Implementation of quality control in order to assure the quality of a manufacturing process within a production line

Implementering av kvalitetskontroll för att kvalitetssäkra tillverkningsprocessen i en produktionslinje

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School of Technology and Design

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**Titel och undertitel/Title and subtitle**  
“Implementering av kvalitetskontroll för kvalitetssäkring av tillverkningsprocessen i en produktionslinje”  
“Implementation of quality control in order to assure the quality of a manufacturing process within a production line”.

**Sammanfattning (på svenska)**  
Denna studie är utförd på Volvo Construction Equipments i Braås, vilka är världssedande inom tillverkning av anläggningsmaskiner för byggarbetsplatser. Kvalitén är en viktig faktor vid ökning av produktionskapacitet i en tillverkningsprocess då den påverkar mängden felfria produkter. I denna studie läggs vikten vid implementering av kvalitetskontroll för att kvalitetssäkra tillverkningsprocessen i en produktionslinje med fokus på den manuella och automatiska hanteringen inom tillverkningsprocessen. Genom standardisering och analysering av de samlade och mätta data från tillverkningsprocessen kommer kvalitén att säkras genom särskilt utformade kvalitetskontroller. Detta resulterar i en utvecklad manual för implementering av kvalitetskontroller vilket kommer att medföra att kvalitén förbättras. Kvalitativa och kvantitativa mätningstekniker har tillämpats i syfte att kunna utföra en nulägesanalys av situationen i produktionen, vilket är väsentligt vid utförande av förbättringar. Intervjuer har utförts för att identifiera brister i kommunikationen mellan operatörer och deras chefer. slutsatsen av detta arbete blir att använda manualen för implementering av kvalitetskontroller och styra tillverkningsprocessen.

**Nyckelord**  
Kvalitet, kvalitetssäkring, mätningar, implementering, kvalitets kontroll, kvalitets verktyg, process kontroll, standardisering

**Abstract (in English)**  
This project is performed at Volvo Construction Equipments in Braås, which is one of the world leading producers of equipment for construction places. The quality aspect is an important factor when increasing the production in a manufacturing company and the role of quality should be highlighted in order to increase the level of error-free products and better production methods and tools. This case study emphasizes ways of implementing quality control in order to assure the manufacturing process with a focus on the manual and automatic handling. By standardizing and analyzing the collected and measured data in the manufacturing process the quality will be assured by implementing of quality control. The result of the study is to use a developed manual for implementation of quality control, which will increase the quality level. To reach the goal of this study qualitative and quantitative measurement has been used for identifying the present situation and which factors that is important when making improvements. Then interviews have been performed to define gaps in the communication between managers and operators. The conclusion is to use a manual for how to implement quality control and controlling a process.

**Key Words**  
Quality, quality assurance, measurements, implementation, quality control, quality tools, process control, standardisation

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This report is the result of the degree work in Therotechnology for a Master degree in Production Manager, at Växjö University during the spring of 2007. The project is made as an investigation of the existing quality situation at the case company, defining how to control and keep a satisfying quality level.

Through this project the researchers have learned about how to combine existing theories with the empirical findings in a real company situation by collect necessary data, calculate and analyse. The aim of the report is to select the best suitable way to develop a manual for implementation of quality control in a manufacturing process based on relevant data from an existing company.

The group would like to thank the case company Volvo Construction Equipment in Braås and the contact person Joakim Carlborg for giving us the opportunity to evaluate and analyse their manufacturing situation, his support and information regarding the problem addressed. Also we would like to thank the production leader Tommy Abrahamsson and the production technicians for their support regarding necessary information about the company. Last but not least a great thank you to our supervisor Göran Lundgren at Högskolan i Kalmar for his support regarding the report and structure of the project.

Växjö 25 of May 2007

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1 Introduction

The introduction part will give an overview and general description of the problem area addressed in this study.

1.1 Background

Quality is today known as the path to gain and keep a good place on the market and has historically shown to be the given reason for the Japanese success over the traditional American organization (Vroman and Luchsinger, 1994). As the subject of quality became a trend in the 1970s, methods of managing, control and assurance of the quality in every level of the company became an important aspect.

Total quality management (TQM) is the most common strategy that involves achievement of quality through the whole organization from suppliers and customers, processes, functions, and operators (Sandholm, 2000). The Japanese way is the TQC (total quality control), where “the ideal state of quality control is where control no longer calls for inspections” (Ishikawa, 1985). According to Ishikawa (1985) the quality must be built into each design and each process, because quality cannot be created afterwards through inspections. The quality control goal is to prevent errors.

Bad quality gives loss of sales in a competitive market and costs of poor quality through remanufacturing and costumer complaints. By controlling and assuring the manufacturing process and avoid errors and failures further along the production line, unnecessary costs can be avoided (Juran, 1988).

1.2 Problem discussion

As the market gets more competitive and the demand of a product increases, the question of production capacity will occur. This means that the quality aspect becomes more important in order to keep the market shares and produce as many error-free products as possible without having to invest in new and costly production equipments. According to Ishikawa (1985) this is the most important factor when it comes to gaining a high quality level by building quality into each design and process, which means that the quality control and assurance must begin in the raw material processing and machining, as the raw material and the basic component is the fundamental part of the product.

As the demand of the product increases, the pressure of producing in a higher speed becomes a daily situation. The quality outcome of the process decreases, especially in the manual working areas. Therefore it is important that the product has the right quality and dimensions according to a company’s standards.

1.3 Problem presentation

To be able to meet the increasing demand of the market and use the capacity available, the quality of the product must be assured and easy to control. As explained in the problem discussion the controlling and assurance must begin in the fundamental process or components, so what is the quality level of the process outcome today? Can the frame manufacturing process be quality assured? What is the most affective way to control the process? How should the quality be measured in order to gain the most accurate data? Which factors influence and affect the outcome of the quality and how can the strategies and methods for control be implemented into a functional process?
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1.4 Problem formulation
How can quality control and assurance be implemented in the early state of a process by analysing, measuring and standardizing the manual and automatic handling within the manufacturing area?

1.5 Purpose
The objectives of this project and report conclusion are to find a way for a company to secure the quality throughout the total production line by focusing on the fundamental process in the manufacturing area because of its significance for the quality of the end product. This will lead to a development of a manual to function as guidance for implementation of quality control in order to gain assurance. Through observations and interviews in the production area the researchers will learn about the company and its situation. Through this be able to develop new strategies and standards in order to gain more qualitative production output without having to invest in costly equipments or new technology, but with possibility to initiate some equipment that are cost effective and which could be helpful.

1.6 Relevance
The relevance of the project for a company is to lower cost and improve profit through minimising failures and re-manufacturing by controlling and assuring the quality of the product. By producing “good quality” products the company will gain a stronger place on the market. As the demands on the market increase, the need for higher production speed and more capacity will occur, which could lead to stress and problems causing quality failures.

Since there already exists a lot of information regarding the subject of quality in the literature, the relevance of this project is to develop a useful guideline of how to implement quality control in order to achieve quality assurance in a manufacturing process. Other companies with similar situations can use the results of this project in order to find a suitable solution for their processes. Therefore the results of this project can affect an industrial company in a manner of improving its quality in the manufacturing process. From the usual four main causes in the cause and effect diagram, ten causes has been developed in purpose to give the researchers interview a wider range in order to gain a clear overview on many fields of the particular manufacturing process and for the relevance of the project.

