LEAN AUTOMATION:
COMBINING LEAN WITH INDUSTRIAL ROBOTICS IN REAL EXAMPLES

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ABSTRACT

The purpose of this report is to analyze whether we can have a better automation manufacturing using lean solutions. First, this report is started with the background and problem description. After that the research questions are mentioned and the delimitations and expected results are discussed.

The theoretical part of this thesis is describing the research methodology and the literatures review of automation and related challenges. A theoretical review of lean and lean automation concepts has been conducted.

In the empirical part of the thesis some challenges of automation are listed based on interviews and case studies. Some observed lean automation solutions are discussed and evaluated. In the discussion and analysis part, a concept of lean automation is presented based on the results from the case studies and interviews.

Finally, in the conclusion chapter, the research questions are answered and future research is proposed for further studies.

Keywords: Lean, Automation, Robot, Lean Automation
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INTRODUCTION

This chapter aims to generate an apprehension of why the research project has been executed and the importance of it. The chapter is structured with a traditional background and problem description that gives the reader an understanding of the topic of this thesis. Furthermore the chapter describes the purpose of the project and formulates the research questions. Finally, the boundaries, the researcher’s role and the expected outcome are discussed.

1.1 BACKGROUND

Since researches indicate that the next generation of production systems could be a combination of lean production and robotic production. Still, obstacles may exist which prevent us to implement the optimal production system using robots. In this manner, in cases of automation, maybe the best solution is correlated with lean production? Besides, the cost of applying robots is often a huge barrier for many companies and with lean concepts, possibly the expenditures and advantages of robotics production can be justified?

1.2 PROBLEM DESCRIPTION

In the following subject there are many challenges to be discussed, however in this researcher’s viewpoint there exist two kinds of
problem. The first problem is what the current challenges and obstacles of Automation indicate - what may be encountered when a firm wants to invest in an automation system; the second problem is about how we can combine Lean with Automation? Supposing that we can combine Lean with Automation then we may make challenges of Automation more competitive and handful. By the new concept an automated cell may be lean as well.

1.3 PURPOSE

The purpose of this study is to declare and develop a general concept for Lean Automation to be employed for further studying, as though the subject of Lean Automation is a new term whom Mälardalens University has worked on it since a few years ago and there are quite a few literatures about it. This concept should be clarified more to be understood by researchers and companies if they want to implement it. Another purpose of this study is to investigate the ways of aligning Lean with Automation. This means that if a robotic cell is engaged, which perspectives of Automation and Lean could be used and how they could complement each other's side? The last aim of this research is to investigate a system of Real "Lean Automation" cell which is a combination of Robot Production and Lean Production concepts.

1.4 RESEARCH QUESTIONS

The questions for this study are:
RQ-1 How we could improve the automated cell based on the lean concepts?
RQ-2 How we could minimize the non-added value activities?
1.5 DELIMITATIONS

This report is related to a project for Lean Automation run by Mälardalen University and other companies. This project is delineated in the area of MITC and XPRES lab which is developed in Mälardalen University. The research is conducted in an interactive environment where study is carried out at both university and workplace interchangeably. As a participant of XPRES lab the researcher's role is to create knowledge that is relevant both for academia and industry with an emphasis on the academic relevance. As if this is a new concept, there are not many literatures about it, wherefore one of the delimitations is the range of articles and books. The other boundary is about the experts, those in companies must be recognized about the meanings and conceptual understanding of lean and also automation, and much harder, the lean automation concept. The range of companies is very limited as not all companies have invested in robotic cells. Moreover, implementing lean automation is also limited as there are scarcities in having companies that want to implement a lean automation cell.

1.6 EXPECTED RESULTS

One of the expected results is having a clear concept of “Lean Automation” which can be globalized and be accepted by the others. Furthermore, development of automation processes with lean is what many robotic suppliers and users need in nowadays market. At last, having a cost-effective support method for Robotic production system, top in the wish list for all manufacturers, is another outcome of this study.
RESEARCH METHODOLOGY

This chapter intends to highlight the researchers' scientific views. Furthermore, the chapter aims to present and justify the choice of research through a discussion that includes strategies for data collection. Finally, the chapter will present the methodology for analyzing methods and validity related to these methods.

2.1 METHOD

The method for this research is “Library and Field study research” (Saunders et al., 2009) which starts with the investigating of existing literatures about it and then interviewing the group members of Lean automation project in the department of IDT. At last some industrial and educational examples are reviewed to check the circumstances of real world.

2.2 RESEARCH APPROACH

The research approach is based on the concept of Research Onion (Saunders et al., 2009). As shown below, this concept has some layers which being described as follows then the options which selected are introduced based on the description:
2.2.1 PHILOSOPHIES

The research philosophy being adopted and presented in this thesis contains important assumptions about the way in which the world is viewed. The adapted philosophy will be influenced by practical considerations. However, the main influence is likely to be a particular view of the relationship between knowledge and the process by which it is developed. These assumptions will underpin research strategy and the methods we choose as a part of that strategy (Johnson and Clark, 2006). In this part some philosophies are mentioned and investigated based on the concept of Research Onion (Saunders et al., 2009).

Pragmatism (Guba and Lincoln, 1994, Tashakkori and Teddlie, 2003) argues that the most important determinant is the research question. Moreover, if the research question does not suggest unambiguously that either a positivist or interpretivist philosophy is adopted, the pragmatist’s view confirms that it is perfectly possible to work with variations in epistemology, ontology and axiology.
Ontology (Saunders et al., 2009) is concerned with nature of reality which is related to questions of the assumptions about the way the world operates and the commitment held to particular views. The first aspect of ontology is objectivism (Smircich, 1983) which characterizes the position that social entities exist in reality external to social actors concerned with their existence. The second aspect, subjectivism (Remenyi et al., 1998), holds that social occurrences are created from the comprehensions, thus consequent actions of those social actors concerned with their existence.

Epistemology (Bhaskar, 1989) concerns in what constitutes acceptable knowledge in a field of study. The researcher or the resources is likely to be more related to the position of the natural scientist. The most important distinction is the researchers’ views of what they consider important in the study.

If the research reflects the philosophy of positivism (Remenyi et al., 1998) then probably the philosophical stance of the natural scientist will be adopted. Preferably, researcher wants to work with an observable social reality and the end product of such research can be law-like generalizations which are similar to those produced by the physical and natural scientists.

Realism (Bhaskar, 1989) is a branch of epistemology which is identical to positivism in that it ascertains a scientific approach to the development of knowledge. Realism is another philosophical position which is identified by scientific enquiry, constructs the collection of data and the apprehension of those data. The attribute of realism is that what the senses show us as reality is the truth: that objects have an independent existence of the human mind. The philosophy of realism is that there is a reality which is completely independent of the human mind. In this sense, realism is opposed to idealism which is the theory that only the human intelligence and its contents exist (Saunders et al., 2009).

Interpretivism advocates that it is necessary for the researcher to understand differences between humans in our role as social actors. This gives priority to the distinction between conducting research among people rather than objects such as trucks and computers (Saunders et al., 2009).
In this study the philosophy of Positivism is selected because here some data were collected and the endeavor is for realizing these data in the concept of Lean Automation. By this meaning, the philosophy of Realism can also be selected, however as this study is related to engineering perspective, Positivism is more conformable to this viewpoint.

2.2.2 RESEARCH PARADIGMS

Paradigm defines a way of examining social phenomena from which particular understandings of these phenomena can be gained and explanations attempted.

![Research Paradigms](image)

Figure 2. The Research Paradigms. (Saunders et al., 2009)

In the bottom right corner of the quadrant is the functionalist paradigm which is located on the objectivist and regulatory dimensions. Objectivism is the ontological position we are likely to adopt if we are operating with this paradigm. It will probably be more concerned with a diagnostic explanation of why a particular organizational problem is arising and promoting a set of recommendations within the current structure of the organization’s current management.

Contained in the bottom left corner of the quadrant is the interpretive paradigm. The philosophical position to which this refers is the way humans attempt to make sense of the world around him. The concern would be to understand the fundamental meanings attached to
organizational life. Far from emphasizing rationality, the principal concern may be discovering irrationalities.

In the top left corner the radical humanist paradigm is located within the subjectivist and radical change dimensions. The radical change dimension adopts a critical perspective on organizational life. As such, working within this paradigm we would be concerned with changing the status quo.

Finally, in the top right corner of the quadrant is the radical structuralist paradigm. The concern here would be to approach our research with a view to achieving fundamental change based upon an analysis of such organizational phenomena as power relationships and patterns of conflict. The radical structuralist paradigm is involved with structural patterns with work organizations such as hierarchies and reporting relationships and the extent to which these may produce dysfunctionalities (Burrell and Morgan, 1982).

2.2.3 RESEARCH APPROACHES

Deduction is one of the approaches which means testing theory; Robson (Robson, 2002) lists five sequential stages through which deductive research will progress:

1- A testable proposition about the relationship between two or more concepts or variables is created from the theory;

2- Expressing exactly how the concepts or variables are to be measured which propose a relationship between two specific concepts or variables;

3- Testing this operational hypothesis;

4- Examining the specific outcome of the inquiry; it will either tend to confirm the theory or indicate the need for its modification;

5- Modifying the theory based on the findings, if it is necessary (Robson, 2002).

Important characteristic of deduction approach controls to allow the testing of hypotheses, structured methodology, operationalized, reductionism, and generalization.
On the other hand, induction means building theory, the purpose here would be to get a feel of what was going on, so as to understand better the nature of the problem. The task then would be to make sense of the interview data which had been collected by analyzing those data. The result of this analysis would be the formulation of a theory. Research using an inductive approach is likely to be specifically connected with the context in which such events were occurring. Therefore, the study of a small sample of subjects might be more appropriate than a large number as with the deductive approach (Easterby-Smith et al., 2008).

In this study the approach of Deduction is chosen as the Lean Automation concepts needs to be more clarified and established.

2.2.4 RESEARCH PURPOSE

The categorization of research purpose most often utilized in the research methods’ literature is the threefold one of exploratory, descriptive and explanatory.

An exploratory study is a valuable means of apperceiving ‘what is happening; to seek new insights; to ask questions and to assess phenomena in a new light (Robson, 2002)’. It is particularly useful for clarification of realizing a problem, such as if we are unsure of the precise nature of the problem. There are three principal ways of conducting exploratory research (Yin, 2003):

• A search of the literature;
• Interviewing ‘experts’ in the subject;
• Conducting focus group interviews.

The object of descriptive research is ‘to portray an accurate profile of persons, events or situations’ (Robson, 2002). This may be an extension of a piece of exploratory research or, more often, a piece of explanatory research. It is essential to have a crystal clear picture of the phenomena on which we wish to gather data prior to the collection of the data.

Studies that organize causal relationships between variables may be labeled explanatory research. The emphasis here is about studying a situation or a problem in order to explain the relationships between variables (Saunders et al., 2009).
In this study the exploratory purpose is chosen to assess the Lean Automation concept in a new and practical way.

2.2.5 RESEARCH STRATEGIES

The choice of research strategy will be guided by research questions and objectives, the extent of existing knowledge, the amount of time and other available resources, as well as our own philosophical underpinnings.

Experiment (Hakim, 2000) is a form of research that owes much to the natural sciences, although it features strongly in much social science research, particularly psychology. The intention of an experiment is to study causal links; whether a change in one independent variable produces a change in another dependent variable. Experiments therefore tend to be used in exploratory and explanatory research to answer ‘how’ and ‘why’ questions.

The survey strategy (Saunders et al., 2009) is usually associated with the deductive approach. It is a popular and common strategy in engineering research and is most frequently used to answer who, what, where, how much and how many questions. It is therefore conducive to be used for exploratory and descriptive research. Surveys are popular as they allow the collection of a large amount of data from a sizeable population in a highly economical way. Often obtained by using a questionnaire administered to a sample, these data are standardized, allowing easy comparison. The survey strategy allows collecting quantitative data which can be analyzed quantitatively using descriptive and inferential statistics. In addition, the data collected using a survey strategy can be used to suggest possible reasons for particular relationships between variables and to produce models of these relationships. The data collected by the survey strategy is unlikely to be as wide-ranging as those collected by other research strategies. The questionnaire, however, is not the only data collection technique that belongs to the survey strategy. Structured observation, of the type most frequently, associated with organization and methods (O&M) research, and structured interviews, where standardized questions are asked of all interviewees, also often fall into this strategy (Saunders et al., 2009).
Robson defines case study as ‘a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context, using multiple sources of evidence (Robson, 2002)’. Yin also highlights the importance of context, adding that, within a case study, the boundaries between the phenomenon being studied and the context within which it is being studied are not clearly evident. This is the complete opposite of the experimental strategy, it also differs from the survey strategy where, although the research is undertaken in context, the ability to explore and understand this context is limited by the number of variables for which data can be collected. For this reason the case study strategy is most often used in explanatory and exploratory research. The data collection techniques employed may be diverse and are likely to be used in combination. They may include, for example, interviews, observation, documentary analysis and questionnaires. Yin distinguishes between four case study strategies based upon two discrete dimensions (Yin, 2003):

- Single case v. multiple cases;
- Holistic case v. embedded case.

