted from a warehousing system based on the customer orders. Picking process is an important part of the supply chain process and it is originally considered as the most labor-intensive and costly activity in warehouse system. Its efficiency influences the order fulfillment and customer satisfaction. When there are thousands of picks to be performed each hour, the warehouse personnel have to be accurate as well as to ensure customer satisfaction is maintained. The order picking processes involve the cost of order picking estimated to be around 55% of the total warehouse operating cost (de Koster, Le-Duc and Roodbergen, 2007).

Traditionally, warehouse operations are performed by human operators and the manual operations accounts for more than a half of a warehouse's operational cost. However, the required workforce is increasingly harder to obtain due to the issues related to health and safety problems, commonly night-working hours, hard and uninspiring work content and low wages.

The high labor mobility also because additional problems related to training and quality assurance. As the drivers such as increasing customer service levels and requirements, reducing high operational costs, difficulties to obtain qualified employees and increasing health, safety and ergonomics regulations, implementing automated systems in the warehouse is becoming an inevitable trend (Richards, 2014).

5.4.1 Industrial maturity of warehouse automation

Automated systems are widely implemented in large warehouses. Almost one third of the large warehouses have introduced at least one type of automated equipment or facility such conveyor, sorting system, automated storage and retrieval systems (ASRS) etc. (Baker, and Halim, 2007). A survey made by the Material Handling Industry of America (2011) found more than 90% of the respondents using automated systems in their internal logistics systems. According to Hoy (2014) warehouse robots is a rapidly growing technology within the supply chain. The warehouse robotics market was estimated to be $4 billion in 2013. The most well-known automated workers are Amazon's Kiva robots, Carrypick system by Swisslog, GreyOrange and Fetch Robotics, etc. (Technology at work v2.0, 2016). Amazon continues to progress in using automated systems in its 120 giant warehouses worldwide. In 2015, Amazon employed about 30,000 Kiva robots in 13 fulfillment centers up from 1,400 at the end of 2013.

Warehouse system is increasingly robotized. This includes handling with robot arms, automated guided vehicles, automatic sorting systems, etc. The high potential for automated forklifts is represents around 1% of European market. Due to the increasing labor cost, automated solutions for warehouse system are expected to grow significantly (SPARC, 2015). However, robotic handling systems are at an early stage of development. The most basic picking, packing and unpacking functions can be realized in research environments but haven't produced in the real industrial environment. Packing and unpacking is also currently manually done. The current systems can handle only regular package. However, according to SPARC (2015), the future systems will be a mix of working and collaboration between humans and automated systems. The system will need more capabilities of human and robot's interactions to be able to adapt to the more variable business environment.

5.4.2 Applications of warehouse automation

The following sections will describe automated applications in the warehouse system including typical automated applications in internal transportation, automated applications in order picking system and applications in storing and warehousing practices.

(1) Typical automated applications in internal transportation

Automated guided vehicle (AGV) is widely used in manufacturing and distribution settings and it can replace the human operations which are originally driver operated (Chung, and Tanchoco, 2009). They serve and dispose manufacturing facilities, connect production and storage areas, delivery entrance and storage areas, production and shipping areas, etc. It is controlled by the on-board computer which is part of the large systems coordinated by a stationary main computer. AGVs can help save the personnel costs, reduce transport damages, reduce the possibility of congestion and especially in the multi-shift operation (Sai-nan, 2008).

In Comparing AGVs which can only travel on pre-defined routes, the autonomous mobile robots (AMR) is completely eliminated of guided paths, wires or lasers (Introduction to autonomous mobile robots, 2011). The comparison between AMR and AGV are summarized in table 5-4.

Table 5-4: The comparison between AMR and AGV
Source: (Aethon, 2015).

AMR	AGV
Trackless navigation	Require tracks
Can go around obstacles	Obstacles stop it
Can be easily re-mapped	Difficult to re-map
No Depots needed	Need depots
Deliver to user location	Do not deliver to user
Travel around people	Travel in dedicated areas
Easy to expand and change	Difficult to expand

AMRs use computer-based vision systems to navigate through warehouse and search for the products needed to fulfill each order such as Amazon robotics (Kiva robotics). Before implementing Kiva robots, the workers in Amazon need to roam around the warehouse, find the products, then pick and pack the products to fulfill each customer order as shown in the figure 5-5. On average the workers need to walk around 7 to 15 miles every day based on the different roles (Mwpvl.com, 2012). With the help of Kiva robots, the shelves can glide across the floor to the workers by themselves. The workers then pick and pack the goods on a stationary place as shown in the figure 5-6 below. According to Amazon, Kiva robots have significantly reduced the order processing time from 1.5 hours to as fast as only 13 minutes (Technology at work v2.0, 2016)

Figure 5-5: Before the implement of Kiva robots
Source: (Technology at work v2.0, 2016) page 83

Figure 5-6 After the implement of Kiva robots
Source: (Technology at work v2.0, 2016) page 83

(2) Typical automated applications in order picking

Technologies such as pick to light system, pick to voice system together with radio frequency devices are widely used for order picking to speed up the human operator's work and enhance the capabilities of employees (Robotics and the "New" Supply Chain: 2015-2020, 2014). A pick to light system includes lights above the racks or bins where employee can pick products. The operators then scan the barcode and the data will be collected automatically in the computer system. In the pick to voice system, workers are directed by the voice they hear from wearing headphones instead of reading instructions or scanning barcodes to confirm the information and operations. The voice picking system allows warehouse workers free their hands and eyes and become more focused on the packing process. This helps to improve accuracy and efficiency at the same time reducing safety issues (Connolly, 2008).

Depending on the purpose, four different methods of different picking units can be chosen as seen in the table 5-5.

Table 5-5: Applications in automatic order picking system
Summarized based on source: (Blake, 2011).

Name	Description	Benefit
Compact picking system (CPS)	Goods to person system, Pick at ease ergonomic workstation	Sustainable performance Improve storage density by 60% High customer service levels Order lead time<1 hour, rush order<10 min), 5-10 minutes learning curve Certified tested ergonomics

Batch picking system (BPS)/ Pick-to-belt	Orders are grouped in batches Operators place products on a conveyor belt Products are sorted to consolidate the orders	Reduction of walking distance up to 90% Minimize number of pick walks Avoid congestion, 99.99% delivery accuracy, Traceability
Automated tote picking (ATP)	Totes are stored in automated storage and retrieval system Transport to palletizing Automatic palletizing	Hardly any manual labor necessary; Increase storage density up to 60%, energy efficiency, Store friendly delivery
Automated case picking (ACP)	Fully automated picking of cartons and totes	40% reduction of order picking cost per case No dependency on labor resource Avoidance of the ergonomic and safety risks of traditional warehouse Store friendly delivery multiple store formats, 100% accuracy (fully automated picking) Short lead time (1 pallet ready in 15min), Less floor space required

(3) Typical automated applications in information technologies

The implementation of RFID technology in a warehouse system helps to get a better visibility of products throughout all operations, facilitate precise inventory control, accurate knowledge of labor and equipment resource availability. This reduces the workload for warehouse operators and reduces the cost (Nof, 2009). It can help improve the receiving efficiency and accuracy, picking and ordering accuracy, reduce inventory level and improve operational efficiency and productivity in the warehouse system. It can help to make the right goods reach the right customers at the right time to improve customer satisfaction. RFID can be used in many phases of the whole supply chain such as conveyor scanning, entryway scanning, overhead scanning, forklift reader and hand held mobile, etc. It can help track different units such as each product inside the case, cases on the pallets and the whole pallets.

The information from isolated business units within organization can be integrated by intranet to help manage the internal supply chains. Electronic data interchange (EDI) can be used to reduce or eliminate human intervention and data entry. It can help pave the way for collaboration initiatives between organizations. In VMI system (Vendor-managed inventory), customers send inventory and consumption information to suppliers. The suppliers can then schedule deliveries to customers according to customers' real needs. This can help customers sustain the inventory within agreed ranges which reduces operational cost and inventory investment (Nof, 2009).

5.4.3 Benefits of automation in warehouse system

Automated systems have various benefits to warehouse systems such as decrease labor costs, improve safety condition and create a better working environment for employees. It can also help perform tasks that go beyond the capability and reliability of human operators. Automated systems can offer flexibility to handle peak demand particularly in areas where staff availability is a problem or in operations where the use of additional staffing may result in congestion and productivity issues (Naish and Baker, 2004).

Automated systems in the warehouse can speed up the planning and queuing time, improve order-picking, improve packing efficiency, improve fill rate and significantly reduce order-to-delivery cycle. All these contribute to a high customer satisfaction (Welch et al., 2012). Warehouse automation can significantly improve space utilization which can help save more space to adjust operations according to future changes. Besides that, warehouse automation can also be a good approach to open up new strategic operations such as increase service categories and provide service to more customers.