1.7 Limitations and delimitations
The limitations of this project are the time of ten weeks according to the schedule from Växjö University and the authors’ knowledge regarding the topic of quality work and work strategies are connected to the courses taken and literature viewed during the education time.
Aspects regarding quality work within the case company will only be viewed from the chosen factory’s point of view, with a study focus on the fundamental manufacturing area. However the result should be possible to implement and use on the total production line. Cost for computer systems or new investments in expensive equipments will not be calculated, as the aim of the project is to use existing technology and education methods.
The delimitations are due to the limited time and therefore the measurement of quality of the manufacturing process can not be performed in a quantitative way as the lead time of one object is to long. This means that the researchers need a couple of weeks for perform the measurements in the production area to gain valid quantitative data useful for the project,
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therefore the quantitative measurements will be based on already existing data collected by the company. Instead a qualitative measurement will be performed by the researchers in form of interviews to show the quality level of the manufacturing process through the operators’ point of view.

### 1.8 Timeframe

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*Figure 1.8.1. The timeframe of the project, presented in a Gantt chart.*
2 Research methodology
The methodology will give an understanding about how the problem is approached, existing strategies for a case study, which data that is necessary and important tools, models and methods to be used.

2.1 Research strategy
When performing a study the goal is to find a conclusion, but what kind of conclusion is the researcher looking for? There are different ways of approaching a study depending on the strategies used the conclusions will be different. The process of how to draw a conclusion can be divided into inductive, deductive and hypothetic-deductive approach.

*Inductive* approach is when the researcher draws general conclusions out of a few observed case studies or collected empirical findings (Thurén, 2002). The researcher can do an exploring study without having any existing connection to earlier founded theories, and by doing the study find and develop an own theory. The wideness or usefulness of the conclusion or developed theory can be hard to define as the study usually is based on a smaller group of case studies of empirical findings (Patel and Davidson, 2003).

*Deductive* approach is a conclusion based on logic and is valid if it has a logic connection (Thurén, 2002). The researcher is making the study on already analysed and accepted facts, by drawing new conclusions based on existing theories. The limitation of using an existing theory as the study object is that the study is affected by the theory and can decrease the possibility to gain new interesting empirical findings (Patel and Davidson, 2003).

*Hypothetic-deductive* approach is deductive conclusions based on hypotheses drawn from the already existing theories (Thurén, 2002). With the aim to gain a conclusion closer to reality, the hypotheses are empirically tested in real life in order to define the validity of the conclusion. Even in this approach the conclusion is affected by the studied theory, but the researcher gets the opportunity to test the conclusion before developing a new theory (Patel and Davidson, 2003).

The study strategy can be done in a qualitative or quantitative way, where the focus lays on the number of study objects or cases that are viewed during the research or how much knowledge there are to collect. A qualitative study aims to give a deeper knowledge, while the quantitative study gives a wider description from different point of views (Patel and Davidson, 2003).

2.1.1 Research strategy used in this project
This research will use a hypothetic-deductive approach, where the main question or the problem formulation, regarding implementation of quality control in order to gain assurance, is the base for the report. The theory that is connected to the subject is collected and viewed to understand the theoretical process of how to control and assure quality within manufacturing. The study object will be evaluated and the existing situation will be defined. The result of the study will give a conclusion that helps to define how to apply and gain the goal of the theory in an industrial work area similar to the empirically tested area. In other words how to measure, control and assure the quality within the frame manufacturing at the factory in the case study.

The study strategy will be qualitative, meaning that only one company and production area will be evaluated and analysed and thereby give more information and useful results.
2.2 Research technique
Regarding the study techniques, these are usually divided depending on to the amount of knowledge of the problem or that problem area and which kind of knowledge that is available and useful. The techniques can be divided in explorative, descriptive and hypothetically testing or challenging studies (Patel and Davidson, 2003).

Explorative studies are used when there are gaps in the knowledge of the problem area, meaning that more knowledge has to be collected and explored to understand the actual problem. When gathering knowledge any kind of method, qualitative or quantitative, can be used because the main reason of the technique is to get as much data as possible and give a study results that can be useful in future studies.

Descriptive techniques are used when most of the knowledge about the problem area is known and it is possible to start systemising the data into models in order to describe the figures. The descriptive study has its focus on some chosen aspects of the problem, where the description will give a more detailed view of the aspect. The method used in this type of technique is usually quantitative like figures.

Hypothetically challenging study is used when the knowledge is very high and many theories exist. When this technique is used it is important that there is a lot of knowledge of the problem area, so that hypotheses through theory easily can be connected to reality. Both qualitative and quantitative methods can be used to gather information and facts needed to connect the hypotheses, theory and reality (Patel and Davidson, 2003).

2.2.1 Research technique used in this project
This research will be made in a hypothetically challenging way, using the existing knowledge of the production area and connect it to theory in order to see if the hypotheses regarding the subject of quality measurements, control and assurance is useful, such as statistical quality control (SQC) and process control. Finally the materials and the results will be analysed through a Cause-Effect diagram and Pareto diagram, and a manual will be developed regarding how to apply quality control in order to assure the quality in reality.

2.3 Data collection types
There are two types of data that can be collected, qualitative and quantitative. Qualitative methods provide data collected through interviews, analysis, written text and other verbal methods. A quantitative method provides data in the form of measurements and figures, useful for statistic research and analysis (Patel and Davidson, 2003).

When collecting data there are many ways or methods to use, theory study is a way to search for information in a systematic way, select it and be critical to it, it is important when writing a scientific essay or report, but also in the society and working life. The task includes collecting, processing previous research and theories that are found in scientific references. This will lead to deeper understanding of which research methods that might be used and what results could be achieved and also lead to conclusions which is a starting point for a new problem formulations and methods in the project. Therefore the theory part should be studied and written before writing the empirical part of the report (Nyberg, 2000).

Brainstorming means generating ideas by free association in a group of few members, to come up with a solution to a problem. It is important that the environment is acceptable and that all participating members are of equally importance. Each member in the group shall have an opportunity to express their ideas. No negative comments are allowed because all members
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should be encouraged and dare to come up with new ideas. While generating ideas it is also important to be open for other member’s ideas and develop them further. The selected idea should be based on evaluation of advantages and disadvantages of each alternative (Andersen and Schwencke, 1998).

*Internet research* is a way of making the research easier by finding requested data, which makes the contact between the researcher and the information electronically intermediated, like information research in databases, web pages, downloading research files and articles from the internet. This is united with the *information and communication technology*, which involve new technical tools which makes it easier to spread information and gain good communication (Nyberg 2000).

*Interviews* are used to gain specific information from relevant persons, places and situations by investigations, questionnaires or observations. Interview means a selection of people or one person that is interviewed by project members according to a specific model. It can be performed face to face when the subject is more deep-going or by phone when no personal attendance is needed or just some questions are requested.