A single case is often used where it delineates a critical case or, alternatively, a unique case. Conversely, a single case may be opted because it is typical or because it supplies us with a possibility to observe and analyze a phenomenon that few have considered before. A case study strategy can also incorporate multiple cases, that is, more than one case. The rationale for using multiple cases brings to a focus upon the need to establish whether the findings of the first case occur in other cases and, as an outcome, the need to generalize from these findings. For this reason Yin argues that multiple case studies may be preferable to a single case study and that, where we choose to use a single case study, we will need to have a strong justification for this choice. Yin’s second dimension, holistic v. embedded, refers to the unit of analysis. A case study strategy can be a very worthwhile way of exploring existing theory (Yin, 2003).

Lewin first used the term action research in 1946. It has been interpreted subsequently by management researchers in a variety of ways, but there are four common themes within the literature. The first focuses upon and emphasizes the purpose of the research: research in
action rather than research about action, the second relates to the involvement of practitioners in the research and, in particular, a collaborative democratic partnership between practitioners and researchers, other practitioners or internal or external consultants. The third theme emphasizes the iterative nature of the process of diagnosing, planning, taking action and evaluating, the final theme suggests that action research should have implications beyond the immediate project; in other words, it must be clear that the results could inform other contexts (Coghlan and Brannick, 2005).

A grounded theory strategy is, according to Goulding, particularly helpful for research to predict and explain behavior, the emphasis being upon developing and building theory, in grounded theory, data collection starts without the formation of an initial theoretical framework. Theory is derived from the data generated by a series of observations. These data lead to the generation of predictions which are then tested in further observations that may confirm, or otherwise, the predictions (Gouldning, 2002). Constant reference to the data to develop and test theory leads Collis and Hussey to call grounded theory an inductive/deductive approach, theory being grounded in such continual reference to the data (Collis and Hussey, 2003).

Ethnography is rooted firmly in the inductive approach. It emanates from the field of anthropology. The purpose is to describe and explain the social world the research subjects inhabit in the way in which they would describe and explain it. This is obviously a research strategy that is very time-consuming (Saunders et al., 2009).

Archival research makes use of administrative records and documents as the principal source of data. Although the term archival has historical connotations, it can refer to recent as well as historical documents (Bryman, 1989).

Case study and Survey strategy are used in this study, first some questionnaires and surveys are conducted with the Lean Automation group in IDT department and then for real example some cases are reviewed based on the findings from interviews and literatures.
2.2.6 CHOICES

The terms quantitative and qualitative are used widely in business and management research to differentiate both data collection techniques and data analysis procedures. One way of distinguishing between the two is the focus on numeric (numbers) or non-numeric (words) data (Saunders et al., 2009).

Quantitative is used as a synonym for any data collection technique (such as a questionnaire) or data analysis procedure (such as graphs or statistics) that generates or uses numerical data. In contrast, qualitative is used as a synonym for any data collection technique (such as an interview) or data analysis procedure (such as categorizing data) that generates or uses non-numerical data (Saunders et al., 2009).

In choosing methods the researcher will therefore either use a single data collection technique and corresponding analysis procedures (mono method) or use more than one data collection technique and analysis procedures to answer research question (multiple methods). If we choose to use a mono method we will combine either a single quantitative data collection technique, such as questionnaires, with quantitative data analysis procedures; or a single qualitative data collection technique, such as in-depth interviews, with qualitative data analysis procedures (Tashakkori and Teddlie, 2003).

In contrast, if we choose to combine data collection techniques and procedures using some form of multiple methods design, there are four different possibilities. The term multi-method refers to those combinations where more than one data collection technique is used with associated analysis techniques, but this is restricted within either a quantitative or qualitative world view (Tashakkori and Teddlie, 2003). Thus we might choose to collect quantitative data using, for example, both questionnaires and structured observation are analyzing these data using statistical (quantitative) procedures, a multi-method quantitative study. Alternatively, we might choose to collect qualitative data using, for example, in-depth interviews and diary accounts and analyze these data using non-numerical (qualitative) procedures, a multi-method qualitative study. Therefore, if we adopted multi-methods we would not mix quantitative and qualitative techniques and procedures. Mixed methods approach is the general term for when both quantitative and qualitative data collection
techniques and analysis procedures are used in a research design. It is subdivided into two types. Mixed method research applies quantitative and qualitative data collection techniques and analysis procedures either parallel or sequential but does not combine them. This means that, although mixed method research uses both quantitative and qualitative world views at the research methods stage, quantitative data are analyzed quantitatively and qualitative data are analyzed qualitatively. In addition, often either quantitative or qualitative techniques is predominate procedure. In contrast, mixed-model research combines quantitative and qualitative data collection techniques and analysis procedures as well as combining quantitative and qualitative approaches at other phases of the research such as research question generation (Bryman, 2006).

This study used mixed-model method which contains both qualitative and quantitative data collection.

2.2.7 TIME HORIZONS

The ‘snapshot’ time horizon is what here being called cross-sectional while the ‘diary’ perspective is called longitudinal (Saunders et al., 2009). Cross-sectional studies often employ the survey strategy; however, they may also use qualitative methods. Many case studies are based on interviews conducted over a short period of time. The main competency of longitudinal research is the capability that it has to study change and development (Easterby-Smith et al., 2008, Robson, 2002).

The study used cross-sectional time horizon, as it is a report for Master degree thesis.

2.3 RESEARCH PROCESS

In this part, the overall process of doing this research has been presented. As shown below this research has 5 main phases.
Figure 3. The Research Process.

2.4 DATA COLLECTION

2.4.1 OBSERVATION

If the research questions and objectives are concerned with what people do, then an obvious way in which to discover this, is to watch them do it. This is generally what observation involves: the systematic observation, recording, description, analysis and interpretation of people’s behavior. Participant observation is qualitative and deduces from the work of social anthropology early in the twentieth century. Its emphasis is on actualizing the meanings that people attach to their actions. By contrast, structured observation is quantitative and is more bore on the frequency of those actions (Saunders et al., 2009).
Primary observations are those where could be noted what happened or what was said at the time, keeping a diary is a good way of doing this. Secondary observations are statements by observers of what happened or was said. This necessarily involves those observers’ interpretations. Experiential data are those data which is based on perceptions and feelings in the process of researching and the concern would be in quantifying behavior. As such, structured observation may form only a part of the data collection approach because its function is to tell how often things happen rather than why they happen (Delbridge and Kirkpatrick, 1994).

2.4.2 INTERVIEW

The main focus in interviewing is semi-structured, in-depth and group interviews and structured interviews. An interview is a purposeful discussion between two or more people (Kahn and Cannell, 1957). The use of interviews can help the researcher to gather valid and reliable data that are relevant to research questions and objectives.

In reality, the research interview is a general term for several types of interviews. Interviews may be formalized with using standardized questions for each respondent, or they may be unstructured and informal conversations. In between there are intermediate positions. Structured interviews use questionnaires based on a predetermined and ‘standardized’ or identical set of questions and can be referred as interviewer-administered questionnaires. By comparison, semi-structured and in-depth interviews are ‘non-standardized’, these are often referred to as ‘qualitative research interviews’. In semi-structured interviews the researcher will have a list of themes and questions to be covered, although these may vary from interview to interview. Unstructured interviews are informal which would be used to explore in depth a general area in which are interested, and there is no predetermined list of questions to work through in this situation. The interviewee has the opportunity to talk freely about events, behavior and beliefs in relation to the topic area (King, 2004).

Standardized interviews are normally used to gather data, which will then be the subject of quantitative analysis, for example as part of a survey strategy. Non-standardized interviews are used to gather data, which are normally analyzed qualitatively (Saunders et al., 2009).
In an exploratory study, in-depth interviews can be very helpful to ‘find out what is happening and to seek new insights’ (Robson, 2002). Semi-structured interviews may also be used in relation to an exploratory study. In descriptive studies, structured interviews can be used to identify general patterns. In an explanatory study, semi-structured interviews may be used in order to understand the relationships between variables, such as those revealed from a descriptive study. Structured interviews may also be used in relation to an explanatory study, in a statistical sense (Saunders et al., 2009).

Group interview has been used as a general term to describe all non-standardized interviews conducted with two or more people. In contrast, the term focus group is used here by the researcher to refer to those group interviews where the topic is defined clearly and precisely and there is a focus on enabling and recording interactive discussion between participants. Moreover, focus group, sometimes called a ‘focus group interview’ (Carson et al., 2001), is a group interview that focuses clearly upon a particular issue, product, service or topic and encompasses the need for interactive discussion amongst participants.

2.5 ANALYSIS OF DATA

Qualitative data implied to all non-numeric data or data that have not been quantified and can be an aftereffect of all research strategies. Qualitative data analysis procedures assist the researcher to develop theory from data. They include both deductive and inductive approaches and range from the simple categorization of responses to processes for identifying relationships between categories.

Many authors draw a distinction between qualitative and quantitative research, while ‘number depends on meaning (Dey, 1993)’, it is not always the case that the meaning is dependent on number. Dey points out that ‘the more ambiguous and elastic our concepts, the less possible it is to quantify our data in a meaningful way (Dey, 1993)’. Qualitative data are associated with such concepts and are characterized by their richness and fullness based on the opportunity to explore a subject in as real a manner as is possible (Robson, 2002). The nature of the qualitative data collected has implications for its analysis.
During analysis, the non-standardized and complex nature of the data will probably need to be summarized, categorized or restructured as a narrative to support meaningful analysis; otherwise the most that may result may be an impressionistic view of what they mean. While it may be possible to make some use of diagrams and statistics at this stage, such as the frequency of occurrence of certain categories of data, the way for analyzing the qualitative data is through the creation of a conceptual framework. Open questions could be used to collect qualitative data from respondents, these being recorded in writing by either the respondent or an interviewer (Saunders et al., 2009).

Data analysis and the development and verification of propositions are very much an interrelated and interactive set of processes. Analysis occurs during the collection of data as well as after it (Kvale, 1996). This analysis helps to shape the direction of data collection.

Where a research project uses a deductive approach, it uses existing theory to shape the adoptive approach to the qualitative research process and to aspects of data analysis; on the other hand, an inductive research project will seek to build up a theory that is adequately grounded in the data. A descriptive framework will rely more on the researcher's prior experience and expectations of occurrence, although it is of course possible to develop an explanatory framework based on a mixture of theory and researcher own expectations (Yin, 2003).

There is no standardized procedure for analyzing such data. Despite this, it is still possible to group data into three main types of processes (Saunders et al., 2009):

• Summarizing (condensation) of meanings;
• Categorization (grouping) of meanings;
• Structuring (ordering) of meanings using narrative.

Some procedures for analyzing qualitative data may be highly structured, whereas others adopt a much lower level of structure. Related to this, some approaches to analyzing qualitative data may be highly formalized such as those associated with categorization, whereas others, such as those associated with structuring meanings through narrative; rely much more on the researcher's interpretation. A further way of differentiating between procedures is whether they are used deductively or inductively. Some procedures can be used
Yin’s preference for data collection as a means of analyzing data emphasizes a number of specific analytical procedures. Pattern matching involves predicting a pattern of outcomes based on theoretical propositions to explain findings. Using this approach, the researcher will need to develop a conceptual or analytical framework, utilizing existing theory, and subsequently test the adequacy of the framework as a means to explain findings. If the pattern of data matches that which has been predicted through the conceptual framework an explanation will have been found, where possible threats to the validity of conclusions can be discounted. Another pattern matching procedure involves an attempt to build an explanation while collecting data and analyzing them, rather than testing a predicted explanation. This procedure, which is labeled explanation building, appears to be similar to grounded theory and analytic induction. However, unlike these, explanation building is designed to test a theoretical proposition, albeit in an iterative manner, rather than to generate theory inductively (Yin, 2003).

On the other hand, a number of inductively based analytical procedures to analyze qualitative data are:

• Data display and analysis;
• Template analysis;
• Analytic induction;
• Grounded theory;
• Discourse analysis;
• Narrative analysis (Saunders et al., 2009).