5.4.4 Challenges of automation in warehouse system

According to Baker and Halim (2007), the most commonly mentioned difficulties and potential challenges of using automated systems in logistics operations are lack of flexibility, high cost of equipment and financial justification. Besides that, the reliability of equipment, software-related problems, the integration of new equipment into existing systems, service disturbance, high maintenance cost, the need of training programs etc. are also factors which influence the performance of the automation project.

(1) High investment

According to Granlund and Wiktorsson (2014), manual operations are better than using automated systems in circumstances when there is a high level of operation variation, short product life cycle, highly customized services or products. Implementing automated systems might cause unnecessarily complexity and high investment. Besides that, ignoring the strategic impact and focusing on the high investment also have a negative impact on automation projects. This is common when it comes to the selection of equipment and technology (Trebilcock, 2011). The dramatic differences in automation investments depend on the complexity and scale of warehouse operations (Welch et al., 2012). However, with the development of technology, the cost of facilities and equipment is reducing quickly (Technology at work v2.0, 2016).

Choosing the appropriate automation level can help balance the investment and service quality. According to Welch et al. (2012), there are three options to consider when deciding to use automated systems. These are semi-automated process improvements, fully automated storage-and-retrieval systems (ASRS) and second-generation solutions. The semi-automated process requires less investment compared to fully automated ASRS. Semi-automated processes can improve picking productivity, track order progress, reduce errors and reduce labor operations. Semi-automated processes are also more suitable for smaller-scale operations. For the fully automated ASRS, the benefits of operations' efficiency are more than semi-automated process. It can significantly improve labor efficiency and ensure quality control. Amazon robotics is one of the successful innovators as analyzed in the previous section. The layout can easily be installed, occupying a significant small space and adapt to new service requirements (Welch et al., 2012).

(2) Technology reliability and integration

According to Baines (2004), choosing the right technology and integrating it with the existing system is crucial for the warehouse automation project. Using the wrong technology or poorly implementing the right technology can cause harm to the warehouse system. The correct solution can meet customer's expectation in terms of cost, lead time and service quality, etc. Information technology is the key aspect for most of the warehouse automation project. This is due to the fact that, most projects involve new equipment and control system such as implementing a warehouse management system (WMS) or modifying the existing enterprise resource planning system. It is a major issue when various systems need to be integrated. This results in high complexity which requires a long time and high cost investments (Higginson and Bookbinder, 2005). Computer simulation is a good way to mitigate potential challenges, test the operations and identify the potential bottlenecks related to new technologies and equipment. It can also simulate how the future operations and working flows can be realized especially when there is a breakdown.

(3) Service disturbance

There is normally a build-up period such as substantial test, commission, certificate faults of automated equipment and technologies before the warehouse automation projects are in operation. This affects the service level and responsiveness (Naish and Baker, 2004). Besides that, implementing automated systems in warehouse often lead to a redistribution of resources in the organization. Different product groups or geographical areas need to be allocated to the warehouse (Echelmeyer, Kirchheim, and Wellbrock, 2008). This influence the responsiveness of the warehouse system, disturb the existing operations and cover its potential benefits.

(4) Stakeholder commitment

New IT systems or implementing other automated systems might change the workers' skills and knowledge needed to work. Also, changing the operations from manual to automated procedures might result to the few acceptances among employees and the need for proper training. The operator's role as a problem solver or decision maker might also increase which shows the need for competent professionals in the automated warehouse. Other potential obstacles such as lack of commitment from top management and issues concerning change in culture, etc. will also influence the success of warehouse automation projects (Baker and Halim, 2007). Besides that, the use of automated systems will improve the working efficiency which might cause a reduction of the of employees. According to Frohm (2008), there is the possibility to lack important information exchange related to the problem handling and operations knowledge (Frohm, 2008).

5.4.5 Summary of warehouse automation applications, benefits and challenges

Nowadays, warehouse automation is increasing at a fast speed, especially for the large warehouse systems where robots and automated systems have been already installed. Machines guided by human operators are already performing most of the loading and unloading, transporting and delivering activities. With the help of autonomous tracking, robotic warehouses, automatic order picking and self-driving delivery, there might be no human intervention needed (Technology at work v2.0, 2016). The automated applications in warehouse system are summarized in table 5-6 below, together with the benefits and challenges of implementing automation.

Table 5-6: Summary of warehouse automation

Applications	Benefits	Challenges
Automated internal transportation	Save personnel costs	High investment cost
Automated order picking	Improve operations accuracy	Reliability of equipment and information security
Warehouse information system	Enhance the capabilities of employee	Stakeholders' engagement
	Improve visibility and communication	Potential services disturbance
	Reduce product damage	

6 INSIGHTS FROM THE TRUCK OEM

This section describes the phases of preventive maintenance for the truck OEM, current skills of the technician and the execution of some selected tasks.

Preventive maintenance

According to Kelly (2006), preventive maintenance means “the maintenance carried out at predetermined interval, or corresponding to prescribed criteria, and intended to reduce the probability of failure or the performance degradation of an item”. On the other hand, Swanson (2001) stated that preventive maintenance is normally referred to us the use based maintenance comprising of activities that are undertaken after a specified period of time. This maintenance activity includes equipment lubrication, parts replacement, etc. (Swanson, 2001).

A typical package of preventive maintenance includes lubrication, oil and fluid level check, inside cap check, front and steering gear suspension, beneath the truck check and vehicle external check. Specific truck OEM’s original parts and materials are suggested and all the inspections needed to be carried out in accordance with applicable laws.

The dealers use service planning tool where all service plans are updated with time, mileage, vehicle condition etc. The service plan is made for maximizing the trucks availability and maximizes its uptime. All maintenance and service work is performed on the customer's truck in the workshop. Customers receive an optimized individual service plan for each truck to meet the needs of the truck and the business. All service work will be handled when the truck is in for scheduled maintenance.

6.1 The OEM maintenance workshop

A workshop is a room or building that provides both the area and tools (or machinery) that is required for the manufacture or repair of manufactured goods (Franceschini, 2014). Various tools and machines are used in the truck maintenance workshop. Amongst some of the tools used in the automotive workshop are hand tools such as hammer, screw drivers, spanners and electric drilling machine. The mechanical workshops use similar tools and have same standardization which normally is provided by the truck OEM. Differences can be found in the tool used to remove the filter. Some choose to use the ratchet with socket to loosen the oil filter and a type of clamp to release the filters that are completely round while others may use the clamp on all filters.

6.2 Preventive maintenance phases in the workshop

The work in the truck maintenance workshop can be broken down into phases. Each phase is described below.

Phase 1: Customer booking

In the case of the focal company, there is an online platform for customers to communicate directly with Volvo-accredited Service Advisors to get critical information about the truck status. Customers can communicate directly with dealers to plan the workshop visit in advance by using the web page, email or any other Smartphone platform (Volvo Trucks, 2013). This web portal includes all the scheduled maintenance and can work independently on all mobiles, PCs and tablet devices. The booking can also be made by phone call. The customer service takes all the bookings two or three days ahead to register what need to be done for the truck as shown in figure 6-1.

Figure 6-1: Employee booking a customer for preventive maintenance
Source: (Images.volvotrucks.com, 2016)

Phase 2: Arrival of the truck at the premises

After the customer service gathers all the bookings, they will give it to the foreman, as shown in the figure 6-2 below. The foreman will check the work order and prepare all the parts and special tools needed for the maintenance work. The tools are then arranged in a toolbox with the work order attached to it and finally placed on the shelf. When the truck arrives, the preparation job should be finished.

Figure 6-2: The preparation based on customer need
Source: (Images.volvotrucks.com, 2016)

The customer receptionist will give the work order to the foreman when the truck arrives. The foreman will then check the work and hand it over to the technician and give instructions of what needs to be done as shown in the figure 6-3 below.

Figure 6-3: Foreman instructing a technician on how to go about a customer's order
Source: (Images.volvotrucks.com, 2016)

Phase 3: Diagnosis and verification

The technician connects the diagnostic tool to verify the faults or scheduled maintenance works reported to be fixed.

Figure 6-4: Technician verifying faults with the diagnostic tool
Source: (Images.volvotrucks.com, 2016)

Phase 4: Execution of task

The technician performs the task with the support of flexible tools and sometimes with manuals and checklist.

Figure 6-5: Technician changing the engine oil
Source: (Images.volvotrucks.com, 2016)

Phase 5: Billing and departure

In the case of the focal company, all invoices are updated on the online platform and financial follow ups can also be made.