**Preparation of the interview:** Prior to the interview it is necessary to establish an interview guide which is an array of questions and it should be prepared with main questions and details, and based on theory and research. It does not have to be followed chronologically.

**Realization of the interview:** When performing the interview the statements should be annotated or if possible recorded with a tape-recorder to later be able to put the information in the project exactly as it is. (It is important to think about how you asking you questions, your body language and other factors that can affect the interviewed person to give correct statements.)

**Processing the interview:** It is important to create a structure and make a compilation of questions and statements as immediate as possible while the memory is still fresh in order to avoid information errors for later work.

**Analysis of the results:** Do the analysis and interpretation of the information for searching connections, opposites in the collected material. Think about if the result gives the answers and solutions to your problem formulation because you may be able to generate a conclusion based on it (Andersen and Schwencke, 1998).

*Observing* different situations gives opportunities of obtaining knowledge and entirety of an situation by looking and hearing how other persons are acting in practice and not only telling how they are working. Sometimes it can be difficult to understand the observations if you are not involved enough in the process and also there is *research effect* which is a disadvantage with observations, meaning that the observation affects the person’s actions.

**Preparation of the observation:** It is very suitable to combine observations with interviews to gain more information. Before any observations are done and to avoid the research effect it is good to be on the place where you will observe just so that the participants will be familiar with your presence and so that you are more involved in the process. An advantage is to interview the persons before you are observing them in order to make yourself prepared for the observations. Also interviews can be done after observations to control how the working situation is in agreement with the impression from the observation.

**Realization of the observation:** While observing it is important to make notes and also know what and who the focus should be on. A standard pattern can be used beforehand when making notes. Some elements in the standard pattern should be included such as: time and day, place, attended persons and which type of situation the observation it is concerning.
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Processing the observation and analysing the material: The description from the observations can be used for better understanding of the problem formulation and the material can be used for finding the solutions. Combining the material from observations with results from interviews and the theoretical part makes it possible to come up with a conclusion for the problem formulation (Andersen and Schwencke, 1998).

Pilot study: Based on the problem formulation and how the research arrangement is planned to be means that the investigation method has to be determined for accomplishment of the research. The pilot study is a method for collecting information by testing a technique. This method is performed on a group of people that are concerned with the research of the project (Patel and Davidson, 2003). This is a preparing study as the real research but in less scale. In this method you can test your investigation methods, questions and interview technique and by using the experience from the pilot study you can improve your questions and develop your technique (Nyberg, 2000).

2.3.1 Data collection types used in this project
In this research the theory study will cover the fundamentals of quality concept and methods for measuring the quality in the production which is necessary for gaining the knowledge about the topic and for later generating results and solutions. The methods that are used are both qualitative and quantitative. The qualitative data is theory studies of literature, internet and articles, observations and interviews made at the problem area and earlier work experience regarding the subject quality and the strategies used by the company. The quantitative data however are the measurements made by the company to define the existing quality. Also a qualitative measurement using a smaller amount of questions that will be used by the researchers in order to check the outcome of quality failures. The brainstorming methods will be used for generating, selecting and evaluating suggested ideas for improvements and development of a manual regarding how to implement the quality assurances and control in the production. Besides the literature book the internet research will be used for finding scientific articles which gives the latest information on the related topics of this research. The total production line will be viewed and observed to understand the flow and all connected areas before interviewing the operators in the chosen manufacturing process.

2.4 Validity and Reliability
When doing research and collecting data and information it is important to measure the right thing in the right way, especially when the research is quantitative and made in an inductive strategy. The research results must be both reliable and valid in order to give the most realistic result (Thurén, 2002).

Validity means measuring the right thing, the right factors or processes in the areas connected to the problem. Reliability is to measure in the right way, with the right equipment or methods, which gives the best understanding (Thurén, 2002).

2.4.1 Validity and reliability of this project
This research will provide the validity of the data and results by collecting the theory needed for subjects for example quality control, quality measurements and assurance while focusing on the fundamental parts of the product in order to assure a good quality from the beginning of the production process. The viewed objects are the fundamental parts of the product according
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to the company, as it is the basic component that everything is build upon. This is why the manufacturing of the frame is one of the most important processes. If the quality is not right from the beginning it will be poor throughout the whole production line and cost more than necessary. By measuring the quality output in the manufacturing area and analysing the reasons of quality failure through a Cause-Effect diagram and Pareto-diagram the present quality situation can be established.

To gain reliability of the result the measurements have to be made more than once in order to check the outcome of the measuring results. To get an additional understanding the operators, group leaders, quality responsible and all labour connected to the manufacturing area will be observed and interviewed in order to see how the work situation affect the quality and how the workers look at quality. The questions asked in the interviews are connected to every part of the process in order to gain a full view of the problem area, therefore different operators and group leaders will be interviewed in order to reach a wider perspective. As for the researchers they will obtain practical experience by gaining access and observing the manufacturing area during two weeks in order to understand the process, work, equipments and material flow, this will hopefully lead to easier understanding of connections in the process, critical areas and where to measure. The relevance of the project is to collect and develop a quality control and assurance method in order to find out how to implement it into a functional process.

2.5 Generalising

When the research is made it is important to know how useful and connected the result is to the case study, is it possible to use in other situations on other problem areas or is it just useful in the study area? Generalisation means that the researcher takes samples or measurements from one area and gain a result that is applicable in other areas or processes (Patel and Davidson, 2003).

2.5.1 This project

The aim of this research is to find how to measure, control and assure the quality within the frame manufacturing area and how to implement it in a chosen process, as a base to gain a good result that is applicable in the rest of the production as well. To secure the quality in the beginning of the process makes it easier to control and assure the quality throughout the total production line. This means that connecting processes as component preparing and assembly has to be evaluated in order to understand the affect they have on the manufacturing and opposite and through that make the result more generalising.

As good quality is the goal for most companies today, the recommended manual and work guideline for implementing quality control and assurance in a process will be useful for other companies as well by doing some small modifications to fit the specific process.
3 Theory
The theory part will give the information needed to understand the problem and theories, tools and methods necessary for evaluating the company situation.

3.1 Quality
“Quality is the degree to which the product or service conforms to customer requirements” and “it implies meeting these requirements the first time and every time” (Vroman and Luchsinger, 1994). But quality does not just happen, quality is the result of what you use as input and how you handle it in order to gain output. Quality is something that has to be worked on and continuously achieved. This means that quality demands attention throughout the total manufacturing and transformation system; the quality and suitability of the inputs, the manner in which the input is handled (delivered, stored and transformed) and how the final product is delivered, installed and used by the customer (Drummond, 1992).

There are some known factors that affect the quality; the market through competition, growth and development and money by economic fluctuations. Management through responsibility and control, manpower through technical knowledge and understanding, and motivation of the market and employees through education and opportunities to gain experience. For the manufacturing area the materials are important, the raw material used, production cost and costs for special requirements. The machines and mechanisation contributes to cost reduction and capacity. The modern information methods such as computers that give the opportunity to communicate in a wider and easier way and the mounting product requirements that has its concerns regarding environment aspects (Feigenbaum, 1991).