In this study most of the time qualitative analyses are applicable.
Determining the quality of the conducted research is an important but difficult task, especially when, as in this research, the results are based on qualitative data. The two most commonly used terms when judging the quality of research are validity and reliability.

Validity is concerned with whether the findings are really about what they appear to be about, to ensure that research results are reliable and useful, validation is of utmost importance (Robson, 2002). This research is studying about complex systems, furthermore, Lean Automation could consist of many parts and relationships that can make the results difficult to judge. To secure the validity of this research, there has been focus on describing the view of the system. Parts and relationships were continuously being assessed, and when it is needed the results and methods used were revised. In fact the choice of Onion Research Method is the reason for obtaining validity for this research.

Reliability refers to the extent to which the data collection techniques or analysis procedures will yield consistent findings (Easterby-Smith et al., 2008). A lot of discussion has been made for the reliability of this research as this research is based on the researcher's viewpoint and interpretations; however it is tried to concentrate how data and information is gathered, analyzed and interpreted. During the research, the reliability aspect has been addressed by carefully documenting every step in the empirical studies. This was done by in full describing the limitations, pre-requisites and given circumstances during the studies, as well as all the steps in the process of collecting and analyzing data. This is discussed by Yin, who states that the general way of approaching the reliability problem in case studies is to make as many operational steps as possible and to conduct research as if "someone were always looking over your shoulder" (Yin, 2003).
FRAME OF REFERENCE

This chapter introduces the theoretical framework applied in the research conducted in the field of Lean Automation. Three sections separate the chapter: Automation, Automation Challenges, Lean and Lean Automation.

3.1 AUTOMATION

The advent of automation in manufacturing companies resulted from technological evolution and economic reasons. Cheap and more reliable equipment became available that could work 24h a day (Ribeiro and Barata, 2011). Automation is often regarded as the main solution to improve efficiency in manufacturing (Winroth et al., 2006) and potentially is to ameliorate the competitiveness of manufacturing companies (Säfsten et al., 2007).

Automation is also regarded as either an ‘on or off’-decision, i.e. the system is either considered to be entirely manual or fully automated (Winroth et al., 2006). As well as, it is affiliated to acquire greater production throughput, high levels of productivity and greater value adding (Orr, 1997). On the other hand, the pressure to reduce the price per unit in the production site imposed the need for an increased pace in production that could only be achieved by automating some of the process tasks (Ribeiro and Barata, 2011). There really can be no argument that there are some things that must be produced by somewhat automated processes, for example, items with very tight
tolerances, small electronic components, parts that are much too heavy to handle manually, or medical products that just cannot be touched by human hands (Harris and Harris, 2008). Mainly, the reasons for automating these tasks are ergonomic, as examples maybe the parts are heavy or awkward to manipulate (Kochan, 1998).

A number of factors are important to consider when designing competitive production systems. These include changes in: customization, integrated information systems, rapid changeability, robustness, level of automation, and flexibility in terms of changeovers, production volume, and product variants. For SMEs, automation could be a prerequisite in order to survive in a new market that requires high flexibility, intelligent manufacturing systems and robots. For deciding which type of production equipment is appropriate we can use production volume and product lifetime as key-characteristics. The product lifetime is vital since the shorter the product lifetime, the greater is the need for a system which can be reconfigured for new products or product variants. In the case when both the product lifetime and the production volume is uncertain, the production system have to be reconfigurable both in the sense of temporarily changings and capacity in order to re-use equipment between product types (Hedelind et al., 2008a).

Companies seeking to obtain a competitive advantage from automation should adopt encompassing worker involvement programs; acquaint the automation of processes gradually and incrementally, whilst increasing the flow of ideas across work boundaries (Orr, 1997). Automation has been and still is the key driver of the transformation of production, from its initiation as a modern industrial revolution to the present and the future (Jovane et al., 2003).

One of the driving forces for using automation within industry is reduction of cost. Within the automotive industry there is a noticeable difference between companies that reside in countries where there is a high labor cost and those in countries with a lower labor cost (Hedelind and Jackson, 2008b). Industries represent technological difficulties for automation and consequently make investment in automation for these industries unprofitable. Clearly, in these manufacturing environments, automation is considered a long-term investment (Orr, 1997). However, robot automation investments are in many cases, regarded as too expensive and too technically advanced, especially within small and
medium sized enterprises. Ever since the first industrial robots were launched to help, mainly in the automotive industry during the early 1960s, the robot has been used to replace humans in workstations unsuitable for humans due to, for example, heavy lifting, monotonous movements, or being in hazardous environments (Jackson et al., 2011).

In this regard the flexible capacities of automated manufacturing systems were considered to be of major strategic importance. Companies now use automation to shorten the time taken for product conception and design as well as introducing new products at full-scale production volumes as quickly as possible. Other benefits typically experienced included cost reductions and the ability to produce larger volumes with existing manufacturing resources (Orr, 1997). Important success factors are considered to be in-house product development and good control of the manufacturing process, which includes tool manufacturing and planning methods. On the contrary, automation considered not to be suitable in the following cases: when ramping up manufacturing of new products, manufacturing of a large variety of products and variants in small volumes, very short product life cycle and requisites of product e.g. visual inspection (Winroth et al., 2006).

Long accepted by industry as a method for improving quality, performance and efficiency, robotics has for at least three decades been a key technology in manufacturing industries (Jackson et al., 2011). Thereafter, the most important factors when making decisions about automation are quality, work environment and rationalization. Quality is related to the customer perspective, work environment is connected with the internal perspective and rationalization can be described as the shareholder perspective (Lindström et al., 2006). Kaplan & Atkinson argued that automation offers improved quality and reliability for production processes, and permits much greater manufacturing flexibility by virtually eliminating set-up or changeover times. Goldhar & Jelinek (1986) suggested that by automating manufacturing processes, firms can compete on economies of scope that is, the ability to produce a wide variety of products in small batches efficiently. Hansen & Mowen (1997) quoted that automation could increase both the quantity and the timeliness of information (Hoque, 2000).

The best result of automation efforts is achieved if the decision is well supported at all levels concerned and that it is in line with the company’s overall objectives. The main key to success has been a
combination of good industrial engineering and business development (Winroth et al., 2006). When top management initiates automation, often with the aim to reduce manufacturing cost, the decision on automation tends to be the only concern, i.e. automation is the manufacturing strategy (Säfsten et al., 2007).

Automation strategies are used in terms of guidelines for implementation, rather than long-term plans for appropriate use of automation. Furthermore, automation strategies are often treated as human factors’ engineering problems, with focus on the human perspective of automation, such as task allocation. On the other hand, when automation is treated within Advanced Manufacturing Technology (AMT) literature, focus is mainly on the technical solutions without considering the human aspects. The level of automation (LoA) is a matter of task allocation between the human being and the equipment. The tasks are separated into two categories, information & control tasks and mechanical tasks. Some companies talk about semi-automation, which often is referred to the humans performing some tasks, such as changing work piece or pushing the button to start each operation (Winroth et al., 2006). It could be said automation is the technology by which a process or procedure is accomplished without human assistance. It is assigned using a program of commands integrated with a control system that executes the commands (Groover, 2000).

A common solution is to integrate manual and automated operations into semi-automated manufacturing systems. Automation can involve automation of activities both at facilities level and on support systems level, i.e. physical issues as well as decision and control tasks can be automated. The resulting function allocation may be described as the level of automation, ranging from entirely manual operations to full automation. Automation, or similarly level of technology, is mainly treated within the structural decision area involving issues related to the production process. An appropriate level of automation, ‘rightomation’, contributes positively in several respects, whereas the effects from both under and over automation can have negative effects on manufacturing performance (Säfsten et al., 2007).

When it is decided which parts of the process must be automated, the different levels of automation need to be considered. As different levels of automation need to be considered, discovering how many
functions the machine has to perform is also important. Does the automation have to be in one machine, or can it be spread over multiple machines? First, there are five different levels of automation that usually exist in industry. In the first level, everything is done manually. The operator loads the machine and starts the machine, and the machine cycles. Next the operator unloads the part and manually transfers it to the next production step. An example of this machine arrangement would be a manual press in which the operator loaded the press, pressed the part, unloaded the press, and took the part to the next station. The second level of automation is when the operator manually loads the machine, the machine automatically cycles, and the operator manually removes the part and takes it to the next station. In level three, the operator manually loads the part into the machine and the part automatically cycles. The part is automatically unloaded from the machine and the operator then moves the part. In level four automatically the part is loaded; it is automatically cycled, automatically unloaded, and then manually transferred to the next process. Finally, level five is entirely automatic. The machine is automatically loaded, cycled, and unloaded, and the part is transferred by automation (Harris and Harris, 2008).

There is a great divide between level three and level four automation. This divide represents MONEY in the form of maintenance costs, engineering costs, costs of the machine, etc. When making the jump to level four, cost often increases while flexibility can decrease. A level-three piece of equipment can and does run with about 95% uptime, while level four will likely run at 70-75% uptime, and level five equipment will likely run with uptime in the 65-70% range. There is a gradual decline in the amount of uptime that a machine will likely have as it becomes more automated. Changeover is also an area in which the change from level three to level four or five is impacted. In levels one, two, and three the changeover time is often much less than level four or five. A very desirable machine attribute is that it can changeover in one customer demand rate cycle (takt time). It tends to be much easier to accomplish this task within the first three levels of automation versus the latter two. The lower the changeover time, the fewer inventories the company needs to carry. It is not uncommon that when a level five machine is developed to eliminate the need for a production associate, the result is the need to hire a maintenance technician and an engineer to constantly tend to the machine. If the
company were to adopt a philosophy of employing many different simple single-purpose machines with the right levels of automation, they would likely have higher uptime, quicker changeovers, and more flexibility. It is important to remember that flexibility is a key ingredient to compete in a global market. When designing automation, it is important to keep this in mind, and not design machines solely based upon the future forecasted demand, because the forecast is not likely to be correct, and would probably change (Harris and Harris, 2008).

Another model for quantifying work functions was developed from an original LoA scale presented by Sheridan and ranges from LoA 1 (totally manual work) to LoA 10 (totally automated work) and was separated into the two basic classes of activities mechanized tasks and computerized tasks. Classifications of manufacturing systems include: Types of operations performed, number of workstations and system layout, level of automation, and part or product variety (Lindström et al., 2006).

Also Groover defines three possible levels of automation and three different types of workstations and layout of the stations. Learning curves are also mentioned as one aspect of the manufacturing system where the learning rate for various types of work is plotted. Three levels of automation and control are included the positioning system level, the machine tool level, and the manufacturing system level. Five possible levels of automation in a production plant can be identified. They are defined as Device level, Machine level, Cell or system level, Plant level, Enterprise level. The level 2 technologies include the individual controllers (e.g. programmable logic controllers, digital computer controllers, numerical control machines and industrial robots). The material handling equipment represents technologies at level 2, although some of the handling equipment is sophisticated as automated systems by themselves. Work environment is one of several characteristics that should be considered when selecting a robot application (Groover, 2000).

To summarize, Automation is often regarded as the main solution to improve efficiency and quality, productivity and reduction of cost. Automation permits much greater manufacturing flexibility, that is, products which have larger volumes or ergonomically awkward to manipulate can be produced in an easy way. Automation strategies are
often treated as human engineering problems therefore we should observe level of automation between the human being and the equipment. There are a lot of classifications of level of automation between researchers from five-levels of Harris’s classification to three-levels of Groover’s classification. Meanwhile, the best level which could be called "rightomation" may be Semi-Automation.

3.2 AUTOMATION CHALLENGES

Orr mentioned that the automation of mass production resulted in a lower capital outlay per unit produced by the line and a lower level of complexity than for other manufacturing approaches; nevertheless the automated equipment utilized in these lines tended to be customized, which resulted in relatively high equipment development costs; there was a risk with the introduction of new products onto an existing production line that much of the custom-automated manufacturing equipment needed to be substantially redesigned or totally replaced; customized automated equipment for mass production lines tended to have high "write-off" costs. This primarily resulted from the fact that equipment changeovers also needed to be automated (Orr, 1997).

Winroth said that the most important barriers for automation are “technical feasibility”, “education and qualification”, and “economic viability”. Other problems are: adapting the product to automation, the high number of different products and variants, problems to get the money back from the investment and the lack of competence at shop floor level. In the vaster view, he investigated that the automation strategy was not linked to the company’s manufacturing capabilities; the equipment was however too complicated and enormous problems occur in balancing the manual part of the line since the work content varies. Huge buffers, which increase the cost for work-in-process, are built up and have to be taken care of thus causing extra cost. In this case, the investment was not correlated to the long-term business and manufacturing strategies (Winroth et al., 2006, Winroth et al., 2007).