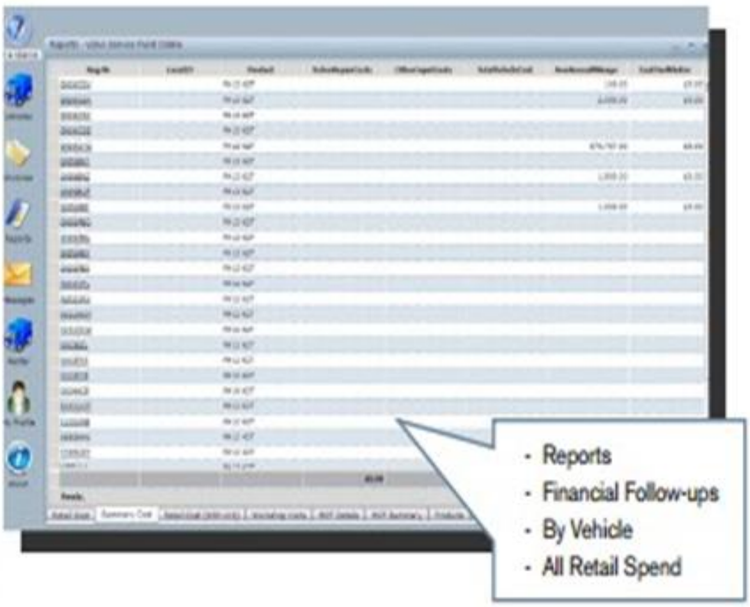

Figure 6-6: Online billing VOLVO Trucks
Source: (Volvo Trucks, 2013).

6.3 Preventative maintenance operations in the workshop

In this thesis, the maintenance tasks that are chosen to be focused on are maintenance under the truck with concentration on change of coolant, change of engine oil, change of gearbox oil, change of axle oil and fuel filter. This is due to the fact that, most of the ergonomically unsound tasks in a truck service are executed under the truck. The work involves raising the truck and supporting it to a stand. Hence, the great potential of serious accidents exists even though the execution of these activities can be considered simple. Also, lubrication change, oil change and fluid check results in the mess of the technician’s hands and the surrounding as the technician works with greasy parts and tools. Furthermore, it is recommended to change the oil after driving (Service Manual Trucks - Volvo Trucks, n.d.). However, the oil is hot after driving and can cause burns in case of any spillage.

To perform these tasks, the technician requires skills set to navigate today’s diagnostics scan tools for maintenance and the use of special and basic tools. Table 6-1 shows current skills of the technician to work in the workshop.

Table 6-1: Current skills set of the technician

Current skills of the technician
Excellent computer skills
Communication skills
Mechanical and electronic skills

The most common tool used for these operations is the torque wrench. This is used beneath the truck to unscrew bolts. The operations related to coolant change includes locate coupling, drain coolant, fill coolant, re-attach and remove tool. Oil change includes locate coupling, drain oil, fill oil, re-attach and remove tool. Changing filters include operations such as locate filters, remove filters, change tool and attach new filters. The operations can be performed using a grease pit or a column lift. Figure 6-7 shows a technician changing oil. In this picture, the truck has been parked on the grease pit with the technician beneath the truck performing the task.

Figure 6-7: Grease pit with a tractor conveniently parked on
Source: (Images.volvotrucks.com, 2016)

Today, the grease pit is not the only option to serve a truck but there is also the possibility to perform service when the truck is placed on the floor. One benefit of using grease pit is the installed drainage system for the oil. When using the column lift, the mechanic has to collect the drained oil and remove it after the service. The column lift also prevents the mechanic access to the cab during the service and the mechanic cannot perform service above the truck without lowering it. But when the service sequence is included in a big truck repair, mechanics prefer the column lift because of the ergonomic improvement. The column lift gives the mechanic a larger working area compared to the grease pit as certain tools are difficult to use in the grease pit because of the narrow space. However, it is very time consuming to lift the truck only for this purpose.

Normally, when changing oil, coolant and filters the process is done by one mechanic. This is to reduce the risk of error with more manpower. Complications during this process are rare and are always because of the human factor. Every mechanic has their own individual working process. Service processes differ between the mechanical workshops more than between the mechanics at the same mechanical workshop. The differences are partly due to the method of draining and filling of oil and coolant. The mechanical workshops have different capabilities. The mechanics influence at the time depends on how much work they can perform in parallel, which can decrease the required time. According to the mechanics, it is very common when removing the filters that extra tools are necessary because the filter gets stuck. This gives an impact on the total service time up to 15 minutes extra and if the filter breaks during removal, this could take even longer time.

When the task is completed, detailed description of the work performed is recorded. This includes major work done and next servicing date and a bill issued to the customer.

7 ANALYSIS OF THE LEVELS OF AUTOMATION IN THE WORKSHOP

This part will analyze the current level of automation for different phases of preventive maintenance and suggest ideas on how to improve the current automation level for the different phases. Phase 4 which is execution of the task for the preventive maintenance is analyzed using the framework developed for the level of automation for the workshop. Also, the current skills of the technician and the new skills required for an increase in automation at the workshop will be analyzed.

ASSUMPTIONS FOR IMPROVEMENT TO HIGHER LEVELS

(1) All maintenance work including change of coolant, change of engine oil, change of gearbox oil, axle oil and fuel filter booked on the work order can be performed by the automated system.

(2) There are always spare parts available at the workshop

7.1 Analysis of current phases

The table 7-1 below summarizes the phases of preventive maintenance and their corresponding level of automation.

Table 7-1: Levels of automation of current phases

Phase	Automation level	Name	Narrative definition
1 Customer booking	3	Partially automated	Bookings can be done online but has been alternated with manual assistance.
2 Arrival of the truck at the premises	3	Partially automated	The customer service personnel verify the booking with a computer and print the work order for the Foreman.
3 Diagnosis and verification	3	Partial automated	The technician scans the on-board diagnosis software installed in the truck with a diagnostics tool and compares the faults found to the work order.
4 Execution of task	2	Vehicle diagnostics assistance	Manual work with the support of a flexible tool such as torque wrench.
5 Billing and departure	4	Highly automated	Invoices can be paid at the service desk or through the online service portal

7.1.1 Phase 1 - Customer booking

Currently, the customer can book a time slot either using an online platform or by calling the truck dealer and have a discussion with the customer service for available time slots to be booked on his behalf. A work order is created at this point. This already represents level 3(partially automated) since the booking has been automated with an alternative for manual assistance.

7.1.2 Phase 2 - Arrival of the truck at the premises

Currently, upon arrival at the premises, the customer goes to the customer service where he issues his car registration number. Upon verification by the service personnel of the booking and time, the personnel print the work order and issue it to a foreman who takes the truck for the next step. This represents level 3 (partial automated) since the verification and work order part of the work is done by a computer with the personnel doing very little manual work of typing, paper handling if needed, etc.

7.1.3 Phase 3 - Diagnosis and verification

The technician connects a diagnostic tool to the truck which scans the onboard diagnostics software installed in the truck for faults. The faults found are compared with the work order issues and if more faults were found, the foreman will discuss with the customer and an agreed course of action is taken. This step requires some manual work since the output of the diagnostic tool must be fed to another tool or the technician must manually initiate the next step. As such this phase is level 3 (partially automated).

7.1.4 Phase 4 – Execution of task

Today, the work involved in changing engine oil, etc. can be classified as not ergonomically friendly to the technician. This is because the technician has to work under the truck for prolonged hours and stand in awkward postures to perform the task. This can result in an accident if the supporting equipment is not firmly grounded. In addition to that, any spillage into the eyes can cause serious health issues.

The spare parts and tools are also heavy and technicians need to carry the spare parts and tools box to the working area. These all poses serious health issues to their back and shoulders in the long run.

The work is also seen as dirty work and can cause blisters to the technician hands as some parts of the task is carried out with basic tools such as screw driver.

Also, because the tools are expensive and not many, the technician goes back and forth checking on the availability of the tool to use. This and many others cause unfavorable working environment in the workshop for the technician.

Using the framework developed for the level of automation for the workshop in section 4.1.2, chassis lubrication, engine oil change, filter change, coolant change and oil change in the gearbox are classified under vehicle diagnostics assistance. This is because when a truck arrives at the workshop; all the above faults are diagnosed with the help of a diagnostics tool which the technician connects to the truck. Due to this, the technician does not undertake any of the above tasks based on his personal experience but by the information produced by the diagnostics tool which reduces the cognitive burden.

To solve these tasks, the technician uses flexible tools like torque wrench to turn drain plugs and unscrew locking devices as well as filter wrench to undo existing oil filters. This requires some muscle power hence the decision to classify all the above as level 3 (vehicle diagnostics assistance).

7.1.5 Phase 5 – Billing and departure

Based on the work order, the finance department prints an invoice for the customer who can either pay at the premises or later at the customer's convenience. This phase is already in Level 4 (highly automated) with the finance department doing very minimal work.

7.2 Improve the level of automation for phase 1 - Customer booking

This section describes how the different levels will develop for customer booking. The current booking system is on level 3 (partial automation) since the customer can either book online or call the customer service.