According to The Juran Trilogy there are three major processes that help an organisation to manage the quality. These are quality planning, quality control and quality improvements. Quality planning is the budgeting and business planning, quality control the cost, inventory and expenses control and quality improvement the cost reduction and profit improvements (Juran, 1988).

3.2 Quality control
In manufacturing the product quality is one of the most important factors that directly affect marketability and customer’s satisfaction. Quality control has been used for inspections of items after the production to make sure that they agree with the specifications and standards. Actually the quality of product can not be inspected after the product is made, because the quality must be integrated into a product already from the design stage through all processing stages until assembly stage (Kalpakjian and Schmid, 2003).

Quality control is described as “the definition encompassing structure, standards, methods and tools that relate to project, product or service” (Vroman and Luchsinger, 1994). According to the Mitra (1993) the quality control is defined as “a system that is used to maintain a desired level of quality in a product or service”. This could be achieved through planning, designing, using proper equipment and procedures, inspections and corrective actions in deviations from the product, service or process output. The quality control is divided into two sections, first statistical control and then acceptance sampling plans.

For sampled products or services the most common method of checking quality is SPC (statistical process control) to draw conclusions by analysing the outputs of a process. This method deals with sampling the process while producing or delivering goods and is also based
on decisions that are made regarding whether the process is operating as it should or if there is any problems then the process can be stopped and problem identified and solved (Slack, Chambers, Johnston and Betts, 2006). The SPC should control the process performance, making its acceptable level stable; reduce the variation in performance from its target level in order to improve the process performance. The main part in statistical process control is the control chart which register aspects of quality over some time to see if the process is performing as it should or not. The machines in the production will not give exactly the same results every time it is used because all material vary a little bit so the processes varies to some extent and also the people that works beside the machines is performing their work with a little bit variances when they doing their tasks, which means that the measurement of performance quality in the processes will vary. By using a control charts the variations will be identified and the result will show if the process is in control (Slack, Chambers, Johnston and Betts, 2006). SPC is used for improving the company’s competitiveness and is an effective approach to solve problems and improve processes (Oakland, 1999). The process control can be described in a flow chart, see figure 3.2.1.

Another applicable method for quality control is SQC (statistical quality control), used when analysing variations in manufacturing processes and putting the measurement data into a control chart (Sandholm, 2000). In SQC the aim is on finding and eliminating problems and their causes. Quality chart is used for finding quality problems in the production process and also to ensure the stability of the output (Evans and Lindsay, 2002). The statistical quality control (SQC) is modern control of quality that has been developed in the 1930s with industrial usage of control charts by Dr.W.A. Shewhart of the Bell Laboratories. In the SQC it is important to know the customers’ requirements and the meaning of them (Ishikawa, 1985).

To control means to ensure the conformance to requirements and correct the problem when needed. There are two significant reasons of controlling the quality, by using quality control methods as a fundamental for daily management of processes and for making long-term improvements possible. Thereby having a good quality control system is necessary for manufacturing companies before any extensive quality management structure.
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

All control systems include three elements; having a standard or aim, do measurements of performance and comparison between results and standards for corrective action. An effective quality control system must have quality policy, mode of procedure and specification on how to perform process control, inspection and testing (Evans and Lindsay, 2002). The procedure of control is described by Fredric W. Taylor with a “plan-do-check-action” (PDCA-method) which is also called a Control Circle that is divided into six phases, see figure 3.2.2.

According to Evans and Lindsay (2002) they define statistics as “the collection, organisation, analysis, interpretation and presentation of data”. The data that are collected must be organised, analysed and interpreted and statistical data provides with meaningful information for managers when improving processes. The statistical concept in quality management is important when putting into practice the continuous improvement philosophy. The statistical thinking is a philosophy that is based on three principles:

1. The work that occurs in a system is connected processes.
2. In all processes exists variation.
3. The key to successes is understanding and reduction of variation.

By understanding processes it is possible to determine the effects of variation and the proper way of managerial actions. By defining work as process then statistical tools can be applied to generate and study consistent and predictable processes to improve them (Ishikawa, 1985).

3.3 Quality assurance

Quality assurance means using methods, which helps to ensure that the products have a predefined quality standard. Quality assurance has to do with methods and equipment that determines the level of quality of temporary products and services (Vroman and Luchsinger, 1994). A significant perspective in production operations is quality assurance combined with measurement and inspection activity (Evans and Lindsay, 2002). The purpose of quality assurance function is to have a system that ensures all procedures which has been designed and planned to be then followed in implementation. The goal of the quality assurance function is to have a formal system which constantly inspects the effectiveness of quality approach and
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

then the system should check the different departments and help them to meet their responsibilities when producing quality products. The quality assurance can be leading in product design stage by checking the procedures followed by that department. Some question can be generated to get the information from the marketing department for usage when further designing the product. The quality assurance function should be used when trying to attain to answers on the questions and if any deviation occurs then the quality assurance function would recommend the department to do changes. In this way the quality assurance function works as a watchdog over the whole system (Mitra, 1993).

The quality assurance should not only be taken into consideration when something is wrong due to the quality in the production. The operators must be responsible for quality of the process and the role of quality assurance is to support meeting this responsibility (Oakland, 1999). Depending on the company, the quality assurance can be different, usually it consists of (Vroman and Luchsinger, 1994):

*Enforcement:* Enforcement of quality is when checking goods or chemicals in-process and end-product, and this is done in old-designed organisations. In the new-designed organisations the quality assurance is accomplished by quality improvement teams with supplement support from quality assurance units.

*Failure analysis and problem solving:* In both old-design and new-design quality assurance, the inspectors have the responsibility for solving the problem.

*Facilitation:* Facilitating team solving is a part of the team structure for helping to handle; group-, organisational- and technical problems.

*Education and championing:* The quality assurance in this point of view has two important roles which are, in the new-design companies the concentration is laid on education and leadership within the quality assurance units. Then the teams need continuous training and championing of quality leadership with technical knowledge as the second role.

Every manager that is responsible for a production should try to improve and analyse the quality of the involved processes. Since some managers have the lack of technical expertise that is needed when performing the statistical tests or analyses, the quality assurance experts in this department should support the managers on this missions. The company’s quality assurance department is responsible for supervising and instructing the company’s exertion to achievement of its objective, not to do the actual quality work throughout the whole company (Evans and Lindsay, 2002).

The quality assurance is a main part of the quality control and there are three factors that are included (Ishikawa, 1985):

1. The quality must be assured in a company and meet the requirements of the consumer and national standards.
2. In case of shipment to foreign countries, all products must meet the requirements of consumers abroad.
3. The importance of quality assurance must be known to the top executive in the company and they should make sure that the company will give its outermost to achieve the goal. With effective quality assurance, the effects will be satisfied customers and also executives, increased sales and earned profit.
3.4 Quality measurement and standards
To be able to gain higher quality and to plan the manufacturing in a way that supports the quality, measurements are needed in order to establish standards (Juran, 1988). Measured quality means setting a value to the output in a process and put it into quality tools which keeps the level of quality connected to the process (Vroman and Luchsinger, 1994). Measurements of an activity or process can be made directly or indirectly depending on how available the activity is. For an internal measuring of quality it is important to break down the steps within the process and measure in more direct way in order to understand and define the output of all activities. An indirect measurement can be made by determining the final customers’ view of the quality of the product. Two measuring tools or methods can be used for the internal measurement, the SPC (statistical process control) and the SQC (statistical quality control).