Frohm believes that automation includes more complex production systems and it is more difficult to automate machining and manufacturing due to the complexity of the product and the investment cost in more advanced automation. It was also confirmed that
automation of introduction and ramp-up of new product, production of occasional products, or making of products with short life cycle are not suitable for automation. Further, several companies acknowledge that too many products or variants in production can be a problem when automating. On the other hand, tasks that involve bad ergonomic conditions and great production volumes are not suitable to be conducted manually. However, as demands for more customized products increase and production systems become more and more complex, increased levels and extent of automation do not necessarily result in desired results. Many also affirm that too many products or variants in production and adapting the products for automated production can be a problem. In their research, some firms mentioned that they did not have sufficient time for planning the usage of automation, or for training the operators on the new investment, also they found that it may be difficult to get payback on investments in automation. Based on the delphi survey in their exploration, many of the companies admit that the competence of the operators was the primary problem when automating tasks, such as the production of occasional products or small batches or occasional products over a limited time on the grounds that automation of such products would not be cost-efficient and that the change-over time would be too high (Frohm et al., 2006).

Hedelind believes that lack of flexibility could be considered as a challenge to automation. The flexibility of a manufacturing system can be defined and determined by its sensitivity to change and can also be seen as a measurement for how many different product variants a certain manufacturing system can handle. A flexible system is a system that has been designed in accordance with the ability to deal with changes effectively and handle short-term changes quickly at a low cost within an existing production system. Lack of reconfigurability could be another challenge to the automation which defined as a system's ability to adapt rapidly in response to changing needs and opportunities. He found that some of the main barriers for small and medium sized companies in investment of industrial robotics are costs and the need for expertise and experience (Hedelind et al., 2008a).

In other Hedelind's research, some said that Automation and industrial robotics creates complexity. There are different issues that have been identified as reasons for the reluctance to use industrial robotics. One
of the major reasons is that the production management argues that the robotic working cells have low availability. The operators working on the factory floor are reluctant to use industrial robotics, based on that they do not feel comfortable working with technologies which they do not fully understand. Another problem was that the follow-up protocols used in the robotic working cells were not providing any real information on which types of problems were experienced. This type of follow-up of production is of course useless since no information about the reason for the stop is provided. A manual measurement of the stops showed that changeover was the most common reason for stoppage in the production process. The most common breakdowns reported was short stops where the robot was unable to pick up components, or dropped components (Hedelind and Jackson, 2008b).

Jackson believed that SMEs also feel discomfort in the fact that the company has to rely on outside experts in order to handle day-to-day activities, such as introducing new products or fixing small problems. Robotic automation is often regarded as a large investment which often is hard to justify beforehand. The reason for this is that many of the SMEs have a rather short planning horizon when it comes to product lifetimes. Many of the companies are sub-suppliers with small batch sizes, although the total order size can be rather large, it is often divided into several smaller orders, making it more difficult to predict the total number of articles that should be produced. Other challenges are: not invest in robot automation with the short life-cycles, product variety and costs to reprogram the system, reluctance in investing in advanced technology and the need to rely on external experts, costs related to the need of flexibility and reconfigurability. However, complex and complicated production equipment could give disturbances due to the rigid solutions and limited transparency into the automated process (Jackson et al., 2011).

Hedelind noted that there are many detailed and specific challenges that any firm may be encountered as such the small buffers between stations may cause any stops in one station and affected other stations as well. The times of changeover in the stations may be another challenge, the most wonderful notification that he made was a wide variety of automation solutions in the factory. This was because various suppliers and system integrators were utilized without any detailed technical specifications provided from the company. In the
same category, there was also low confidence in the ability of the operators employed by the company to resolve issues arising in the automated stations. The company may have external consultants doing the work of the industrial robots and that robot stations being felt like “black boxes” by operators. One of the things that can make trouble for the operator in an automatic manufacturing is that there exist several points of access to each station. These points include a robot controller that has some hard buttons, a teach pendant connected to robot (usually like a small computer with a touch-screen), a PLC-user interface, an external computer with machine vision software or similar external sensor interfaces, and some external computer for managing production orders. Additionally, each machine will have its own user interface when there are several computer-controlled machines in the station. In cases where production-monitoring systems are used, they are then run on external computers and connected to one or more machines in the station. Most of these interfaces are necessary for the set-up and configuration of each of the entities in the station. However, from an operator perspective, they all carry some important information during production that the user might be interested in but does not always know where to find and this leads to a big challenge for the normal people. Interviews of this research revealed that the two most challenging operations for just operators are changeovers and failure recovery. Those are the situations in which the operator needs to configure the robot, as these configurations are spread over several entities and controllers in the station; it can be difficult to ensure that consistent changes have been made to all configurable devices in the system. In the case of failure recovery, this becomes increasingly difficult as it is based on number of computers and devices in a station (Hedelind and Jackson, 2011).

To boil it down, main challenges are development costs, equipment, technical feasibility, education and qualification, economic viability, competency of the operators, flexibility and reconfigurability, availability, changeovers, relying on outside experts, having small batch sizes, transparency of processes and automation solutions.
3.3 LEAN

JIT is a manufacturing philosophy that emphasizes achieving excellence through the principles of continuous improvement and waste reduction. Some of its purported benefits include higher quality production, lower inventory levels, improved throughput times, and shortened customer response times. Although reducing inventories may not be the primary purpose for implementing JIT, it is a natural consequence (Fullerton and McWatters, 2001). The term lean means using less human effort in the factory with less manufacturing space, less investment in tools, less engineering hours in developing a new product in shorter time, keeping less inventory, fewer defects in production, and producing greater and ever growing variety of products. As implementation of JIT in U.S. manufacturers provides improved performance in the following areas: lead times, quality levels, labor productivity, employee relations, inventory levels, and manufacturing costs (White et al., 1999). Lean producers, set their sights explicitly on perfection of continually declining costs, zero defects, zero inventories, and endless product variety (Womack et al., 1990).

A lean manufacturing system is one that meets with high amount of raw material or service demands with very little inventory, and with minimal waste (Ribeiro and Barata, 2011) therefore, lean practice has primarily two objectives: “eliminate waste” and “create value for end-user customers” (Hedelind and Jackson, 2008b, Jackson et al., 2011). One of the basic tenets of lean production is the avoidance of waste or non-value adding activities (Orr, 1997). The most important idea behind lean manufacturing is avoiding waste, “Muda”, which is the Japanese word for waste. “Muda” is any human activity that absorbs resources but creates no value. Lean organizations claim they are more efficient because they only spend resources in activities that add value. There is, of course, the problem of identifying the value of an activity (Ribeiro and Barata, 2011).

Today, lean producers led by Toyota have emerged as global leaders. The lean producer incorporates the good points of craft and mass production, while bypassing the high cost of the former and the austerity of the latter. Lean producers administer teams of multi skilled workers at all levels of the organization and use highly flexible,
increasingly automated machines to produce volumes of products in enormous varieties (Womack et al., 1990). Thus, another aspect of lean manufacturing is the way the production line (shop floor) is organized. Shop floor workers are organized into teams with a team leader rather than a foreman, as occurred in mass production. The workers are polyvalent and able to execute the various tasks assigned to the team. This provides generally a greater sense of fulfilling in the workers since they are not confined to the repetitive execution of the same tasks as in mass production. Further, teams have the right to stop the assembly line, whenever they think it is necessary, as when repairing it. Workers are stimulated to participate with suggestions to improve the process. This continuous improvement (kaizen in Japanese) took place in collaboration with industrial engineers who are much lesser than in the mass production case. The continuous improvement strategy can be effective because workers, if properly motivated, can contribute substantially since they are the ones that truly master the processes being taken care of (Ribeiro and Barata, 2011).

The other aspect of lean thinking is the reduction of inventory. In lean thinking buffers and warehouses are avoided because they are a kind of “muda”, which is costly. The idea behind this is that an item must only be produced when it is needed or there is an order for it. This requires a highly synchronized system involving the plant, its suppliers and customers (Ribeiro and Barata, 2011). In this manner, all efforts are going to eliminate the wasteful stocking of parts both in production facility as well as at suppliers’ plants (Kochan, 1998).

Lean management is not simply “cutting out the fat” in an organization. By and of itself, lean depends on personal responsibility and customer satisfaction to the level which customer specifies that (Chen, 2010). Lean manufacturing is considered to be an enhancement of mass production, hence it is assumed not to be a new technique. Its objectives are to maximize profit by reducing costs and waste of material and improving quality, in such a way one can say these are essentially the underlying principles of mass production (Mehrabi, 2002). On the other hand, just in time (JIT) or kanban in Japanese is the philosophy which is used to coordinate the flow of parts within the supply chain. JIT is therefore a method of production supply and inventory control to guarantee a synchronized flow of materials to produce only what is needed with no waste and low inventories through
the whole supply chain. JIT is often confused with lean production. However, JIT is only a philosophy, with roots as far back as the 1880s, while lean production is a combination of Kanban, Kaizen and Muda. A visible effect of well-applied JIT is the elimination of warehouses inside the final producer to store product components, which only arrive at the company whenever they are required (Ribeiro and Barata, 2011). While the advantages of lean implementation are well mentioned in detail, some of the adverse influences of lean on employee outcomes, work characteristics, product design, and an organization’s innovation capability have also been studied (Chen, 2010). Some critics say that JIT implementations are just a clever way of transferring the inventories from the final producer into its suppliers. Although, lean manufacturing principles have been successfully implemented in many American and European companies (Ribeiro and Barata, 2011).

Researchers studying JIT implementations in U.S. manufacturers suggest that effective implementation requires that all employees be involved in the system improvement process (White et al., 1999). Case studies show that companies that implement lean manufacturing principles or JIT production can reach competitive advantage over those that does not (Hedelind and Jackson, 2008b). However, implementation of a lean production philosophy is more or less successful depending on how much the internal structure and culture of the company is reluctant to be changed (Jackson et al., 2011).

Lean emphasizes on achieving supremacy through the principles of continuous improvement, reducing inventories, waste reduction and creating value for end-user customers. Lean can improve lead times, quality levels, labor productivity, employee relations, inventory levels, and manufacturing costs. All the entities in the company are organized into teams with a team leader and use continuous improvement strategy to collaborate with each other. However, lean production is the next step of mass production and there is a difference between JIT and Lean production. While it is verified that lean manufacturing principles have been effectively implemented in many companies, it can also have adverse influences in the organization.
3.4 LEAN AUTOMATION

The organization that introduces the greatest number of products into the market in the shortest possible time with the lowest overheads will be the strongest competitor. To achieve this, many of the organizations adopted lean manufacturing methods. Therefore, besides ensuring competitiveness through continuous innovations, these companies also want to closely monitor and forecast the market demand and technology trends, assess their own competitive advantages, conduct sensitivity analysis, and generate scenario analyses (Chen, 2010). These organizations found that lean manufacturing had the following impacts upon the method and extent to which they have adopted automation:

1. Automated manufacturing plant was frequently designed for specific factory requirements, of which a major component was flexibility;

2. Approaches such as Quality Function Deployment (QFD) and Design For Assembly (DFA) were used to facilitate automated manufacture and subsequently to shorten the time lag between product development and full-scale manufacturing;

3. Research and development staff of these organizations tended to represent a significant component of the total workforce (Orr, 1997).

Berliner & Brimson (1988) claim that the implementation of JIT production system makes it easier for an organization to automate. Other researchers suggested that an organization should implement the JIT philosophy first, and then simplify its manufacturing processes, and only then should automation be sought. Hansen & Mowen (1997) share this view, as they suggested the implementation of automated manufacturing typically follows JIT production and is a response to the increased need for quality and shorter response time (Hoque, 2000). However, being agile is different from being flexible. The latter often refers to the ability of producing a range of products which are mostly predetermined with multipurpose equipment. It is also different from being lean which related to methods of producing without waste (Ribeiro and Barata, 2011). A company can avoid many issues by using just-in-time techniques for example, line balancing by maximum use of automated manufacturing equipment through a focus on flexible automation rather than fixed automation, even for product lines with
little or no product variation. These organizations also focused on product and process design for automated manufacture (Orr, 1997).