7.2.1 Level 4 – High automation

The personnel in level 3 (partial automation) can be replaced with an automated answering machine which can interact with the customer. The customer can however still talk to a foreman upon request.

7.2.2 Level 5 - Totally automatic

In this phase, there are no personnel on site so booking is solely done online or using an automated answering machine. The customer has approved software installed on his mobile device which he uses to interact with the workshop and book a time slot.

7.3 Improve the level of automation for phase 2 – Arrival of truck at the premises

This section describes how the different levels will develop for arrival of truck at the parking space and interacting with the customer service personnel (premises). The current phase of arrival at the truck at the premises is at level 3 (partial automation) since the verification and work order part of the work is done by an automated system with the personnel doing very little manual work of typing, etc. if needed.

7.3.1 Level 4 – High automation

Automatic Vehicle Identification based on RFID is mounted on every truck that's legally registered. Electronic tags are normally attached to the surface of the truck or embedded within the truck such as vehicle number plate. Each tag has a unique ID number or electronic code and cannot be altered even with high security. Upon arriving at the premises, an RFID enabled automatic identification system identifies the truck and transmit all kinds of truck information at real time to the data processing unit. The technician is notified of the arrival of the truck which is parked at the parking space by the customer. When ready, the technician drives the truck to the workshop for further work.

7.3.2 Level 5 - Totally automatic

This phase is similar to that of level 4 but since there is no technician on site, upon identification of the truck by the RFID system, the door opens and the customer enters the workshop with the truck and parks it on the automatic parking system. He then goes away to the waiting room. The automatic parking system then cleans and presents the truck to the automated system on the grease pit.

7.4 Improve the level of automation for phase 3 – Diagnosis and verification

This section describes how the different levels will develop for diagnosis and verification. The current system is on level 3 (partial automation) since the technician must manually feed the output of this phase to either a tool or an automated system. The technician must have excellent computer skills.

7.4.1 Level 4 - High automation

The technician connects the automated system that is going to perform the tasks to the onboard diagnostics program in the truck and approves for the automated system to perform its own diagnosis to match that of the work order. The technician can then discuss with the customer if new faults are found by the automated system to be added to the work order. The finalized work order is then approved and issued to the automated system to commence work. The technician requires monitoring and excellent computer skills.

7.4.2 Level 5 – Totally automatic

The automated system which will work on the tasks connects itself to the onboard diagnostic of the truck by way of a special port under the truck or elsewhere and performs its fault finding. The faults found are then sent to the customer's mobile device for confirmation. If new faults were found apart from what was included by the customer in the working order, the customer has the opportunity to accept all or some or reject all. The finalized work order is then confirmed by the customer and it's sent to the automated system upon confirmation.

7.5 Improve the level of automation for phase 4 - Execution of task

This section describes how the different levels will develop to execute the task. The current execution of task is on automation level 2 (vehicle diagnostics assistance) because the technician gets information of what to do from a diagnostics tool and also performs the task using flexible tools.

7.5.1 Level 3 - Partial automation

Since this level reduces the use of muscle power of the technician, then an automated system is used to perform the tasks found in the vehicle diagnostics phase. Since the automated system will work on different trucks and each truck has its own configuration as to how the various items are placed under the trucks, then a configuration file must be loaded to the automated system to configure the automated system to operate at the correct places. This means that there is one configuration file per truck type and the technician after performing the diagnosis with the diagnostics tool adds the configuration file to the work order and approves it for the automated system to start working on it. Before the automated system starts working, the technician has to perform the following tasks

(1) Ensure that under the truck is clean of snow or dirt so the automated system can identify all necessary parts. This is a visual verification done during phase 3(diagnosis and verification) and possibly cleaning done if necessary

(2) Ensure that all tires are pumped to the acceptable level so the truck can stand very straight for easy identification of various parts.

(3) Ensure that the truck is correctly positioned on the grease pit for easy access by the automated system.

When all the above are satisfied, the technician pushes the start button for the automated system to start work. While the automated system is working, the technician can observe the entire work flow using a 3D vision system which is similar to the vision system installed for surgeons to perform robotic surgery. This makes it possible for the technician to detect when the automated system faces challenges in for instance identifying parts of the vehicle and can step in to assist.

When the automated system finishes its tasks, the technician can re-diagnose the truck with the diagnostics tool to ensure all faults are cleared. The technician requires excellent computer skills, robotics and mechanical skills.

7.5.2 Level 4 - High automation

Based on the identification performed in phase 2 (arrival of the truck at the premises), the trucks configuration file is automatically added to the work order for the technician to approve. After phase 2, the technician drives the truck onto an automatic parking system which taking a cue from the automatic milking of cows, is able to detect dirt and clean under the truck as well as balances the truck properly before moving it over to the grease pit for the automated system to work on it. This ensures consistency and removes a lot of the work done by the technician to present the truck in a proper state to the automated system. When the truck is on the grease pit, the technician connects the automated system to the truck which is when phase 3 (diagnosis and verification) starts. When phase 3 is completed, the automated system adjust its tools based on the configuration file loaded and performs the task which it verifies by reading the onboard diagnostic in the truck to clear the faults and alarms. The technician can also observe the work done by the automated system using the 3D vision system provided. After the work is done the automatic parking system moves the truck away from the grease pit. The technician requires excellent computer skills, monitoring, robotics and mechanical skills.

7.5.3 Level 5 – Totally automatic

After parking the truck on the automatic parking system in phase 2 (arrival of the truck at the premises) by the customer, the automatic parking system presents the truck to the automated system on the grease pit. The automated system connects itself to the truck and starts phase

3(diagnosis and verification). Upon completion of phase 3 the trucks configuration file is loaded by the automated system and the automated system adjusts its tools based on the configuration file loaded and performs the task which it verifies by reading the onboard diagnostics in the truck to clear the faults and alarms. The automatic parking system then moves the truck to the exit for the customer to drive off and notifies the customer of the completion of the work.

7.6 Improve the level of automation for phase 5 – Billing and departure

This section describes how the different levels will develop for Billing. The current system is on level 4 (high automation) because the finance department does very minimal work to bill a customer.

7.6.1 Level 5 – Totally automatic

The system generates an invoice based on the work order and sends it to the customer's specialized mobile software for billing to take effect.

7.7 Potential challenges for implementing automated truck maintenance workshop

The challenges are learnt from dairy industry. For an effective and efficient system, the following are the initial challenges.

- Ensuring that under the truck is clean of dirt or snow so that the automated system can identify all necessary parts.
- Getting the truck to the automated system.
- Ensuring that the truck is correctly positioned on the grease pit for easy access by the automated system.
- Getting the truck to leave the automated system.

7.7.1 How to overcome initial challenges of automated truck maintenance workshop

This section is inspired by dairy industry and robotic surgery.

- When the workshop has matured to level 3, then the technician must ensure that under the truck is clean of dirt for easy identification of parts by the automated system.
- When the workshop has matured to level 4 or 5, the automatic parking system has to clean under the trucks before presenting it to the automated system on the grease pit to execute the task.
- For consistency and ensuring that the truck is correctly parked on the grease pit, the automatic parking system is to present the truck to the automated system on the grease pit to execute the task. However, in level 3, the technician can ensure that the tires are pumped to the acceptable level and present the truck to the automated system.
- In situations where the automated system is not locating the parts or finding it difficult to locate a position to execute the task, the technician can view the entire process behind the 3D vision system similar in robotic surgery at real time and step in.
- Depending on the maturity of the automated workshop, getting the truck to leave the grease pit can be done by either the technician or the automatic parking system.

7.7.2 Benefits of automated truck maintenance workshop

First of all, an automated workshop will improve on the safety and health issues of the technician. With the help of automated systems, the technician will no longer work under the truck which is dangerous and prone to injury. The technician will be responsible for supervisory roles, monitoring and verification. Skilled technicians who have the ability to master new, advanced technologies, work in highly collaborative team environments, use critical thinking and problem-solving skills, adapt to ever-changing environments and embrace an attitude of never-ending learning will be required.

Having a programmed automated system to perform the task also improves the quality and increases the accuracy of the job which reduces the operating errors once performed by the human operators. In addition, automated systems can work faster and longer in executing task compared to humans. The number of trucks maintained in a day will increase which ultimately increases the total revenue made in a day. The automated systems can improve the possibility of facing the fast changing business environment.

7.7.3 Challenges of automated truck maintenance workshop

The main challenge for an automated truck maintenance workshop is the high capital cost to purchase the automated systems. There are also hidden costs such as the cost in researching and developing the automated process, cost in training the technician on how to operate and collaborate with the automated system in a safe environment and the cost related to equipment maintenance. The higher the level of automation, the higher the investment cost and the lower the operating cost such as labor cost. The concerns of high investment and long investment payback period will cause the resistance from dealers and top management.