The standards are established by the company through the results of measurements and the amount of finished products that come out without defects or as little re-work needed as possible. There are a lot of available systems or certification schemes on the market that help a company to achieve quality within the organisation. One example is the ISO9000 series, containing different certificates for different kind of quality areas providing guidelines for the company (Wellemin, 1990).

3.5 Quality tools
When it comes to measuring and presenting results of quality there are seven quality control tools (7QC) that are helpful for quality improvement; Flowcharts, Check sheet, Histograms, Pareto diagrams, Cause-Effect diagrams, Scatter diagrams and Control charts (Evans and Lindsey, 2002). These 7QC-tools are included in Total Quality Management (TQM) which is a Japanese concept for managing a company with the aim to achieve quality in every activity and at the same time accomplish the company’s goals (Grimsdal and Gunnarson, 1993). The different areas of application for different tools are (Evans and Lindsey, 2002):

1. Flow chart is used for identifying sequence of activities or the flow of material and information in a process, and is used for understanding and establishing control procedures.
2. The check sheets are tables that are used for collecting data.
3. Histograms are statistical tools that show frequency or number of observations of particular value or group and is used for identifying problems.
4. Cause and effect diagrams are used for generating ideas and identifying possible causes to problems.
5. Pareto diagram is used for understanding and identifying problems and also analysing the collected data from the check sheets.
6. Scatter diagram is used for developing solutions and these diagrams appoint the important relationship between particular variables.
7. Control charts are used for understanding the variation. A tool used to identify the changes over time and defects in samples with constant size.
3.5.1 Cause and effect analysis
Cause and effect analysis is an analytical method used for investigating and analysing problems. The purpose is to find possible root causes and to indicate the possible fields of where to collect information with the goal to find solution to the problem. The mode of procedure is described in four steps (Kanji & Asher, 1996):

1. Brainstorm possible causes of the problem or effects to analyse them.
2. There are four M:s that are the usual major causes, material, manpower, methods and machinery. Other causes could be processes, equipment, instruction and situation. For every major cause there should be classified sub factors or contributors.
3. The cause and effect diagram can then be drawn in an Ishikawa (fish bone) diagram, see figure 3.5.1.1.
4. For every classification the effects should be defined.

![Cause and effect diagram](image)

Figure 3.5.1.1. Cause and effect diagram (Evans and Lindsey, 2002).

The Cause-Effect diagram is founded by Kaoru Ishikawa from Japan and because of its appearance it is often called fishbone diagram. When the causes and effects are sorted at the end of the Cause-Effect diagram the main problem is listed. The branches that are attached or connected to the problem causes are contributors to those causes. The Cause-Effect diagram shows the causes to a problem in order to gain more data and give inputs for an analysis of the situation (Evans and Lindsey, 2002).

3.5.2 Pareto analysis
The Pareto method was developed by Joseph Juran in 1950 and is used for analysing the data related to a problem and identifying the most significant factors to this problem. This method is also called 80/20 rule which means that 80 percent of the problem is caused by 20 percent of the activities. The focus should therefore be on 20 percent of activities which are the most important or significant factors (Kanji & Asher, 1996).

The analysis differentiates the most important causes from less important and gives a direction for choosing projects for improvement. A Pareto distribution is created for observing and ordering characteristics of causes from greatest to smallest. This is needed in order to draw a Pareto diagram that is a kind of histogram distributing the greatest frequency to the smallest.

A cumulative frequency is drawn which is a curve that shows the relative size of the defects and is also used for determining the opportunities for improvements. The most significant problems will be visible (Evans and Lindsey, 2002).

The mode of procedure is described in six steps (Kanji & Asher, 1996):
1. The causes or activities should be listed in a table and the number of times they occur should be noted.
2. Then they should be ordered downwards in the table.
3. Calculation on the total should be done for the whole list.
4. Calculation of the percentage should be done of the total that each cause signifies.
5. Then a Pareto diagram can be drawn. The vertical axis should represent the percentage of total and the horizontal axis of the diagram should represent the cause or activity. Afterwards the cumulative curve can be drawn that represents the percentage from all causes.
6. The result should be interpreted.

The table of Pareto analysis consists of error description, error code and sum of occurred errors. Also a percentage of the total and percentage of accumulative are included. Then the Pareto diagram will carry out the significant errors that should be eliminated (Kanji & Asher, 1996).

3.5.3 Control chart
The control chart is a graphical method used to evaluate if a frequently used process is or is not under “statistic control” and within the company’s standard limitations. The technique is usually for in-process control, where the measurements are made in the period of hour-by-hour or day-by-day, to understand the changes of the outcome during one day or one week (Feigenbaum, 1991) and to identify when the number of defects occurs (Kanji and Asher, 1996).

An upper, lower and mean control limit is established based on the company standards and by doing periodical sampling and plotting of the outcome result the control chart will give a view of how even and within the limits the outcome is and at which time a day or week (Feigenbaum, 1991).

This can give the input of which time in the period is the quality outside of the limits, is the quality affected after lunch or is it affected by setups in the morning and who is working with the product during this time.

![Control chart](image-url)
3.6 Quality improvement

Improvement are changes to reach a better state and can according to Sandholm (2001) be divided in to two sections. The first one is improvement made to meet customers’ needs and the second one are the changes made to improve the production processes.

As explained in chapter 3.1 is quality improvement, according to Juran (1988) one of the major processes used for managing quality within an organisation. Quality planning prepares the process with activities needed for reaching the requested quality level and quality control that controls the operating activities in order to keep the requested quality level throughout the total production line. While quality improvement is basically the effort or activities used to gain a higher quality level than before (Sandholm, 2000).

When working with Jurans philosophy of quality improvements some steps are to be followed (Mitra, 1993);

1. Prove the need for improvement
2. Identify specific projects for improvement
3. Organise to guide the projects
4. Organise for diagnosis – for discovery of causes
5. Find causes
6. Provide remedies
7. Prove that the remedies are effective under operating conditions
8. Provide for control to hold the gains.

While Deming goes deeper into the causes, he is collecting information regarding (Drummond, 1992);

- Products
- Methods of production
- Material requirements
- Marketing (handling) strategies
- Training and education

One important way to gain good quality is according to both Deming and Crosby (scientists in the subject of quality) to focus on education for both the managers and their operators in order to gain and work with the same understanding and towards the same goals (Mitra, 1993).

Figure 3.6.1. The organisational structure of Deming’s philosophy on quality education and training (Mitra, 1993).
The quality thinking should be established at the working station and known by every operator. When causes for quality failures are found, they have to be evaluated in order to be improved. 

**What is the origin of the defects or failures?**
- Design
- Manufacturing
- Etc.

**How are the defects or failures primarily managed?**
- Management-controllable
- Worker-controllable
- System-controllable

By using the PDCA method (plan, do, check and act) a continuous improvement can be gained through learning from earlier experiences (Evans and Lindsay, 2002).