The high levels of flexibility possible with automation can enable organizations to step outside the archetypal manufacturing environments. The reconfigurable manufacturing system (RMS) was set forth to claim to this new market oriented manufacturing environment. In terms of design, RMS has a modular structure that allows ease of reconfiguration as a strategy to adapt to market demands. This proposes RMS the aptitude to be amended quickly to the production of new models, to be coordinated with the exact capacity requirements quickly as market expands and product changes, and to be able to integrate new technology. RMS can complement other production systems and has the potential to address some of their shortcomings (Mehrabi, 2002).

Effective lean production systems use both manual and automated processes and the task is to determine the appropriate type of automation. The question for engineers in lean production environments is, first: what absolutely must be automated? The next question is: what in the process does not have to be automated? As discussed about the levels of automation, researchers found that level three tends to fit better into a lean production system using production cells, because in many instances operators find it relatively easy to load and transfer the workpiece, thus the expense of going to a level four or five machine is sometimes not worth the result. Also, level three tends to have higher uptimes and quicker changeover times than levels four and five. This is because level three tends to employ simpler machines that are dedicated to a single task which leads us into the next part of lean automation design, machine functionality. This production system is built around a machine, though a lean production system is created to flow material and products. Machines are added to enhance that flow, or because they are absolutely necessary to create the product. The second reason that this is not the ideal choice of automation for a lean production system is that it hampers the flexibility that the company needs to react to customer demand. (Harris and Harris, 2008).

One subject and debate within industry, during the changeover towards lean manufacturing is whether traditional robot automation conforms to the principles and practices of lean. Therefore, the term Lean
Automation has risen nowadays in industrial environment. This is about the adaptation of automation to the principles and practices of lean production. Thus, automation in lean production is about deciding the appropriate level of automation (Jackson et al., 2011). The lean metamorphosis within the company is based on increased availability, controlled buffers, a more open layout, and flow-based manufacturing with reduced batch sizes which all affect the equipment and machinery (Hedelind and Jackson, 2008b).

The phrase “lean automation” has been defined in different situations. Some pharmaceutical industries are eager to make their production more efficient through the use of automation, and have defined lean automation as “Lean automation is a technique which applies the right amount of automation to a given task. It stresses robust, reliable components and minimizes overly complicated solutions” (Jackson et al., 2011). One of the pillars of the Toyota Production System is called Jidoka, which comprises autonomation, also known as “automation with a human touch”. Autonomation means “making equipment or processes that are ‘smart’ enough to detect an undesired, abnormal state and stop so as not to produce a defective product”. The concept of autonomation was developed since the Toyota Corporation saw a problem in that normal automation do not have any built in checking for quality problems. This may lead to hundreds of defect parts produced if automated production equipment is producing without human supervision. “At Toyota, a machine automated with a human touch is one that is attached to an automatic stopping device”. This stopping device is not only a stopping device that is used to stop that particular cell or workstation, but it is a stopping device for the whole production line, i.e. a line stopping device. This means that autonomation is an important part of the Visual Control system, or Management by Sight, where it is important that the current state of production is always visible and any problems are brought to attention as soon as they occur. As a result of this, the equipment may produce unattended and without human worker presence until there is a defect or malfunction. The original meaning of jidouka was “Automation”. The sentence was later changed at Toyota into the spelling shown in, the pronunciation of jidouka was the same but they added two extra lines, spelling human. This was an important statement, meaning that the automation (or autonomation) should be working the same way as a human; it should be intelligent. The three words spell out: “Self
moving transformation”, while the extra two lines adds the “human touch” (Hedelind and Jackson, 2008b).

The literatures suggest that the following factors are important when automating lean production manufacturing environments: improve job design and existing manufacturing practices; remove wastage in these areas first; simplify the whole manufacturing process; apply automation in small-scale projects first; simplify products and raw materials to simplify the tasks being automated; only use flexible automation; design automated systems so that they can be readily adapted to other products or processes; design the automated systems to be self-correcting; integrate automated manufacturing equipment and production scheduling so that production which must be stored as inventory is avoided; all automated equipment should offer simple visual inspection to identify production problems (Orr, 1997).

In particular, the organizations utilized automation in a lean production environment to achieve: faster product development; lower inventory levels; a simplified operations management process; increased inventory turnover rates improved output quality. Some of the organizations found that quality control was more easily achieved with automated manufacturing than with human-based quality control processes. This high level of quality control is an important factor in a lean manufacturing production environment. The organizations utilizing automation in a lean manufacturing production environment minimized the capital outlay associated with large levels of inventory and large levels of waste. Capital was invested in automated manufacturing equipment and product and process development instead. Maintenance programs such as Total Productive Maintenance (TPM), Preventive Maintenance and Predictive Maintenance can all help to maximize the reliability of automated manufacturing equipment under these conditions. The companies also ensured that their automated manufacturing systems were designed to simplify the maintenance and repair process, were easy to maintain on a routine basis and were monitored by staff trained and empowered to identify issues and seek opportunities for improvement. Workers can not only provide recommendations for process improvements, but also recommendations for improvements in the flexibility of their automated manufacturing equipment. These recommendations were developed using total quality control circles and employee suggestion
programs. In this manner, the company can introduce new products into automated production cells slowly so that production problems could be solved at a rate which was conducive to high levels of employee input and good planning. Many of the organizations can utilize continuous training of employees during the implementation of automation. Other programs such as suggestion schemes, quality circles and on-the-job training schemes further involved operators and managers in automation projects (Orr, 1997).

As a matter of course, elaborate automation has been employed by companies that are not discerned about lean, while companies such as Toyota have developed so-called low-cost automation. Lean automation does not reduce the flexibility and robustness of the system. Lean automation uses robust, reliable components and minimizes overly complicated solutions (Hedelind and Jackson, 2011). In order for the robot automation to correspond lean principles and practices there is a commitment for development of robotized working cells with increased availability, reduced set-up times by improving the ability for easy reconfiguration, and improved information design to clearly present visual information and options to the operators (Hedelind and Jackson, 2008b). Some of the key-enablers in the Lean Robotics which are vital for future robotic working cells are: increased ease-of-use, intuitive user interfaces, and better ways to visualize what is going on in the cell (Hedelind et al., 2008a) and focus on simplicity and usability. The focus on simplicity enables fast ramp up of production volumes when new orders are being placed (Granlund et al., 2009).

Lean production systems are not always manual, and lean experts are not opposed to the use of automation. Lean systems are, in fact, well-suited to the right type and level of automation. The next shift in thinking required when designing automation for lean production is that the complexity and simplicity of machines must be considered. Complexity is not always the right answer. A facility's flexibility can be greatly hampered by a machine that performs many different functions. In this instance, often a company has built its production system around the machine, and has not developed a system to flow production. Many companies face this predicament, and they end up succeeding, or failing, solely because of the effectiveness of a machine that has low uptime and long changeover times. Unfortunately, it is
difficult to find machine builders that are interested in building these simple pieces of equipment. Machines in today’s fiercely competitive global market need to have high uptime and be very flexible, and that requirement calls for machines that are fairly simple (Harris and Harris, 2008).

There have been three approaches for how to deal with the complexity of advanced manufacturing systems. The first one regards how to ensure robust operations in the manufacturing plant. This has been investigated through the development and implementation of maintenance strategies. Total productive maintenance (TPM) has been identified as a means for improving maintenance performance. However, the implementation of TPM is required throughout the whole company, not simply in the manufacturing functions. The second one is to standardize the solutions in each plant which this leads to fewer spare parts and reduces the requisite for a wide variety of special training and expertise in different technical solutions. The third and final approach for handling complexity is to lessen the perceived complexity of the system for the operators. Designing a user interface that sorts the information in the system and only displays that information that is relevant at any point in time is a critical task in making the system easier to use. Along with, this user interface should converge all the relevant information from all the sub-systems in the station and group them in an articulate way (Hedelind and Jackson, 2011). This user interface could employs windows-style communication for ease of use and an easy-to-use programming unit with function keys, joy-stick and large display (Hollingum, 1994).

Based on the researches (Hedelind et al., 2008a, Hedelind and Jackson, 2008b, Hedelind and Jackson, 2011), here are some facts about making the industrial robotic working cells more easy to use:

Software used in the cells:
- User interfaces
- Cell programming
- Interfaces between cell and surrounding IT-structure
- Jidoka

Maintenance of the cells:
- Operator maintenance
- Preventive maintenance
- Measurements in the cell
- SMED

Manuals for how to purchase, integrate, and manage the cells:
- Manual for operator
- Manual for purchasers
- Manual for integrators
- Technical specification
- Scope of supply

Visualization of the cells:
- Andon charts
- Visualization of production flow
- Visualization of current state of production (Hedelind and Jackson, 2008b).

A lean philosophy introduces extra demands on the workstations in the production system. Automation fitting lean principles should not reduce flexibility and robustness of the system. In order for automation to fit lean principles and practices, there is a need for development of solutions giving increased availability, reduced set-up times, improving the ability for easily reconfiguration, and information design to clearly present visual information and options to the operators. A possible development of robot automation towards Jidouka and “automation with a human touch” could be to give information support to operators and reducing the perceived level of complexity (Jackson et al., 2011). Leading this, the automation technologies used in world class manufacturing plants have to comply with lean principles such as Andon, Jidoka, and visual control (Hedelind and Jackson, 2008b).

Lean Automation seeks to achieve cost effective methods which is neither over engineered nor under engineered. Leanness does not necessarily mean lowest investment cost, but the total investment cost
will be lower compared with the traditional route because all matters are “on the table” from the beginning and all eventualities are considered (Hollingum, 1994). Lean producers throughout the world would likely benefit from a leader in lean-machine building that understood the philosophy behind machine design for lean production systems, and welcomed the opportunity to build them. Understanding the impact of the various forms of automation and machine design on a lean production system is imperative to creating a flexible, efficient, world-class production system. A lean production system should be designed to flow, and automation should be selected after deciding how best to improve flow and fit into the flow. Lean is NOT manual, but the right type of automation is required (Harris and Harris, 2008).

Adding together what all researchers believe, many organizations adopted lean manufacturing methods to ensure competitiveness through technology trends. Lean philosophy makes it easier for an organization to automate and this is because of increasing need for quality and shorter response time. Lean Automation can use both manual and automated processes, however first it is needed to adapt automation to the principles and practices of lean production. Lean Automation can be described as a technique which applies the right amount of 'smart' equipment to a given task and can be utilized for faster product development; lower inventory levels; simplifying operation processes; increasing turnovers rates, improving quality and maximizing the reliability of equipment.
With the methodological and theoretical frameworks presented earlier in this report, time has come to introduce the empirical approach chosen by the researcher. Two research questions were posed in relation to the subject of Lean Automation in the methodological chapter. The research questions will be answered through a cross-case analysis of interviews and case studies presented in this chapter. Automation Challenges and Lean Automation are the two main areas which are focused in this chapter.

4.1 AUTOMATION CHALLENGES

In this part some aspects of the automation challenges collected in empirical studies as well as from the literature will be evaluated. The first part is illustrating the methodology, the second part presents the interviews with the experts, and the third part belongs to the case studies in the matter of Automation challenges. At last, the result of the interviews, case studies and literatures are discussed.

4.1.1 METHODOLOGY

To completely understand the automation challenges two methods were applied here. Three interviews with the Lean Automation group members were held to apprehend the scientific view of challenges. For attaining qualitative information researchers agreed that interviews are
the best ways. Considering that the Lean Automation group in IDT works with a lot of projects, they envision about what challenges are encountered in each projects, so three interviews were held. Before the interview, the researcher talked with the research group and enlightened them about the process and objective of the research, then dispatched the interview questions by email; the questions are open questions which let the respondent to feel free in answering. Each interviewee responded these questions based on his or her own experience and knowledge. It was advised not to let each other know about the answers because of independency of responses. After 2 weeks, interviewees sent back their responses.

Three cases were observed to perceive the challenges in the real world. These cases are based on the observation of the researcher and the documents which the researcher had an access to them.

4.1.2 INTERVIEWS

In the first part of interview, the researcher made a query about the challenges of automation, here are the responses of the interviewees.

The first interviewee is the researcher in Lean Automation area, he was of the opinion that there could be a lot of challenges. The first one could be the ability to customize products to automation for the company. He believed that the companies should already consider how to produce the intended product at the design stage. Also, manufacturing industries that use automation for machine tending must make a case by case analysis whether automation is a solution to their problem or not, even though it is not necessary that they purchase a machine that comes with a robot, this is of course depends on the volume and the flexibility the company needs in the machine.