The issue with a reliable technology and how to integrate a new technology with existing systems will also influence the performance of the project. As the level of automation in the workshop increases, complex systems will be required to eliminate the human role completely. This will require high integration and need long time. The concerns about information safety and privacy will cause fewer acceptances of participants and make it hard to realize.

Improving the level of automation in the workshop will change the operating structure and will require new skills and knowledge. Changing the operations from manual to automated systems will influence operator’s acceptance such as the resistance from technicians and customer service department, etc. Managing new relationship between machines and human operators will also put new challenge to the workshop manager and foreman which might lead to more resistance.

8 MANAGING CHANGE IN THE WORKSHOP WITH CHANGE DIAMOND MODEL

A successful improvement of automation levels in the workshop requires a full, deep and realistic understanding of the upcoming changes followed with the responding actions. Getting an early insight of the changes can help reduce the risk of underestimating or overlooking at the complexity. The consequent action will help to address the resistance in the organization. A consistent and structured change management approach can produce both tangible and intangible benefits for the automation progress. Private owned dealers and truck OEM owned dealers are two types of dealers for the truck maintenance workshop. The workshop normally consists of workshop manager, foreman, technicians, service manager, parts manager, etc. Although the common goal of all dealers is to meet customers need and make them satisfied, in order to realize their organizational goal, each workshop has different key performance indicators and different concerns of investment. Besides that, how resistant the organization is to change will influence the theory that works best for the organization.

The following section will analyze the change efforts that needs to be taken into considered to improve automation level in the truck maintenance workshop. Four elements in the change diamond model will be analyzed to get a deeper understanding of the change process in order to understand how to make the right investment in order to get a right impact. The section will also analyze how stakeholder management can help to get a real insight and take real actions. Besides that, the importance of better skills will also be discussed to get a better change. And finally, the importance of building up solid and systematic change method will be discussed to contrite to a solid benefit. The learning's of the three industries as analyzed before will also be analyzed in the workshop environment to make the change process more realistic and reduce the potential risk.

8.1 Right investment, right Impact

Understanding which types of investment can offer the best returns in terms of project success can help allocate the right amount for change management. One of the challenges in executing automation project in the workshop is to identify the optimal parts in the organization that needs to be automated. It is also crucial to analyze to which level of automation is more suitable for the specific workshop condition. It is necessary to know the correct amount of automation for both short and long term. This depends on finding, selecting, acquiring and properly implementing the right type and level of automation in relation to the company's needs, goals and prerequisites. Before investing in automated systems, it is important to structure the systems in which the automated system will be part of. Also, ensure the automated system is well integrated with other systems. Analyze the current automation condition and history for the specific workshop to help structure the system in a better way. As learned from Warehouse System Automation, the selection of equipment is an important part of designing and progressing automation project. This is the same in workshop automation process. Thus, more time should initially be invested to describe the requirements before automating.

Identify the drivers for the workshop to implement automation such as benefits and potential challenges. This can be a good start to initiate change and clarify the efforts that needs to be met.

Identify which benefits are more important for the specific workshop to find a deeper meaning and value to focus on. This can help the organization to be inspired, take the right actions and to get the right and quick results. As analyzed in the previous sectors, the benefits of automation can reduce cost, improve the working efficiency, reduce labor cost, improve the working environment for workers and meeting the future market changes, etc.

Identifying the potential challenges beforehand can help make the right investment to the right place and to mitigate risk before they do harm to the automation project. Automation can improve workshop efficiency as less labor effort is needed to perform the same tasks as before. This will cause the risk of losing important information exchange, deskilling technicians due to the lack of exercise, difficult to detect and recover from the errors, etc. Feedback sharing scheme is necessary along the change process where stakeholders can share results, reflections, get information, generate better understanding and review ideas from each other.

Technology is pivotal to implement automation in the workshop and technology investments are risky. A proper approach of technology planning can provide scientific justification for investment decision. This can remove guesswork and reduce the chances to miss the next winning technology or product. As in warehouse automation processes, the simulation of new technology before it is actually invested can be a good way to mitigate risks and define the possible bottleneck. A rigorous scientific process can be used in line of the trial and error process and become a management breakthrough. The process can be used as developing automation strategy and deciding technology investment. Involve flexibility phases in the automation project such as the potential to change time and cost limitation to make the system become less rigid and more adaptable to the changing environment.

The efforts to take in order to achieve the right investment, right impact are summarized in figure 8-1 below.

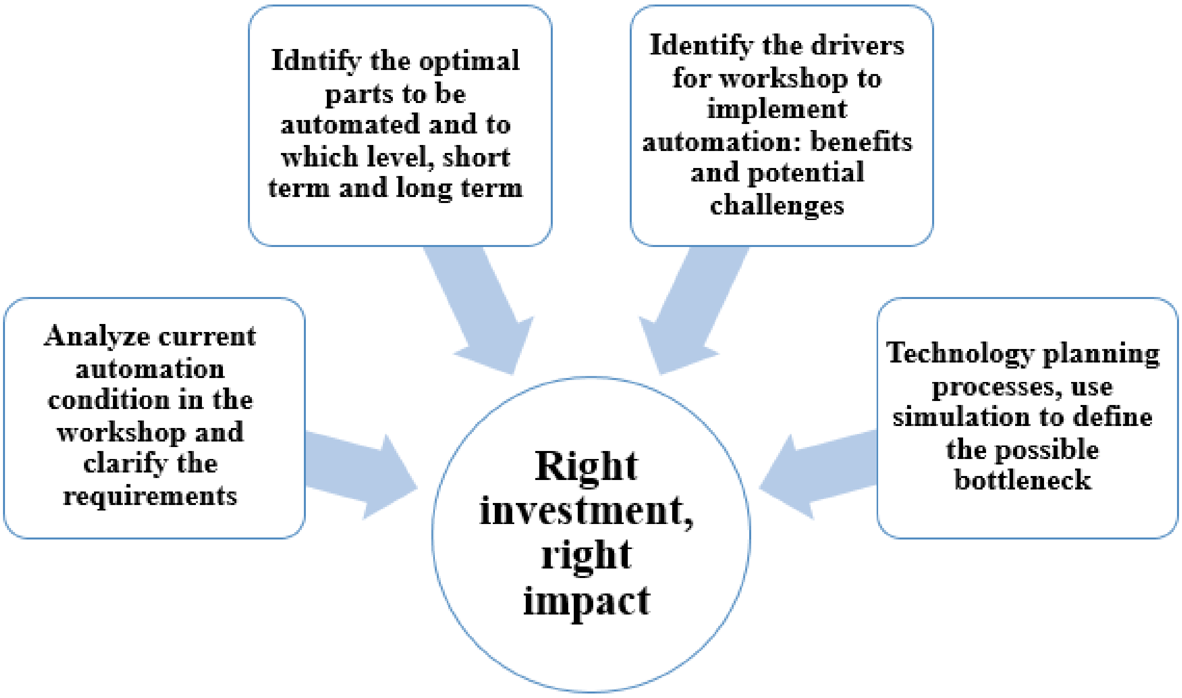

Figure 8-1: Right investment, right impact

8.2 Real insights, real actions

People tend to rely on automated systems that they trust and reject automated systems that they do not trust. Inappropriate reliance often results from a failure of trust of the capabilities of the automated system. It does not only depend on the task structure but also depends on operator's adaptation such as trust and concerns. It is important to understand the factors affecting the system as well as the system requirements. Stakeholder Management can be used to explore what support and hindrances introducing automation to the specific workshop can prevent reaching its potential. It is important to identify stakeholder's influence and attitude about automation in order to motivate them to join in the automation project and experience the outcome. The stakeholders related to the workshop automation project includes technician, foreman, workshop manager, service manager, parts manager, automated facility provider, truck OEM aftermarket department, etc. In order to lead a large engagement collaboratively, certain agreements can be written such as a list of all stakeholders involved in the specific automation project, analysis of stakeholders, prioritization of stakeholders, the specific approaches and mechanisms of engagement.

Stakeholder identification is a continuous practice and it varies along with automation progress in the workshop. Group brainstorming and rapid listing can be suitable methods to identify stakeholders. Since new stakeholders will emerge and old stakeholder will fade away, stakeholder list should be evaluated regularly. The different stages of implementing automated facilities or processes will change the stakeholder's influence level. Appropriate stakeholder influencing analysis methods need to be chosen based on different situation. The stakeholder's characteristics such as power, position, interest, attitude, potential wins and losses, concerns and resistance to the automation project will influence the proper strategies and methods to move them from current situation to the target position.