### 3.7 Process management

To be able to control a process, the management and limitations must be defined. The management can be defined through a three phase method by; initialisation, definition and control (Melan, 1992).

**Initialisation** consists of two steps, establish and assign ownership of the process and define boundaries and interfaces.

**Definition** of the process is establishing a baseline for evaluation of the process and finally the **control** phase that consists of defining control points in the process, do measurements in order to understand the flow and its output and by performing feedback and correction action gain improvements of the process (Melan, 1992).
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

3.8 Welding process
Welding is in easy terms a way to join two pieces of metal together using a pressure or heating process. The heating process can be made through fire welding or electrical resistance spot welding, where the usual energy source is electrical, chemical, mechanical, light or sound. The process of welding offers to create strength and permanency to the joining of metal, which is why it is so often used in construction (Pritchard, 1996).

3.8.1 Welding techniques
There are different kinds of welding techniques such as lead soldering, brazing, TIG (tungsten inert gas), MAG (metal active gas) and MIG (metal inert gas).

MIG or MAG is a welding technique that provides versatile and fast welding with a wide thickness range. In this process the electrodes create the form of a fine wire, which is continuously pushed through to the arc (weld pool) where it is melted and transferred on to the plate as weld metal. At the same time a shielding gas is fed to the weld area in order to protect the weld metal by excluding the air, this to give an even quality of the welding line from the beginning to the end (Pritchard, 1996).

The process of welding with MIG technique is easy, but to set up the weld in order to produce a good result is more complex. It is very important to know and understand the parameters before starting the process in order to use the advantages of this technique (Pritchard, 1996).

3.8.2 Quality in welding
There are many factors interfering with the result of welding, the four main once are; the type of material being welded, the consumables used to hold it together, the procedures used to make the joint and the skill of the welder making the joint. There are a lot of fault that could appear in a welded area (Pritchard, 1996):

- Lack of penetration, when the welding does not cover enough.
- Over-penetration, more welding than needed.
- Lack of fusion, where empty space within the welding occur.
- Undercut, the welding surface is not even.
- Overlap, the welding is over the surface, more than needed.
- Cold lap, especially for MIG, meaning lack of fusion/overlap.
- Porosity, gas entrapment, lack of gas in the process.
- Blowholes, gas whole large enough to be seen on the weld surface.
- Spatter particles of weld is thrown out on the plate surface, making it uneven.

Special failures appearing in the MIG and MAG techniques are (Pritchard, 1996):

- Scattered porosity: Gun at acute starting angle, build-up of silicate slag, oil or other deposits on metal.
- Heavy porosity: Windy condition, not enough shielding gas, no gas turned on.
- Cold lapping: Wire feed too high, voltage too low, welding speed to low, arc not on leading edge of pool.
- Unstable arc: Voltage either too high or too low, clogged contact tip, wire feed erratic, poor return connection.
- High bead with overlap: Voltage too low, wire speed too high.
- Flat rough weld: Voltage too high.
Common failures in welding are pores and blind faults, those can have different causes. The pores in the welded work piece are due to disturbances in the gas protection and its causes are (Karlebo and Weman, 2002):
- The amount of gas protection is faulty adjusted, the flow must be enough and suited for the welding current. If there is to high amount then the whirl formations in the gas mouthpiece causes problems.
- Depending on if there is draught/draft in the place where the welding is performed, the gas protection will be disturbed if the air speed is over than 0.5 m/s.
- The clogged canals or leakage can cause that the gas flow will not come forward and that is why the gas flow should be control measured at the pistol orifice.

The blind fault between the foundation materials can cause problems and the causes are (Karlebo and Weman, 2002):
- At a wrong adjustment and low weld current, low electrode dispatch and when the supplement of heat is not proportional to the melted foundation material.
- If the arcs orifice is not correct along the weld, the fuse can run before the electric arc.
- Great heat department at the coarse work pieces.
- Too narrow joint angle.

One joint edge is not enough heated up because of the electric arc is wrongly directed.
4 Empirical findings

The empirical part provides information regarding the production area and the activities involved in the manufacturing. This part is based on observations, interviews and practicing experience.

4.1 The company and its product

This study is made at Volvo Construction Equipments (CE), located in Braås. Volvo CE produces equipments for construction places and is identified as one of the world leading manufacturers of construction equipment, which provides some of the most productive and efficient machines on the market. Volvo CE offers full range of excavators, wheel loaders, articulated haulers, backhoe loaders, skid steer loaders and motor graders.

The company vision is to be an example of quality and customer satisfaction and care on the market of construction equipment (“One company vision – Volvo CE”, 2007).

The factory in Braås was established in 1966 and produces the product articulated hauler. The production includes component manufacturing and processing of raw material, preparing of raw material and components as well as assembly and final testing of end product. The articulated hauler is a product developed by Volvo as a transport machine with the capacity to transport a large amount of material or heavy weight in difficult terrain. The special construction of the product gives the ability to get to and from loading and unloading sites without having to build temporary roads (“Volvo in Braås”, 2007).

The product is produced in four different models, A25D, A30D, A35D and A40D, based on the loading capacity in American tons. The product is built on one front frame and one rear frame, where the connections between the frames give the product its speciality of a very wide moving angle and the possibility to turn around using a limited space.

As the demand on the market increases the need for faster production speed occurs, which gives less amount of working time for each object and could cause lower quality of the end product.

4.2 The frame manufacturing area

The articulated haulers two fundamental parts or components are produced in the frame shop, as shown in figure 4.2.1.

![Figure 4.2.1. The production area for articulated haulers at Volvo in Braås, with the frame manufacturing area marked (Volvo in Braås, 2006).](image-url)
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

The frame shop or frame manufacturing area is divided into two parts, one for the front frame and one for the rear frame. They also divide the type of product model produced into the light and the heavy product, where the light product consists of models 25 and 30 and the heavy of models 35 and 40.

The object is produced from automatically welded plates and put together into a frame in the tack-welding area by 1-2 operators per fixture, doing the tack-welding manually and afterwards sending the object into a buffer area waiting for the automatic welding work. Then the frame is put into one of the robot welding cells, getting the accurate welding that is necessary, providing straight welding lines. After that the frame goes into the waiting area or buffer again before being moved for the final welding, where the extra manual welding work is done on difficult areas or areas in need of rework. Then the frame is transported to the next production station, the shot blaster. For more details see figure 4.2.4 (Production technician, 2007-04-11).

Figure 4.2.4. The frame (shop) manufacturing area and material moving direction at Volvo CE in Braås.
This frame manufacturing area is working in morning, afternoon, night and weekend shifts. The morning and afternoon shift each includes 18-20 operators. The main organisation surrounding the manufacturing area consists of a group of operators producing the objects (frames) with the group leader, as well as the quality responsible and the production leader. Sub-organisations or supporting systems are the IT-department, quality department, maintenance department, production technician department, human resources, economy and logistics, see figure 4.2.5.

4.2.1 Introduction and education of operators
The newly employed welding operators get an introduction with information about the reception, company information, instructions, supervision, etc and are provided with information according to the introduction lists. These lists are: fundamental information for the operator, welcome sheet, supporter’s duties sheet and instructors welding sheet. The production leader or supervisor is responsible for introducing the new employees. Education regarding welding is made by an external company before starting the work in order to secure the welding skills and performance of the new operators. Five objects will be produced by the new operator as a test before beginning to work in the process.