He mentioned that manufacturing industries that use automation for assembly of products and components have approximately the same challenges as above, but they can see more easily how the pay back of the investment of the automation happens. They must decide which automation they should go for it, so the type and level of automation they will have on the company is so vital.

Purchasing knowledge on what to buy and lack of good specifications when it comes to automation equipment are the missing points in many
companies. These create problems in buying and installing of automation when the system suppliers may not be clearly informed about what they are expected to deliver. This leads to difficulties for the system suppliers to deliver good solutions to the customers. Simultaneously, poorly specifications hinder the suppliers to quote on the automation on equal terms.

Another point is that the operation and the interface of the automation are difficult for companies to be learnt. Complicated user interfaces and programming languages that require multi-year technical training could be a big problem today. Furthermore, lack of having an automation strategy and knowledge of what can be automated and how company would work strategically with automation is blundered virtually in the majority of companies.

The second interviewee is the researcher on Automation in Logistics and she attached weight to that especially inexperienced automation users have problems with finding an appropriate solution for their needs. This is based on: they have a hard time specifying their needs and therefore have nothing to evaluate possible solutions against and as a consequence often end up with poorly solutions, that is, the solution cannot manage everything they need or it is too complex, inflexible or too expensive. They have difficulties identifying potential improvement areas, since they have a poor view of their current situation and the desired situation or objective. They have difficulties identifying possible applications of automation as long as they are not aware of all possibilities with automation and they are inexperienced in this area. They often lack a strategic view on their operations in general but towards automation in particular. Further, during the acquisition process they are very dependent on systems suppliers to help them. Many, especially small and medium sized companies also have a hard time to financially motivate and make large investments in what automation needs.

Automation is still considered inflexible, due to the fact that it is often a “black box” once it is installed. This happens on the ground that the automation knowledge by the users is too low and they cannot make any corrections, add-ons or maintenance and they once again are dependent on a third party to manipulate this. Automation can be considered a weak point when end users are affected with long downtimes since they mostly cannot fix it themselves and have to wait
for assistance which is also very expensive. This interviewee summarized the challenges in the way of finding the right type and level of automation and reducing the perceived complexity and believed that both challenges are referred to the process of acquiring knowledge and the technology.

The third interviewee is a programmer who works in robotic cells to create robot programs. He quoted that the procurement process for an industrial robotic cell can be complicated, especially for small and medium sized companies that have no previous experience in robot automation. He mentioned that, mostly, the company does not know certainly how to perform a proper pre-study for identifying which parts of the production are suitable for automation. Furthermore, if a possibility for improvement is found, the company is quite often in the lack of competence to write good requirement specifications that cover every aspects of the automation. Although, system integrators can help to promote this process, their agenda is to sell automation solutions.

Large batch sizes with few variants have been the “norm” for what we use industrial robots for, but today focus on Lean production leads to smaller batch sizes and increased number of variants. This in turn puts higher demands on flexibility and reconfigurability of the automation cell. A challenge as he saw is how a company can support flexibility and reconfigurability both in hardware like flexible fixtures and software like parameterized programming of robots.

Additionally, several companies complain about how “black boxes” are the automation cells, by way of explanation, we feed them with material and hopefully get something processed back from. We do not really know much about the inner workings of the black boxes and it can be hard to see whether it is producing or it is standing still because of a failure. A notable challenge in this manner is to build automation solutions that are open, easy to understand and have reduction in perceived complexity where we can easily follow the flow of material.

Large enterprises often have their own automation divisions with experts working with robotic automation every day. Small and medium sized companies often lack this possibility and when they invest in robot automation they discard the need for educated personnel. A normal day with production, some changeovers and some minor failures in the automation equipment are probably handled in-house but
when a new product is added or when an existing product changes, the competence in-house handling is not enough. An external expert, probably an integrator, needs to be called to do these kinds of changes. Hence, another challenge is that the company depends on an external expert for doing what should be considered as a “normal work” for an operator.

Integrators often have their preferred brand for HMI-displays (human-machine interfaces) and also for the software where the HMIs are designed. These software tools are advanced design tools with the possibility to customize every aspect of the HMI. Unfortunately, the customizability can lead to cluttered interfaces with too much information displayed at the same time or information that is of no use for the operator. If a company has automation cells from multiple integrators the HMI design and functionality often differ which makes it harder for operators to work at several automation cells. A challenge for the end user companies is to define the requirements of what brand of HMIs and a common visual appearance between all cells in the company should be used.

4.1.3 CASE STUDIES

The first case for analyzing the challenges of automation is related to the company which produces brakes and suspension systems for vehicle industries. The mission of this company is producing parts with reliable and innovative solutions. The case is reviewing on an industrial robot cell which is built based on the lean automation. The followings are a brief summary of challenges which was studied and they would encounter. The challenge of visualizing of robot cell is one of them; this challenge is about to make the cell easy and clear for operators and understanding what happens in robot cell especially when robot is not working. Building HMI and its qualifications is another point to struggle with; this also needs to know how we could maintain communication between robot and HMI, communication of users and machine with or without wire, the methods of connections in cell and communication between robots and other tools. Another group of challenge is related to operators which consists of administering robot cell by many people, coming up with necessary information for operators to do fault searching, give a possibility for operators to solve
any problem, having a simple guide for maintenance, work instructions with robot and identifying and solving problems. Identifying defects in the production line, stop the line when a problem happens and solving complexities in maintenance and fault finding is another type of challenges. The rest of challenges are: adding new arms to robot, positioning of robot's arm, having knowledge for improving HMI programming, using new HMI for every cell without standardizing, visioning and cooperating with existing information system, managing huge production flow, adjust and adapt current cell and moving the robot cell when needed.

The second case is a robot producer which investigated the lean automation concept and installing robot cells in another companies. The most important challenges that they mentioned are: having no strategy for working with robot automation, having many suppliers for robot with different robotic solutions, how measuring OEE in robotic cell, having low confidence in operators' capability in finding faults and existing too many dirty things around the cell like oil.

The third case is related to a holistic study by IDT which presented in Robotdalen. The complexities related to a robot cell can be listed as: deciding which automation level should be chosen, doing automation by the company itself or by outside experts, analyzing and evaluation of robot cell necessities, defining robot cell requirements and specification, selecting automation solutions, developing creative and smart solutions, developing cell programs to use in other events, producing basic requirements of specifications, producing ultimate visionary specifications, managing problems of automation, finding possible area for doing automation, selecting right solutions for automating, adding new product to cell, changing the existing product, changing production line from one product to another product and vice versa, putting and adjusting robot in the cell, managing variants in programs, spreading out program or part of a program to another cell, understanding the function of the robot cell, understanding of well-functioning of the cell, working and controlling the tools and equipment in the robot cell, visualizing the cell functions, understanding of malfunctions of robot cell, entering new parameters into HMI, controlling the cell manually, doing adjustments for big problems, understanding the time for maintenance, finding the specific problems for malfunction of robot cell, doing the right maintenance,
terminating and recycling the robot cell and using current solutions for other projects.

4.1.4 RESULTS

Based on the literatures, interviews and cases here are the list of the challenges one may encounter when installing automation. In this list it is tried to categorize each challenge in a bigger group to be understood and clarified better by the researchers. Each category represents a phase from the start point of installing automation to the end phase of mass production by the automation.

- Category 1: Planning:
  - Investment Costs and Payback of the Investment (Orr, 1997, Jackson et al., 2011; Winroth et al., 2006; Winroth et al., 2007; Frohm et al., 2006; Hedelind et al., 2008a; Part 4.1.2 (interviewee 1, interviewee 2)),
  - Self-Development of Automation or Dependence on Outside Experts (Hedelind and Jackson, 2011; Jackson et al., 2011; Part 4.1.2 (interviewee 2, interviewee 3); Part 4.1.3 (second & third case studies),
  - Defining Necessities of Automation (What Is Needed for Automation from Start to End) (Frohm et al., 2006; Hedelind and Jackson, 2008b; Jackson et al., 2011; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.1.3 (third case study)),
  - Finding the Right Type and Level of Automation (Groover, 2000; Säfsten et al., 2007; Harris and Harris, 2008; Hedelind et al., 2008a; Jackson et al., 2011; Part 4.1.2 (interviewee 1, interviewee 2); Part 4.1.3 (third case study)),
  - Procurement Process of Automation Technology and Knowledge of What to Buy (Orr, 1997; Mehrabi, 2002; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3)),
  - Defining Which Technology Should Be Used for Automation (Mehrabi, 2002; Part 4.1.2 (interviewee 1)),
  - Defining What Brand Should be Used for Automated Cell (Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 3); Part 4.1.3 (second case study)),

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Identifying Potential Improvement Areas and Applications of Automation (Winroth et al., 2006; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.1.3 (third case study)),

Specifying the Basic and Desired Requirements of Automated Cell (Frohm et al., 2006; Winroth et al., 2006; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.1.3 (third case study)),

Having Strategy in Implementing Automation (Winroth et al., 2006; Winroth et al., 2007; Mehrabi, 2002; Part 4.1.2 (interviewee 1, interviewee 2); Part 4.1.3 (second case study)),

Defining Which Automation Solution Is the Best (Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.1.3 (second & third case studies)),

Evaluating of Automation Solution (Creativity and Smartness of the Solution) (Groover, 2000; Säfsten et al., 2007; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.1.3 (second & third case studies)),

Defining the Ways of Answering Automation Problems (Winroth et al., 2006; Hedelind and Jackson, 2008b; Jackson et al., 2011; Part 4.1.2 (interviewee 1, interviewee 2); Part 4.1.3 (first & third case studies))

Manage Programming and Types of Programs in Automated Cell (Groover, 2000; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 3); Part 4.1.3 (first & third case studies))

Category 2: Configuration:

Adapting and Customizing the Product for Automatic Manufacturing (Orr, 1997; Winroth et al., 2006, Winroth et al., 2007; Frohm et al., 2006; Lindström et al., 2006; Hedelind et al., 2008a; Jackson et al., 2011; Part 4.1.2 (interviewee 1, interviewee 3); Part 4.1.3 (third case study)),

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Changing Parameters of Existing Product in the Robot Program (Jovane et al., 2003; Winroth et al., 2006; Frohm et al., 2006; Winroth et al., 2007; Jackson et al., 2011; Hedelind et al., 2008a; Part 4.1.2 (interviewee 1, interviewee 3); Part 4.1.3 (third case study)),

Changing Programs of HMIs (Part 4.1.2 (interviewee 3); Part 4.1.3 (first & third case studies)),

Using Compatible HMIs for Many Automated Cell (Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 3); Part 4.1.3 (first case study)),

Adding New Products to Cell (Orr, 1997; Winroth et al., 2006; Frohm et al., 2006; Hedelind et al., 2008a; Jackson et al., 2011; Part 4.1.2 (interviewee 3); Part 4.1.3 (third case study)),

Changing Production Line from one Product to another Product (Orr, 1997; Frohm et al., 2006; Hedelind et al., 2008a; Part 4.1.3 (third case study)),

Installing Automated Cell (Part 4.1.3 (first, second & third case studies)),

Supporting Flexibility (Orr, 1997; Hoque, 2000; Mehrabi, 2002; Harris and Harris, 2008; Hedelind et al., 2008a; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 3)),

Supporting Ergonomic Issues (Kochan, 1998; Lindström et al., 2006; Frohm et al., 2006; Part 4.1.3 (second case study)),

Category 3: Operation:

Working with Automated Cell and User Interfaces (Orr, 1997; Groover, 2000; Winroth et al., 2006; Hedelind and Jackson, 2008b; Jackson et al., 2011; Part 4.1.2 (interviewee 1, interviewee 3); Part 4.1.3 (first, second & third case studies)),

Controlling the equipment in the Automated Cell (Orr, 1997; Groover, 2000; Winroth et al., 2006; Säfsten et al., 2007; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 3); Part 4.1.3 (second & third case studies)),

Having Manual Operation Mode on Automated Cell Equipment (Winroth et al., 2006; Lindström et al., 2006; Frohm
et al., 2006; Säfsten et al., 2007; Harris and Harris, 2008; Part 4.1.3 (third case study))

- Making Process and Automated Cell Handling Clear for Operators (Happenings in Automated Cell) (Hedelind and Jackson, 2008b; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 2, interviewee 3); Part 4.1.3 (first case study)),

- Ability of Administering and Executing the Automated Cell by Many People (Harris and Harris, 2008; Hedelind and Jackson, 2008b; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 3); Part 4.1.3 (first case study)),

- Having Online Status and Statistics of the Automated Cell (Hoque, 2000; Hedelind et al., 2008a; Hedelind and Jackson, 2008b; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 3); Part 4.1.3 (first & second case studies)),