People are often concerned about the effect that the change will have on them. In the workshop, technicians and foreman may worry about losing their job due to the fact that the automated systems will be used for some of the manual work. The receptionist and customer services may be concerned about automated registration and booking system which will bring strong competition not only among human, but also between humans and machines. Some technicians in the workshop may prefer to choose the methods and tools they are familiar with to perform the task instead of learning and adapting to the new methods which may cause the low efficiency and more mistakes. The workshop manager may be concerned about the big investment of the automation and the potential disturbance if there is a breakdown of the automated systems.

In the workshop, young technicians always show more respect to old and experienced technicians and foreman. Some workshop managers used to be a technician. The technicians have lunch meetings and discuss together which shows the shared history and recognized credentials in the eyes of the stakeholders. So, it is important to analyze the feelings and emotions which cause the motivation or resistance. Identify the stakeholders who are more positive and motivated to automation, ask their needs and fears about the automation level, certain tools, or equipment that can help evaluate the automation project and take the necessary actions to get them involved in. Creating early wins is a powerful method to convince other skeptical stakeholders such as when introducing new technology or automated equipment. The technicians who are more positive to change can be convinced to try the equipment first. By analyzing the technicians' using experience, a comparison of technician's working efficiency and working satisfaction between before and after using automated systems can be made. The real model experience can have a positive effect to the technicians who are resistant to automation.

Uncertainty in a working environment reduces productivity. It is important to communicate what is changing, how and why. According to Bellgran and Säfsten (2010), formal and appropriate process models for automation development are believed to give structure and guidance, thus increasing the probability of a proper automation development process. During the automation process, it is important to have a good dialogue with the different parties performing the automation development (both internal or external), as learned from the warehouse management automation. Appropriate communication among all parties can help reduce concerns and uncertainties. The good communication can help identify and justify the requirements, specify goals and expectations, clarify interfaces, ownership and responsibilities.

It is important to communicate as the project is ongoing in different stages and levels of the automation project. During the change process, participants will develop a better understanding of the intermediate and final states at the same time they would have new questions and concerns. Go around, listen and learn what has been done, what is happening and identify those who are engaged or not engaged in certain situation. Confirm a phenomenon that is interesting to communicate, collect additional data from all stakeholders, and conduct interviews to deep understanding. This can help to identify stakeholder's needs and reflection, generate new ideas and build up relationships to strengthen the communication results.

The efforts to take in order to achieve the real insights and take real actions are summarized in the figure 8-2 below.

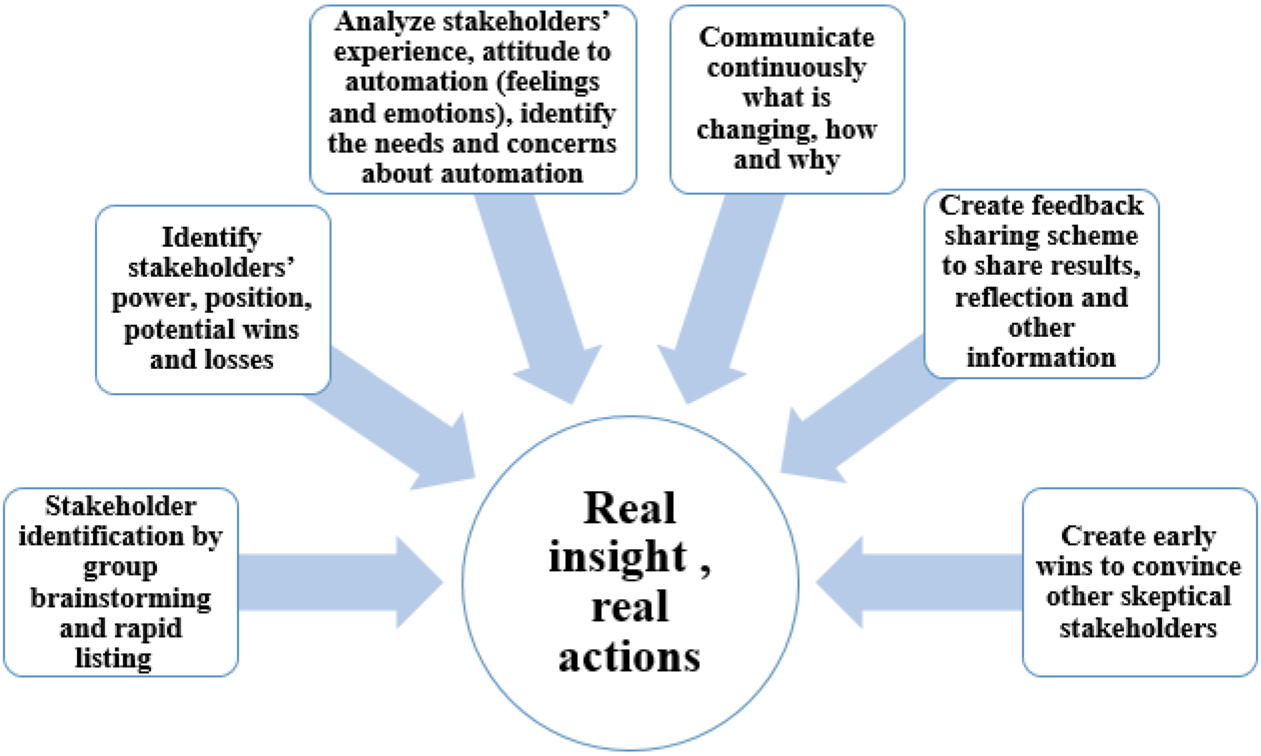

Figure 8-2: Real insight, real actions

8.3 Better skills, better changes

Workshop automation does not simply eliminate tasks that once performed by human operator. It changes the task structure and creates new tasks that need to be supported, thereby opening the door to new types of error. Increasing the level of automation in the truck maintenance workshop might also change the required skills and knowledge to operate the equipment properly. The operator's role as a problem solver or decision maker might also increase. There is also the possibility of frequent service disturbances related to machines and equipment breakdown. The human actor's such as technicians and foreman needs to be involved in the technical advancements in order to handle machines and equipment during unforeseen situations. Building up a learning scheme and framework to assess and train the required skills and knowledge can help the operators to become more prepared for the future challenges.

Getting departments such as the OEM's aftermarket department involved in this automation process can contribute to a better communication among dealers. Leverage resources appropriately to demonstrate top management sponsorship, assign dedicated change managers and empower workshop to enact change. Build and sustain support among executive leaders and stakeholders, provide guidance and governance mechanisms to improve program success. Take time to integrate what have been learned and define how to make it different the next time. Decide how to improve or change the work processes, routines and improve relationships. Besides that, standardizing the learning into organizational processes will improve the knowledge base of the organization and contribute to the next change process.

The leaders in the workshop environment can be foreman, workshop manager, management, board of the dealers or can be the single technician who has a big influence for the automation project and other stakeholders. It is likely to face certain level of resistance when changing the process. Therefore, effective leadership skills are important to recognize, address and overcome resistance, initiate and coordinate change. The leaders related to workshop automation project should be willing to change their leadership style based on different phases and situation and have a positive influence on the staffs. To enhance more team work spirit and efficiency, more development programs and teamwork trainings can be taken for specific situations to have a better influence on the people. The workshop's ability to motivate individuals toward superior levels of performance is closely related to their reward systems. Therefore, for strategic organizational change, leaders need to ensure different types of rewards and training programs are offered to motivate individuals.

The efforts to take in order to achieve better skills and better changes are summarized in the figure 8-3 below.