The welder operators should be provided in the beginning of the introduction with a welding instructions and a round tour in the production. Before they start to work in the production each person has to show their own skills in welding and depending on the need of extra knowledge, extra education is performed in 1-4 weeks. A repetition of reading the welding drawings is performed with the quality responsible person. The operators get a supervisor who is responsible for the specific card of each object. Each newly employed operator should do these five objects during the same shift and at least two objects should be done in front of the supervisor. Then the objects should be controlled by an instructor before
the operator passes the test. After a month a revision is performed on one object and a follow-up after three months when another object is revised (Production technician, 2007-04-11).

4.2.2 Existing quality work and standards
The welding operators have the responsibility to report all failures after finishing the welding of a frame. The operators should fill in the information about the type of failure, number of failures, which frame it concerns (rear or front frame) and its manufacturing number, when the failure occurred, assurance welding control and sign it in a compilation form called “Control of the finished frame”. According to the production technician there are some problems in the welding process where the end product has some failures which are detected in quality check, in the end assembly or after the product is finished. The same numbers of failures are not reported as there are actual failures in the end product. Then there is a problem of getting the right information from the welding operators and possibly problems in communication between the operators or the operator and the job manager. The welding operators are provided with instructions about general rules for tack welding, which consist of three rules for tack welding, re-welding and welding. The tack welding should have the length of 30 mm, have a maximum a-measure of 2 mm and it should be avoided to tack-weld in the beginning or end of the corner of the work object. The re-welding should be done if the slit exceeds 2 mm and with welding joint obstruct the joint so that the robot that welds does not blow holes on the side of the joint. The welding should be done according to the terms of the specification or drawing (Production technician, 2007-04-11).

The Volvo CE uses a quality forum called quality council that consists of information regarding which quality tools and quality methods that is usable. The Juran approach, Six Sigma and other quality tools are applied to fit the production and all these tools and methods are put together in a program called “Volvo CE Quality Improvement Program” (TQM manager, 2007-04-16).

Quality is an expression of Volvos goal to offer reliable products and services. In all aspects of the operations, from product development and production, to delivery and customer support, the focus shall be on customers’ needs and expectations. Their goal is to exceed the costumer’s expectations. With a customer focus based on everyone’s commitment and participation, combined with a process culture, the aim is to be number one in customer satisfaction. This is based on a culture in which all employees are responsive and aware of what must be accomplished to be the best business partner (Quality Policy 960-Q-eng, 2007-05-23).

4.3 Interviews
The interview questions developed by the researchers are based on ten major causes that give information about the situation for the operators and their way of working. Some important questions from the result of the interviews have been highlighted in figure 4.3.1. See the total result in appendix 1.
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

<table>
<thead>
<tr>
<th>Question:</th>
<th>Less than 2 year:</th>
<th>2-4 years:</th>
<th>More than 4 years:</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have earlier experiences of welding?</td>
<td>8 Yes 1 No</td>
<td>7 Yes 3 No</td>
<td>2 No 2 No</td>
<td></td>
</tr>
<tr>
<td>Have you received any extra education in order to be able to do the work?</td>
<td>2 Yes 7 No</td>
<td>4 Yes 3 No</td>
<td>2 No 2 No</td>
<td></td>
</tr>
<tr>
<td>Did you get an introduction before starting to work at the frame manufacturing station?</td>
<td>6 Yes 3 No</td>
<td>4 Yes 3 No</td>
<td>2 No 2 No</td>
<td>Some introduction was two weeks late, after starting the job.</td>
</tr>
<tr>
<td>Did the introduction include quality?</td>
<td>6 Yes 3 No</td>
<td>1 Yes 6 No</td>
<td>2 No 2 No</td>
<td>The introduction did not include round tour for all operators, which would make it easier to be involved in the company and its working area to get a holistic view.</td>
</tr>
<tr>
<td>Do you feel that the introduction should have included more things?</td>
<td>4 Yes 5 No</td>
<td>3 Yes 4 No</td>
<td>2 No 2 No</td>
<td>It would be good with more safety in the production. To understand drawing is important which some operators has difficulties with and also to know which the standards are.</td>
</tr>
<tr>
<td>Could something's make you more motivated?</td>
<td>6 Yes 3 No</td>
<td>7 Yes 0 No</td>
<td>2 No 2 No</td>
<td>The operators would be more motivated if they got a credit for good work, cake or recompense, to hear from managers that they are doing a good job, more care and help from the managers, keep the overlapping of shift times and communicate more with colleagues, extra activities outside of work time, and variation in the work area. The management could be more involved in the operators work and understand it more.</td>
</tr>
<tr>
<td>Are there always material available?</td>
<td>6 Yes 3 No</td>
<td>2 Yes 5 No</td>
<td>2 No 2 No</td>
<td>The material is available 98% of the time. Sometimes when the operators have to wait for material then it is often that the material is not ordered in time.</td>
</tr>
<tr>
<td>Does the raw material have the right quality?</td>
<td>6 Yes 3 No</td>
<td>2 Yes 5 No</td>
<td>1 Yes 3 No</td>
<td>The quality is okay, but sometimes very bad. When the material does not have the right quality it is often because of bent metal sheets or plates and a lot of sand in the castings. The laser misses and makes holes that have to be polished. Also previous work by the robot and pores in the material affect the quality. Even suppliers make their own failure when making the material. Sometimes the material is dirty and oily.</td>
</tr>
<tr>
<td>Do the demands of the market affect the work of the process?</td>
<td>6 Yes 3 No</td>
<td>6 Yes 1 No</td>
<td>2 No 2 No</td>
<td>Production speed increases.</td>
</tr>
<tr>
<td>Could the welding methods be improved?</td>
<td>5 Yes 4 No</td>
<td>3 Yes 4 No</td>
<td>2 No 2 No</td>
<td>The welding methods could be improved by new machines, standards of welding techniques, choice of wire in the welder. To take away media posts where the welding piece sits. Everything is good for better development.</td>
</tr>
<tr>
<td>Do you often have problems with the machines?</td>
<td>6 Yes 3 No</td>
<td>6 Yes 0 No</td>
<td>4 No 0 No</td>
<td>The usual problem with the machines is robot problem, wire problem, pressure, and problem with the tube package every second week. The problems occur for someone almost every day and for some every week.</td>
</tr>
<tr>
<td>Do you fix the problem by yourself?</td>
<td>3 Yes 6 No</td>
<td>4 Yes 3 No</td>
<td>2 No 2 No</td>
<td>As long as it is possible the operators fix the problem by them self, otherwise asks for help from managers or others operators.</td>
</tr>
<tr>
<td>Do the machines or the tools affect the quality of the frame?</td>
<td>7 Yes 2 No</td>
<td>6 Yes 1 No</td>
<td>3 Yes 1 No</td>
<td>If the quality is affected then it is less quality product.</td>
</tr>
<tr>
<td>Do you maintain your equipment?</td>
<td>5 Yes 4 No</td>
<td>4 Yes 3 No</td>
<td>3 Yes 1 No</td>
<td>A daily maintenance is performed by the operators and fills the weld with water and changes the mouthpiece. Every Friday the service is done in welding</td>
</tr>
</tbody>
</table>
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the safety good?</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is not so safe, mostly noisy, toxic gases, dirty, smoky air, too hot during the summer.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there any extreme situations affecting the manufacturing today?</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There are some situations and factors that affect the manufacturing as rebuilding of the manufacturing area that can make it harder for the operators to work. Pores in the welding piece, robot breaks down, or run out of material. The heat on summer makes the production speed slower/decreases. When the manufacturing is still operators has to wait for material, max 30 min. Sometimes there are a lot of reports of sick workers.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it affect the quality?</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The extreme situation affects the quality in form of less time to manufacture and perform controls.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you test the quality today?</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More time to manufacture and not so high production speed, more checking and training for new operators as well as better understanding of drawings would increase the quality. Also that everybody does the tack welding in the same way and that all operators are more quality conscious.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Could something be done to gain a higher quality level?</td>
<td>7</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There is a lot of talk from the management but nothing seems to happen or it takes a lot of time. Money can be handed out to groups if they have come up with some good ideas for improvements in the production.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do they support you if you have any ideas or improvements?</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a Volvo email?</td>
<td>0</td>
<td>9</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have access to intranet?</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log in name and password is missing for some operators. One computer is too little for all operators per shift, and the place where the computer is should be more private.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you receive important information through email or intranet?</td>
<td>1</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.3.1. Selected questions from the result of the interview made by the operators at the frame manufacturing area.
4.4 Measurements
As the manufacturing time for one object is between 3-8 hours per station, the quantitative measurements will be based on data collected by the company, while a qualitative measurement is made by the researchers in order to see the difference of result.