- Having Visual Indicators of the Status of the Automated Cell (Operating or Not Operating) (Orr, 1997; Winroth et al., 2006; Hedelind et al., 2008a; Hedelind and Jackson, 2008b; Part 4.1.2 (interviewee 2, interviewee 3); Part 4.1.3 (first & third case studies)),

- Inspecting Defects or Rejects in the Automated Cell (Orr, 1997; Hoque, 2000; Hedelind and Jackson, 2008b; ,

- Dealing with Too Many Products with Small Batches (Hoque, 2000; Frohm et al., 2006; Winroth et al., 2006; Jackson et al., 2011; Part 4.1.2 (interviewee 1, interviewee 3); Part 4.1.3 (first case study)),

- Educating and Training the Users (Orr, 1997; Frohm et al., 2006; Hedelind and Jackson, 2008b; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.1.3 (first & second case studies)),

- Category 4: Maintenance:
  - Recognizing Main Faults and Stoppages (Hedelind and Jackson, 2008b; Hedelind and Jackson, 2011; Part 4.1.3 (first & second case studies)),
  - Doing Adjustments for Faults in Operator Level (Hedelind et al., 2008a; Hedelind and Jackson, 2008b; Hedelind and
Planning Preventive Maintenance (Orr, 1997; Harris and Harris, 2008; Hedelind et al., 2008a; Hedelind and Jackson, 2008b; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 2); Part 4.1.3 (first, second & third case studies)),

Performing Right Maintenance (Orr, 1997; Harris and Harris, 2008; Hedelind et al., 2008a; Hedelind and Jackson, 2008b; Hedelind and Jackson, 2011; Part 4.1.3 (first, second & third case studies)),

Performing Rapid and Simple Maintenance (Orr, 1997; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 2, interviewee 3); Part 4.1.3 (first & third case studies)),

Category 5: Reusability:

Using HMIs' Programs in another Cell with another HMI (Hollingum, 1994; Groover, 2000; Hedelind et al., 2008a; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 3); Part 4.1.3 (first & third case studies)),

Terminating the Cell and Recycle it (Part 4.1.3 (third case study)),

Using Solutions for another Products or Projects (Orr, 1997; Jackson et al., 2011; Hedelind and Jackson, 2011; Part 4.1.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.1.3 (first, second & third case studies)),

Ability to Move the Automated Cell When Needed (Orr, 1997; Hedelind et al., 2008a; Harris and Harris, 2008; Jackson et al., 2011; Part 4.1.3 (first case study))

4.2 LEAN AUTOMATION

In this part the concept of lean automation will be investigated in interviews and cases. The first part talks about the methodology and it resumes with interviews and cases in the second and the third parts respectively. At the end the results are discussed based on the literatures, interviews and case studies.
4.2.1 METHODOLOGY

First three interviewees were selected from the IDT Lean Automation group to ask about what is lean automation and how we could implement lean automation. The question was asked in the following of the first question about Automation Challenges; hence the procedure for the interview was the same as the previous part. Next, four cases are reviewed to see what is lean automation and how lean automation could be practiced and engaged. Hereafter, the results are captivated based on the supporting material.

4.2.2 INTERVIEWS

The first interviewee was specialized in Lean automation, he declared that by combining Lean with automation we will have an automation that is best suited for the production environment and is required out in the industry today. LEAN principles are aiming for small batch sizes and strive to go for one-piece production. If we have this in mind when designing the automation we will more likely have an automation that can handle these types of demands.

Finally, he defined Lean Automation as: Right solution and right level of automation, Robust solution with no disturbances, Simple and cheap solution (low cost automation) and Reduced perceived level of complexity in automation.

The second interviewee is specialized in automation systems in logistics, she concluded that there is a difference between “combining lean WITH automation” and “combining lean AND automation”, since she considered automation as a tool and lean as a philosophy and therefore the tool needs to fit the philosophy, she looked into “combining automation WITH lean”. To combine them she thought we should look with “lean glasses” on automation. First we should identify what waste is and how we can reduce it. After that, we should define how/what we can automate to reduce waste in our operations.

Moreover, she claimed that we should choose whether simple activities to be automated which they have no value adding and are to free up workers time or our most value adding activities since they are most important and we want to increase the quality of using automation, then we should decide on what the right type and level of automation
can be applied. More, we should define how we can involve the employees in our automation implementation as cross-functional teams can be involved from the early stage to the end to realize all important aspects of automation. Last but not least is the way we can incorporate visual management, that is, to avoid automation cells to be black boxes we need to visualize what happens in the cell, for example using interfaces that are easily understandable, showing online status of the cell and etc.

She summarized the Lean Automation by the important key aspects: "The vision that is to make automation available for new users and new applications and this is happened by reducing the complexity of the automation and focusing on the customers' needs".

The third interviewee is specialized in programming of industrial robots and he expressed that small and medium sized companies must start educating their employees for automated production and let the operators be part of the procurement process when investing in automation. They need to develop better methods for programming industrial robots and especially for designing programs that are parameterized. He mentioned that visual tools where program codes are hidden in boxes or icons can help operators to understand the flow of codes.

He remarked that we should find ways to open up automation cells so that they become more transparent to the outside world. Using light and colors to visualize the flow in the automation cell and replacing safety fences with laser scanners could be solutions to this matter. Accompanying this, HMIs need to be further developed to support the daily work of operators. Graphical wizards should guide the operator through complex tasks such as performing changeovers or failure recovery. All HMIs within a company should have a common layout so operators feel at home and comfortable when using them. Graphical representations of the automation cells should be available and used within the HMIs and failures should be visualized within those graphical representations.

In the end, he believed that reducing the “perceived complexity” is a very important step towards Lean Automation. Computers and cell phones are complicated devices but intuitive and visually appealing user interfaces help reducing the perceived complexity. He thought that
if we start looking at consumer products and how they are designed we can start applying the same thinking to complex automation solutions.

4.2.3 CASE STUDIES

The first case study is related to a company which produces brakes and suspension systems for vehicle industries. In this company there is a cell which is built based on the Lean Automation concept. This company has 4 sets of robot cell and wants to have 15 more sets in the near future. They want to compete with low-wage companies by building these cells so they are going to build a simple cell that anybody can work with it. The main focus of this company is to have a robot cell based on the Lean automation; they believe that if they can improve the HMI they would have a simple cell which everybody can work with it. For the function of HMI they built three levels which are for operators, for maintenance and for programmers, each level has its own graphical user friendly interface and there is an icon for statistics of the robot cell in each level. The cell has some instructions for working, maintenance and for changing parameters of the robot for existing product and for applying into new products, in regards; the system can be connected to other systems to have some reports like OEE and etc. The initial facts about this cell included the following points:

1. A need for an improved follow-up of production data/statistics was identified. The current method of recording the reasons for stops in the station granted the operator the possibility to select, e.g. “no category” as a reason. This was abused, and a majority of the stops fell under this and other types of vague categories that did not really explain the reason for the stop.

2. The company used OEE as the major measure for how well the station worked. The current “feeling” of the production management was that the OEE was too low for this cell.

3. Some of the manufacturing processes required coolants during the manufacturing process and moving the parts around the station could cause spillage on the floor.

The second case is a robot producer which investigated the Lean automation concept and installing robot cells in another companies.
The robot cell that installed here is called the lean robotic, future factory, which has 4 objectives. The first aim of this cell is to have easiness for operation diagnostics, start over again and reconfiguration. The second goal is standardizing for operators, integrators and programmers, this means that having a standard work instruction, layout and other things for using in general situations. The third goal is having robustness which means decreasing the time for maintenance, first installation and calibration, changing tools and increasing the OEE of the machine. The last goal is visualization of the robot which is related to the showing data and statistics online like using Andons and also not securing and protecting the robot cell to make it more transparent and simple. In this cell, safety of the human is also considered so some sensors are built to provide this fact, along with the design of the robot considered to make the robot cell safer. The interface of the robot cell is important here too, they built an advanced interface which can be used in all stations and all equipment. This interface is specialized and uses robot application builder program. The factory must manage the production data that comes from each line so this cell has an online data application and can be viewed by different people like operators, managers, technicians and etc. besides, this system can be connected to other different systems and can be remotely serviced. A workshop was held by the Lean Automation group in IDT in this case. This workshop was held to find lean automation solutions for the projects and check whether they are applicable or not, the results from this workshop are listed below: having an automation strategy, having project planning with clear phases and steps, parameterized programming method of the robot cell, visualizing products' parts and production process like using flow diagram and etc., supporting changes and reconfigurations of products in HMI, giving online feedback to operators and others, having detailed causes of stoppages in robot cell, having service/helpdesk support, visualizing robot cell and product life cycle and preparing handbook of automation.

The third case is related to a robot cell which is built for a science park in Eskilstuna. The aim of the robot cell is for education and also for marketing for the concept of lean automation and factory in a box. The followings are the recommendations for maintaining this cell as a Lean Automation concept representative.
The cell could be portable, a robot in a box, so we should make the cell by the following procedure:

1. Make a cell as a puzzle: Each puzzle contains a machine on it and all the components of producing like container, belts, tending machine, loading and unloading and etc. Then each puzzle fits together and makes a production line. This will lead us to more flexibility and reconfigurability.

   1.1. Moving puzzles with wheels: each puzzle has 4 wheels, which they are movable alongside of a cube box and use a jack to adjust the altitude of wheels.

   1.2. Fixing puzzles with magnets: each puzzle must be placed in a hole which is built for holding cube boxes, then the wheels are released by the jack and the puzzle is magnetized to the ground surface.

2. Robot in a cell: This unit (cell) should consist of a number of modules, tools, fixtures and robots, and should be designed with maximum flexibility for future work tasks. This means that all the components must be existed in this cell like tending machine, unloading and uploading, robot and etc. Flexibility of the cell may be limited and reconfigurability may be confined to particular family products.

   2.1. Moving cell: This cell should be in a container to be able to movable in the factory or between different sites.

As a result, the cell should be a demonstration for the lean automation concept so:

1. We should demonstrate that the cell has its Lean concepts e.g. the cycle time, low buffers and material handling and etc.

2. Programming of the software should be graphical as being graphical makes all people able to work with the HMI more effectively.

3. For user interfaces we should use simple programs with simple "words" to be understandable by all.

4. Preparing a simple manual for how others can program the Robot.

5. Show the programming procedure by visual tools like posters, etc.

6. Preparing a simple manual to show how normal people can do simple maintenance based on the most possible faults.
7. Preparing a time table plan for doing PM for reducing the down times
8. Preparing a simple manual for how others can operate the Robot.
9. Prepare a VSM for the cell and show the main characters of how one can draw a VSM
10. Showing the main statistics of the Robot situation (Andon) like the cycle time, how many products are produced and etc.
11. Putting every tool behind glass to prevent making the Robot cell become a "black Box"
12. Using a note log in the cell to let the visitors write their comments about everything in a cell
13. Presenting a Lean Automation Kaizen

![Diagram of Lean Automation Kaizen]

Figure 4. Lean Automation Kaizen.

14. Using standardized coordinates like having sensors or fixtures to move the cell or reconfigurable for another products
15. Using 5S method to make the cell simpler to understand

The forth case is about a hospital that uses automation tools and AGVs in logistics transportation. By a visit from a researcher, it is obvious that they use automation for just the transportation even though this process is so critical for the firm. The AGVs are used to move drugs and pharmaceuticals between inventory and the patients, whereas this hospital is one of the hugest hospital in Europe, this application of automation is mandatory for the logistics however they do not have much information about the lean automation. As a matter of fact, they use lean concepts in other processes like suppliers, production, transportations and etc., therefore they do not have much knowledge about the Lean concept.

4.2.4 RESULTS

Based on the literatures, interviews and case studies here are the result for Lean Automation. These results could be some hints for implementing Lean Automation.

Lean Automation should be also after one-piece production principles for small batch sizes (Hoque, 2000; Harris and Harris, 2008; Hedelind and Jackson, 2008b; Granlund et al., 2009; Part 4.2.2 (interviewee 1)) and most value added activities should be automated for increasing quality (Orr, 1997; Hoque, 2000; Hedelind and Jackson, 2008b; Part 4.2.2 (interviewee 2)). Having robustness in maintenance, installation, calibration, changing tools and increasing the OEE of the machine could be one of the aspects which can help Lean Automation being implemented in a better way (Hedelind and Jackson, 2011; Jackson et al., 2011; Part 4.2.3 (second case study)).