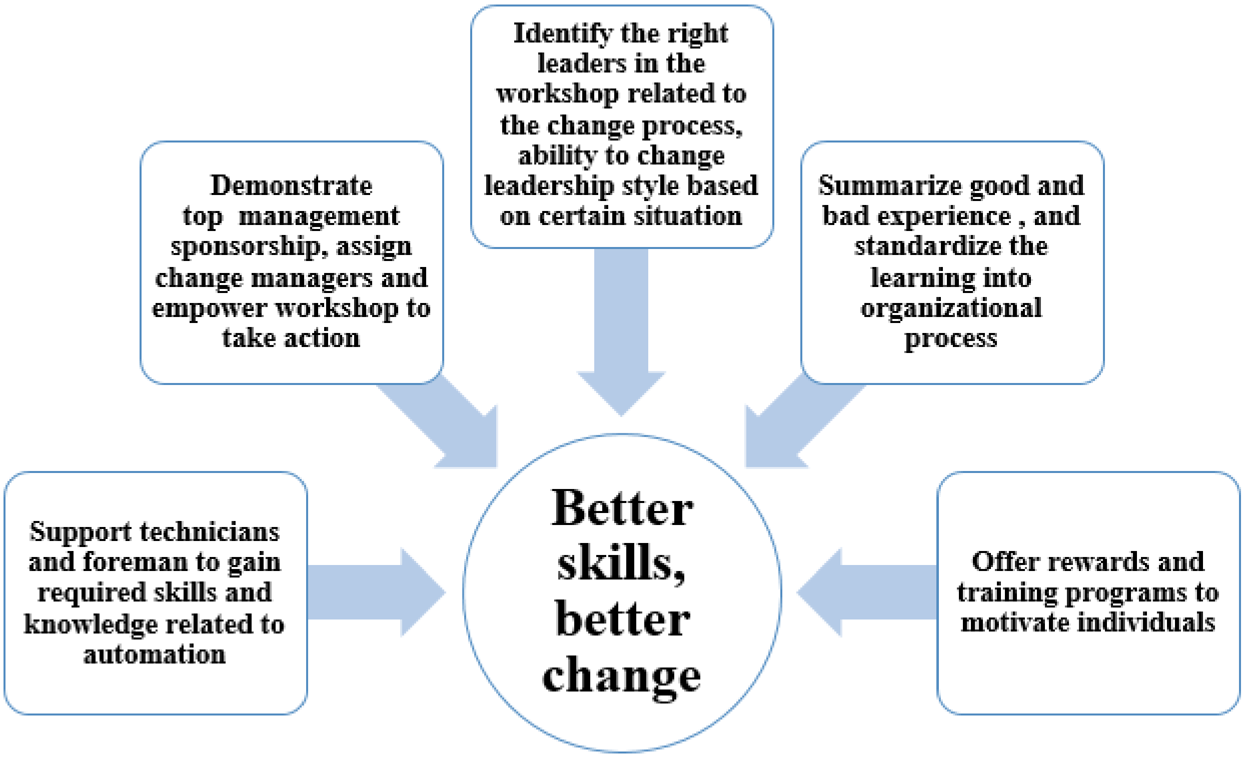

Figure 8-3: Better skills, better change

8.4 Solid methods, solid benefits

Having a systematic change approach which is focused on outcomes and closely aligned with formal project management methodology can benefit a successful change project. Analyzing change histories in the specific workshop can help structure the system and allocate required resources to enact a change. It is important to identify and seek necessary resources to implement automation in order to gain motivation and energy, commitment from all stakeholders, prepare knowledge and information for the specific project, create cross functional change teams, make action plan to deal with the potential challenges within automation, get enough time and monetary budget, etc. There are various relationships in the automated truck maintenance workshop which need to be dealt with properly such as the relationship among human operators, the relationship between human and machine, the relationship between new facilities and the existing systems, etc.

Manage change as a formal work stream within each project instead of only considering change management where there is a big project going on. Control the change effort scope to focus on the main activities and stakeholders who have the most important influence on the success of the project. Assemble a group with enough power to lead the change effort and encourage the group to work as a team to create the guiding coalition. Create a vision to help direct the change effort and also develop strategies for achieving that vision. Get all stakeholders involved in and make action plans for each specific stakeholder based on their needs and interests. Communicate change with all stakeholders to answer the continuous questions and concerns. Continuously, evaluate the change performance and create short term wins to review what has been achieved along the way of automation to encourage all the stakeholders to actively participate in the change process. Finally, make the change theory involved in the organization's culture and standardize the learning's into organizational processes for the next change project, especially benefits for the workshop to continue implementing automated systems.

The efforts to take in order to achieve solid methods and solid benefits are summarized in the figure 8-4 below.

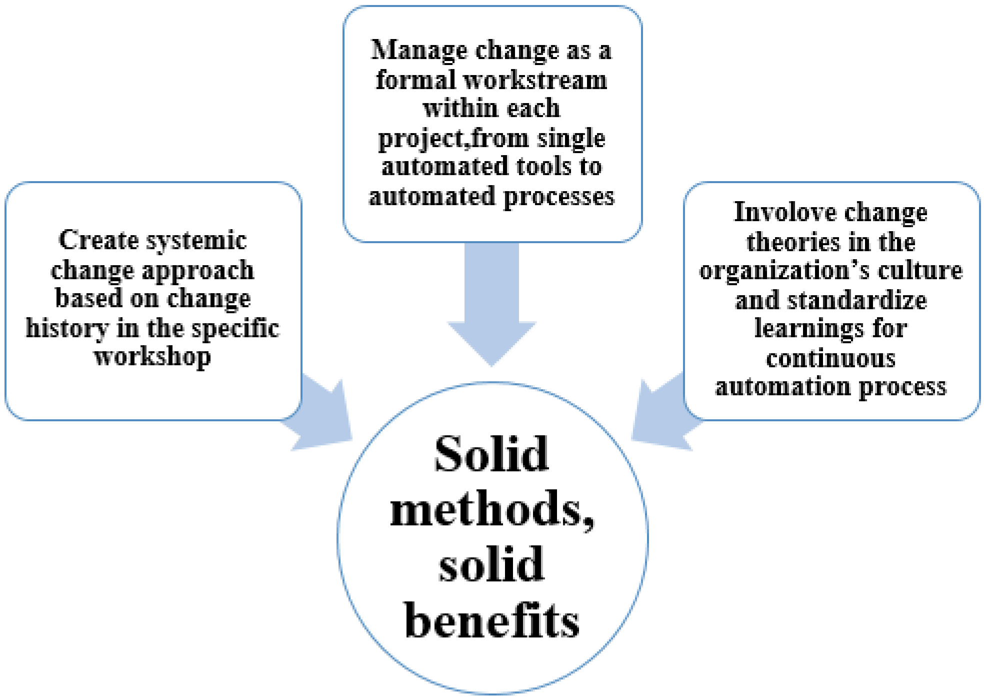

Figure 8-4: Solid methods, solid benefits

8.5 Summary of change diamond model in workshop automation

The unrealistic or undefined objectives are one of the main reasons which lead automation projects to end in failures (Frohm, 2008). Searching, selecting, analyzing, acquiring and properly implementing the right type and level of automation, and making sure it is aligned with company's' needs, goals and prerequisites is crucial for a successful automation project (Daim and Kocaoglu, 2008). The obstacles such as lack of commitment from top management, issues concerning change in culture and worker's acceptance will influence the progress of automation (Baker and Halim, 2007). Thus, change theories are crucial for successful automation projects in the truck maintenance workshop. Considering the four perspectives in the change diamond model such as the right investment, right insights, better skills and solid methods can provide directions and guidelines for workshops to follow in order to manage change in a systematic way which are summarized in the following figure 8-1.

Figure 8-5: Workshop analysis based on change diamond model

9 DISCUSSION

The automotive industry is entering a new age of the digital world where electronics will be the most dominant in the connected car. To stay competitive in the vehicle business, all areas of operations must be improved. Truck workshops have not had any major innovative improvements like the vehicles have had the past decade. Truck workshops have not had any major innovative improvements like the vehicles have had the past decade. Besides that, the work involved in the workshop is not attractive to the new generation. The Swedish Work Environment Authority has also elaborated on how demanding the work involved is for the mechanics. This and many others show the need for improvement in the maintenance workshop. Automation is one area to improve on the operations. It is also a good option to deal with the changes in design and product variation of the truck. Again, it will improve on efficiency, safety and health issues of the technician.

However, many industries focus on how to automate the execution of the task with minimal attention to the logistics. But after reviewing the automation process in the warehouse system, applications such as automated guided vehicle (AGV) or autonomous mobile robots can be used to help carry the heavy objects for technicians, relieve their back and shoulder and reduce the main health problem for the technicians. Automated picking system such as pick to light and pick to voice system can also be used to reduce the effort and time of fetching the tools or parts, relieve the technician’s hands and eyes to focus more on their major work which will also contribute to a better working environment for the technician.

Automation is becoming an inevitable trend. However, the workshop is likely to face challenges in implementing automation or increasing the level of automation in the workshop. One of the major concerns is the high investment including the cost of the equipment and cost of maintaining the automated systems. With the development of technology, the cost of equipment is reducing quickly which can lead to a shorter payback period. The maintenance cost in a short term will account for a big part of operational costs due to issues such as poor operations, technology reliability and updated equipment, etc. A transparent and detailed technology plan can help balance the high investment and raise enough budgets to face these challenges. In the long term, the cost of maintenance will be reduced with the help of training programs and technology development.

The concerns of whether full automation will come in a short time period or should never come are also very hot topics today. Worries about automation replacing human operators are commonly mentioned. Since the industrial revolution in the 1700s, technology improvements have changed the nature of work and types of work. Technology is advancing in a high speed nowadays. In order for the workshop to prepare the upcoming automation trend, systematic training programs should be offered to the operators. New skills such as electrical skills, computer and programming skills, automation and robotics knowledge etc. need to be acquired.

For the truck OEM to succeed in the big change, they need to prioritize the automation steps based on the variations in impact for the stakeholders to fit the impact of the organization, cost and scope of the technology. The automation investment needs to answer how well the solution can create values to all stakeholders. Set out the realistic objectives, time and cost scales for the automation projects. Simulate the automated systems and processes before implementing the actual to foresee the potential bottlenecks. Finally, assign clear responsibilities, create open communication schemes and create early wins to contribute a successful change project.

10 CONCLUSIONS

In this thesis, the automation developments in the three chosen industries which are dairy industry, healthcare industry and warehouse industry are well analyzed. Industry maturity, automated applications, benefits and challenges were discussed to gain a better understanding of automation. Level of automation framework was created for the workshop environment. Based on learning's from three industries, actions and applications of implementing automated systems for the maintenance workshops were advised. Based on the change diamond model, four perspectives including right investment, real actions, right skills, and solid methods are analyzed in the workshop environment to improve the success of the change project.

The main research contribution of this thesis is developing a framework to define the levels of automated maintenance workshop, describing how the workshop will develop through the levels in future and describing how the workshop can succeed the change project. This thesis can serve as a guide for workshops when taking the decision to improve automation level in the workshop in order to meet the future market development and trends.

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APPENDIX

Appendix A- Interview guidelines for Workshop visit

This interview guide is for the directly involved actors in the workshop (Technician, Workshop manager). The goal is to obtain general information about the current operations and performance in the truck maintenance workshop. Workshop visit was carried out on 03/11/2016. The interview guidelines include three parts; Interview with the workshop manager, interview with technician and observing how technicians carry out operations in the workshop and workshop working phases.

Due to the time limitation, interview questions were categorized as high priority, medium priority and low priority. The high priority questions were asked first to acquire enough useful information within the time frame.

Interview guidelines for Technician

(1) High priority

Did you get trained after joining the automotive industry? How is the learning atmosphere here?

What do you like about your job?

Which maintenance operations do you think are complicated and feel technologically difficult to implement? And which are more repetitive operations? From your perspective, which kind of job do you like most? (The challenging job or the repetitive job)

Have you ever faced any challenges or difficulties in maintaining the truck and how did you deal with it? (When you are facing some difficulties, will you ask someone else for help? And who will you turn to?)

Do you think there is anything that can be improved in the workshop such as maintenance processes, the single operations, the tools? What future technologies are you looking at to be implemented in the workshop?

From your perspective, when there is a new technology to be used in the workshop (for instance a new tool or a new working process), how will this influence your work and how will you participate in implementing the new technology?

Are there any automated tools or automated operations? How do you like the automated tools and operations? How much of the maintenance work on the truck is automated?

Do you think there are more tools or operations that can be automated to assist you do a better work? (The logistics part, the specific truck maintenance operations part, the information process part, etc.)

Do you want to get some automated tools like collaborative robots to assist you in finishing your work?

--Yes: what benefits will you get from this?

--No: what is your concern about this?

(2) Medium Priority

Which tools do you always work with in your daily work in maintaining the truck?

How do you evaluate the time and energy spent on fetching, handling and returning tools?

(3) Low Priority

How long have you worked as a technician?

What is your role as a technician?

Where/How did you get your education as a technician?

Can you describe how maintenance is carried out to change? (Engine oil, Filter, broken parts Etc.)

Are you satisfied with your daily work?

What do you think about your workplace, how are you satisfied with it?

Interview guidelines for Workshop Manager

(1) High Priority

Who are the actors involved in the workshop? (Technicians, logistics stuff, cleaner, etc.) How close do you work with them?

Do you have any KPIs to measure the workshop performance? And what are they?

What is your opinion about automation?

How do you evaluate the automation level in the current workshop?

What do you think can be automated in the workshop?

According to your working experience with the stakeholders, what do you think are their opinions about automation?

What future technologies are you looking at to implement in the workshop?

What challenges are you likely to expect from this new implementation of technology? (Facilities, labor, resources, etc.)

How will it affect the success of implementing automation?

How are you planning to solve these challenges?

What are the staffing implications and response to implement this new technology in the workshop (Training new staffs, laying off, etc?)

(2) Low Priority

How long have you worked as a workshop manager?

What is your role as a workshop manager?

What do you like most in your roles as a workshop manager? And what part do you feel is more challenging?

What do you think can be improved in the workshop? (Facilities, layout, operations, etc.)

Appendix B-Interview guide for Volvo Aftermarket and Maintenance Department

This interview was carried out with the **V**olvo Trucks Director of Technical Aftermarket, Director of service sales and the Director of service operations on 03/24/2016. The purpose of the interview was to gather different opinions about the automation in the workshop from Volvo Trucks aftermarket department perspective and understand how the dealers are managed

(1) Questions about the dealership management

How do you manage the dealers (Volvo truck center and private dealers)? What do you think are the differences between them?

When comparing with competitors such as Scania, what do you think are the differences regarding the dealership management? (Especially for the workshop support)

What KPIs are you using to measure the dealers (Especially for their workshop)?

How do you use the information generated by performance reviews to identify training needs for each dealer point?

What are the policies and actions that truck OEMs takes to strengthen workshop productivity and efficiency? (E.g. the information processing system, service planning tool, etc)

How do you manage the dealer point manpower? What influences do you have on the workshop staff such as workshop manager, client receiver, foreman, technician, spare parts staff, etc?

How do you help to build the good dialogue between the customer and the workshop?

To what degree do you think the truck OEM can have influences on dealers' vehicle maintenance workshop? (The facility and operations)

How do you support business development within each dealer point in regarding to the workshop?

(2) Questions about automation in the future vehicle maintenance workshop

What's your opinion about automated workshop/maintenance?

What is the current automation level in the maintenance workshop in general?

Do you think it is a more sustainable way to use automated systems or traditional manual operations are still better?

What future technologies are you looking at to be implemented in the maintenance workshop to improve on customer satisfaction?

What do you think will influence the automation progress in relation to maintenance workshop? (E.g. the human factor, facility integration, management process, etc)

How do you think the automated workshop will influence the current truck OEM maintenance strategy?

What kind of supports will you suggest that in the future, the truck OEM can give when the dealers plan to implement automation in their workshop? (The technical support, financial support, facility support, etc.)

Appendix C- Interview guideline with Volvo GTT employee B

The interview was conducted on 04/14/2016. The goal of this interview was to understand what actions the truck OEM takes to maximize truck uptime and also to understand the interpretation of automation in EMATS project and the desired automated progress phases.

Questions:

How does the current workflow in the workshop look like?

What are the KPIs you use to measure the workshop performance (private and VTC)

How do you define automation in the EMATS project?

What is the level of automation in the workshop on a scale of 1 to 10 and what is the desired state?

What automation technologies and applications are used in the workshop today and what are the benefits of these technologies.

Which parameters do you take into account when making decisions to convert the truck servicing into (semi-automatic or full) automation

What are the incentives factors that will drive truck OEM to adopt automation technologies?

To implement automation in the workshop should be step by step action. Can you picture each step of the change process?

What future automation technologies are applicable to the truck OEM maintenance workshop and industries within similar segment?

Which activities or task are most suitable to consider for automation in the workshop

What are the predicted future challenges if the truck OEM decides to automate the workshop (Economic barriers, cultural and Organizational barriers), and what are the hindering factors behind them?

Do you think it is economically justifiable to implement automation in the workshop?

Which stakeholders do you think will be involved in changing the workshop to semi or fully automated process? Which part of the stakeholders do you think will be hard to get them involved in the change process? What are the suggestions that you will give to make the change process successful?

Appendix D- Interview guide for Director of Sales in ARHO AB

The interview was conducted on 05/04/2016. The goal of this interview was to understand the technical perspectives of automated tools and process such as the function, human role in automation and the potential challenges.

Questions:

How do you categorize and measure the different levels of automation? Or can it be measured (based on which theory or definition)?

What consequences can be due to the changes in levels of automation?

What are some of the safety measures to deal with the automated equipment? Thus, if it fails, does it go berserk or it fails and silently shut down.

How is the automated equipment and human interaction implemented? Meaning does the human needs to operate the equipment from a distance? What is the minimum distance to operate from?

Monitor, confirm, verify, of these 3 which will be the human's main task?

Can the automated equipment be reconfigured to deal with other scenarios like working with different kinds of trucks? How will that be done?

Based on the work carried out by the automated equipment, on a scale of 1 to 5 with 5 being full automation, how will you classify their activity?

Practically do you believe there could be an automated system that does not require human intervention?

What are the major drivers for your customers to implement the automotive equipment? (E.g. reduce error rate, reduce labor cost, improve working condition, reduce waste, etc.)

When the customer has a need for automation, what is the next step for you to work with them to come up with a good solution?

Form your experience, what are your customers most concerns about the automated tools, processes, equipment?

What challenges are your customers likely to face in using the automated equipment? (The relevant knowledge to use the equipment or the collaboration with existing systems etc.)

What do you think is the desired state of automation? And what are the different levels between current status and the desired state?