Companies should involve employees in automation implementation such as in cross-functional teams (Orr, 1997; Harris and Harris, 2008; Hedelind and Jackson, 2011; Part 4.2.2 (interviewee 2, interviewee 3)) and also start educating their employees for automated production to gain much information about the lean automation (Jackson et al., 2011; Part 4.2.2 (interviewee 3); Part 4.2.3 (forth case study)). Reducing the complexity of the automation and having easy ways for operation diagnostics, start over again and reconfiguration is important for implementing Lean Automation (Mehrabi, 2002; Harris and Harris, 2008; Hedelind and Jackson, 2008b; Hedelind and Jackson, 2011;
Jackson et al., 2011; Part 4.2.2 (interviewee 1, interviewee 2, interviewee 3); Part 4.2.3 (second & third case studies)). Focusing on the customers’ needs (Harris and Harris, 2008; Part 4.2.2 (interviewee 2)) and considering levels of functionality for operators, maintenance and programmers are needed for this concept (Orr, 1997; Part 4.2.2 (interviewee 1, interviewee 2); Part 4.2.3 (first case study)), this leads to have standard work instructions, layout and other things for using in general situations (Hedelind and Jackson, 2011; Part 4.2.3 (first & second case studies)). Having detailed causes of stoppages (Hedelind and Jackson, 2008b; Part 4.2.3 (first case study)) and service/helpdesk support (Part 4.2.3 (second case study)) is another requirement for decreasing the complexity of the Automation. Furthermore, open up automation cells to show them more transparently to the outside world (Part 4.2.2 (interviewee 2, interviewee 3); Part 4.2.3 (third case study)) and using 5S method are another ways to make the cell simpler to be understood (Orr, 1997; Harris and Harris, 2008; Part 4.2.2 (interviewee 1); Part 4.2.3 (first, second & third case studies)). Incorporating with visual management (Part 4.2.2 (interviewee 3); (Part 4.2.3 (second & third case studies)) in cell programs, failures and showing data online (Part 4.2.3 (second case study)) can help operators to understand what is happening in the cell to prevent the cell being a black box (Hedelind and Jackson, 2008b; Hedelind and Jackson, 2011; Jackson et al., 2011; Part 4.2.3 (first & second case studies)).

Developing better methods for programming industrial robots (Hollingum, 1994; Groover, 2000; Hedelind and Jackson, 2011; Part 4.2.2 (interviewee 3); Part 4.2.3 (second & third case studies)), using and updating VSMs and considering the process of Lean Automation Kaizen could be helpful in Lean Automation (Orr, 1997; Harris and Harris, 2008; Hedelind and Jackson, 2008b; Part 4.2.2 (interviewee 3); Part 4.2.3 (third case study)). Thereafter, Lean Automation can be summarized in this terms "right solution and right level of automation with robust answers in implementing low cost automation for reduction of perceived level of complexity in automation".
For ensuring competitiveness, companies must aware of new production systems (Orr, 1997; Säfsten et al., 2007; Hedelind et al., 2008a; Chen, 2010). To achieve this, many of the organizations adopted lean manufacturing methods (White et al., 1999; Fullerton and McWatters, 2001; Ribeiro and Barata, 2011), however this method can be updated by the requirements of market, therefore, besides continuous innovations, these companies also want to closely monitor and forecast the market demand and technology trends (Harris and Harris, 2008, Chen, 2010). It seems that implementation of Lean concepts makes it easier for an organization to automate (Hoque, 2000), thus an organization should implement Lean first, and then simplify its processes, and only then should automation be sought as another system for the processes (Orr, 1997), because automated manufacturing typically is a reaction to the increased need for quality and shorter response time which they are being as two main principles of Lean (Womack et al., 1990; Orr, 1997; Hoque, 2000; Fullerton and McWatters, 2001; Mehrabi, 2002).

Effective lean production systems should be a combination of both manual and automated processes and therefore the task is to determine the appropriate type of automation (Groover, 2000; Winroth et al., 2006; Harris and Harris, 2008), here maybe level three of automation tends to fit better into a lean production system, however some facts must stick in our mind that the ideal choice of level of automation for a lean production system is that the machine should not hamper the flexibility that the company needs to react to customer demand (Säfsten et al., 2007; Harris and Harris, 2008; Hedelind et al., 2008a), hence Lean Automation is about deciding the appropriate level of automation with human touch involvement (Hedelind and Jackson, 2008b; Jackson et al., 2011). One-piece production is another perspective for Lean automation which should be considered in the implementation of mass production phase (Orr, 1997; Mehrabi, 2002; Hedelind et al., 2008a; Ribeiro and Barata, 2011).

Both Lean and Automation could be consider as a set of belief, it means that both are philosophy and has some tools to be implemented (Harris and Harris, 2008), therefore we could combine lean AND automation whereas these two have the same dimensions, however
tools which belonging to these philosophies must be aligned with each other like robots and Kanban production, programming and Andon and etc., therefore by combining these two we make a new philosophy which called Lean Automation (Hedelind and Jackson, 2008b).

For implementing Lean automation, one should do the followings. We should improve job design and existing manufacturing practices and remove wastage in these areas first. Afterwards, we should simplify the whole manufacturing process and apply automation in small-scale projects; it is very important to simplify products and raw materials as well to facilitate the tasks being automated (Orr, 1997; Hoque, 2000; Harris and Harris, 2008; Hedelind et al., 2008a; Ribeiro and Barata, 2011). One should keep in mind that for Lean Automation we should only use flexible automation and design automated systems (Womack et al., 1990; Orr, 1997; Hedelind et al., 2008a) so that they can be readily adapted to other products or processes (Orr, 1997; Winroth et al., 2006; Frohm et al., 2006). Designing the automated systems to be self-correcting and integrating automated manufacturing equipment with production scheduling are other considerable steps (Orr, 1997; Hedelind and Jackson, 2008b); by this move, that production which must be stored as inventory is avoided (Orr, 1997; Säfsten et al., 2007; Hedelind and Jackson, 2008b).

All automated equipment should offer simple visual inspection to identify production problems (Orr, 1997; Winroth et al., 2006; Hedelind and Jackson, 2008b; Jackson et al., 2011) and workers should freely not only provide recommendations for process improvements, but also recommendations for improvements in the flexibility of their automated manufacturing equipment (Orr, 1997; White et al., 1999; Ribeiro and Barata, 2011). Preparing VSMs could be so helpful in giving idea to visualize what is happening in the cell or production line; one should not ignore the importance of VSM also in the Lean Automation concepts (Harris and Harris, 2008; Hedelind et al., 2008a; Hedelind and Jackson, 2008b). Having recommendations and visual management may help process of Lean Automation Kaizen to be applied, as this could be a new issue in the area of Lean Automation; a company can use this subject to improve the capability of processes (Ribeiro and Barata, 2011).

Based on the Lean concepts, the company can introduce new products into automated production cells slowly so that production problems
could be solved at a rate which was conducive to high levels of employee input and good planning (Orr, 1997; Chen, 2010), moreover many organizations can utilize continuous training of employees during the implementation of automation to align human with technology more effectively (Orr, 1997; Winroth et al., 2006; Hedelind and Jackson, 2008b). The researcher believes that the foremost aim for the firm should be learning experience of the employees of the automation process, here the training part is one of the crucial steps in implementing Lean Automation, one who wants to work with Lean Automation must have a complete knowledge from the basics to the ultimate principles of this belief (Orr, 1997; Frohm et al., 2006; Hedelind and Jackson, 2008b).

Using 5S methods and standardizing for operators, integrators and programmers in the Lean Automation is a necessity also (Mehrabi, 2002; Hedelind and Jackson, 2008b; Hedelind and Jackson, 2011), this could lead to easiness for operation diagnostics, start over again and reconfiguration for the automated production line and also meet the need for Lean principles.

4.4 RECOMMENDATION

 Whereas Lean Automation is a new concept between scholars and technicians, it is recommended that more studies must be conducted to evaluate the principles. These studies must involve all parts of industries and universities and do a real project, that is, an industrial project must be introduced to implement Lean Automation and scholars and technician must go through it step by step. Now, these kinds of projects are doing individually without any support from both technicians and scholars.

As it is seen in many cases, there is not a logic relationship between Lean and Automation, some said Lean is implemented in programming of automation, some believe first we have an automated cell and then we should Lean principles, however on this writer's view, it is better to have Lean cell and then check which value-added activity can be automated. This means that for having Lean Automation it is better to go through Lean and then implement Automation based on requirements of the Lean cell.
It is recommended that for all automated cell involvement of Human should be considered, that is, machines and robots may have not the ultimate logic for doing the job however human has the ability to decide about everything. In Lean principles the role of human is so much considered therefore if we want to have Lean Automation we must combine human and automation together to reach to the object.

For implementing Lean Automation all principles of lean must be investigated. In this study, only a few principles are reviewed and applied in the cases, however Lean Principles has 14 various perspectives and all must be reviewed to have Lean Automation. One can make a list of principles and check which principles can solve the challenges of Automation. In this manner, the results of solutions may also lead us to the Lean Automation.

This study could be improved in the way of doing more practical projects, this means that a project must be started for Lean Automation in a company and the study should be done on this project. Furthermore, information of this project is restricted to special technicians such as programmers and industrial engineers, however this issue needs various field of proficiency for example mechanical engineers, managers, human resource experts, system analyzer and etc. The most notable implication of this study is realizing the importance of teaching Lean Automation principles to others, i.e., for implementing Lean Automation researchers need to train Lean principles other involvements in the process and then go forward in teaching the facts of automation, thus the vital result is training operators and others in this subject.
CONCLUSIONS AND FUTURE WORK

The fifth and last chapter highlights the conclusions made in the theoretical and empirical research. Furthermore, the research questions are repeated and answered. Finally, the contributions made and the agenda for future work is presented.

5.1 CONCLUSION

The objectives supposed on this research were to understand the various aspects of Lean Automation. The theoretical chapter was established to give an overview of what has been done in the region of Lean automation; subsequently the empirical chapter is to examining these perspectives in the real examples. Here, the two research questions are mentioned again to be answered:

RQ-1 How we could improve the automated cell based on the lean concepts?

It is believed that implementation of Lean concepts makes it easier for an organization to automate the process, therefore for improving an automated cell in effectiveness and performance it is recommended that first the company should implement Lean, and then simplify its processes, and only after that automation should be implemented, Consequently we should improve job design and existing manufacturing practices.
In as much as, Lean principles concentrate on the role of human, hence we should use a combination of both manual and automated processes for the production cell, by the way of explanation, the right and the proper level of automation and appropriate type of automation should be considered in the cell. Important of all, for making an automated cell to be improved we should consider that the machine should not be a barrier for the flexibility of the process, as this may be a contradiction to Lean principles.

Last but not least, is the issue of adaptation of automation to other processes and human. If the cell is asked to be improved, it must be adapted to other products or processes and aligns human with technology more effectively. This makes the automated cell being fitted in the lean concept and can be improved by the means of these principles.

RQ-2 How we could minimize the non-added value activities?

For the non-added value activities first we should prepare VSM of the automated cell, this could help us has a vision of what is going on in the cell, what activities are valued, which of them are non-valued and it helps to reduce the waste which may lean non-value added activities.

Moreover, having visual indicators such as Andon helps the cell to attract attention to value added activities; however having simple visual inspections could be more beneficial. Another thing that may step up the cell to eliminate the non-added value activities is to simplify the whole manufacturing process, by this we can assure that the non-added values may be highlighted by it, in other words simplifying may minimize these activities or may lessen these activities effect in the whole process. One way of simplifying the process of cell is to have 5S methods and standardizing, this also could arrange the process in a neat order which may help to reduce number of these kinds of activities.

One-piece production is another perspective which may provide the cell to be more effective, furthermore Lean Automation Kaizen can be helpful in eliminating non-added value activities in a way of continuous improvement. Ultimately, by combining these two philosophies, Lean and Automation, we make a new philosophy, Lean
Automation, which can help us to have an effective automated production line.

5.2 Future work

This research is just the starting point of a long way. In this research, some preliminary aspects of Lean Automation is reviewed, nevertheless this issue is a new to the researchers' interest, some notable work has been done to vast the realization of different aspect of this issue. For future, researchers can justify the Lean principles (14 principles) and introduce the Lean Automation principles, that is, in future the researchers can upgrade Lean principles to Lean Automation principles. Another viewpoint about the future work is the communication between human and robots, as this is a requirement for Lean Automation, researchers can investigate the use of artificial intelligence in this subject, thus by this, we can accommodate more human perspectives in an automated production cells.
LIST OF REFERENCES