4.4.1 Quantitative measurements
The quantitative measurements are based on data collected by the operators at the company between August 2006 and April 2007, giving the variation of the usual amount of failures and disturbance causes during this time, see figure 4.4.1.1 and 4.4.1.2.

<table>
<thead>
<tr>
<th>Period</th>
<th>aug-06</th>
<th>sep-06</th>
<th>oct-06</th>
<th>nov-06</th>
<th>dec-06</th>
<th>jan-07</th>
<th>feb-07</th>
<th>mar-07</th>
<th>apr-07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>-10%</td>
<td>13%</td>
<td>32%</td>
<td>7%</td>
<td>-36%</td>
<td>9%</td>
<td>-17%</td>
<td>8%</td>
<td>-8%</td>
</tr>
</tbody>
</table>

*Figure 4.4.1.1. Variation of objects affected more or less than usual by disturbance; quality failure, in need of rework or extra work.*

| Rework after robot welding | 59% | 59% |
| Rework after tack welding | 18% | 76% |
| Waiting for the traverse   | 11% | 87% |
| Waiting for frame wagon    | 3%  | 90% |
| Rework after training of new operators | 2% | 93% |
| Waiting for maintenance    | 2%  | 95% |
| Miscellaneous               | 2%  | 97% |
| Rework of bought material  | 1%  | 98% |
| Waiting for object         | 1%  | 99% |
| Rework after FMS           | 0%  | 99% |
| Waiting for bought material| 0%  | 100% |
| Rework after final welding | 0%  | 100% |

*Figure 4.4.1.2. Disturbances within the process, how often it occurs and how much they affect.*

4.4.2 Qualitative measurements
Measurements of quality failures are made in three different areas of the process by collecting qualitative data in form of questions.

*The chosen areas within the frame manufacturing are:*

1. At the pre-welding area, before tacking, in order to measure the quality of the raw material, plates.
2. At the robot cell, before automatic welding, in order to measure the quality of the work made at the pre-welding area.
3. At the final welding, before fixing the problems due to earlier quality failures.

Then each alternative has been weighted depending on importance or how often it occurs and is then compared to the other alternatives in order to gain a percentage rate.

*Weights:*

4 = Often, every time  
3 = Less than often  
2 = Sometimes  
1 = Could happen  
0 = Never happened
Implementation of quality control in order to assure the quality of a manufacturing process within a production line.

Which is the usual source to quality failure noticed by you?

<table>
<thead>
<tr>
<th>Control area:</th>
<th>Factor:</th>
<th>Raw material</th>
<th>Manual handling</th>
<th>Previous station</th>
<th>Miscellaneous</th>
<th>Questioned persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tack welding Rear</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Tack welding Front</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Robot welding Rear</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Robot welding Front</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Final welding Rear</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Final welding Front</td>
<td>7</td>
<td>10</td>
<td>13</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.4.2.1. Source of quality failure.

Which is the most common problem affecting your work and the quality?

<table>
<thead>
<tr>
<th>Control area:</th>
<th>Factor:</th>
<th>Material</th>
<th>Fixture</th>
<th>Tools</th>
<th>Machine</th>
<th>Miscellaneous</th>
<th>Questioned persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tack welding Rear</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>15</td>
<td>0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Tack welding Front</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Robot welding Rear</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Robot welding Front</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Final welding Rear</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Final welding Front</td>
<td>13</td>
<td>11</td>
<td>7</td>
<td>19</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.4.2.2. Problem affecting the operators work.

How do you act when you notice a quality failure?

<table>
<thead>
<tr>
<th>Control area:</th>
<th>Factor: Correct your self</th>
<th>Return to previous</th>
<th>Send forward to the next station</th>
<th>Questioned persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tack welding Rear</td>
<td>8</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Tack welding Front</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Robot welding Rear</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Robot welding Front</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Final welding Rear</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Final welding Front</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 4.4.2.3. The action made by the operators when failure occurs.

After collecting the data the percentage of each control areas and factors can be calculated.
5 Analysis
The analysing part will evaluate and analyse the data collected from the company, using the tools and methods described in the methodology and theory part.

5.1 The situation today
By taking the total answers from the operators, not dividing the working years at the station a percentage of the answers for the chosen questions can be presented and analysed.

<table>
<thead>
<tr>
<th>Factors:</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manpower:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have earlier experiences of welding?</td>
<td>85%</td>
<td>15%</td>
</tr>
<tr>
<td>Have you received any extra education in order to be able to do the work?</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td><strong>Introduction:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did you get an introduction before starting to work at the frame manufacturing station?</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Did the introduction include quality?</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Do you feel that the introduction should have included more things?</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td><strong>Motivation:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Could some things make you more motivated?</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td><strong>Material:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there always material available?</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Does the raw material have the right quality?</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Do the demands of the market affect the work of the process?</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Methods:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Could the welding methods be improved?</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>Machines:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you often have problems with the machines?</td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td>Do you fix the problem by your self?</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Do the machines or the tools affect the quality of the frame?</td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td>Do you maintain your equipment?</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the safety good?</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td><strong>Situation:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there any extreme situations affecting the manufacturing today?</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Does it affect the quality?</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Do you test the quality today?</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Could something be done to gain a higher quality level?</td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Management:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do they support you if you have any ideas or improvements?</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>Information:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a Volvo email?</td>
<td>15%</td>
<td>85%</td>
</tr>
<tr>
<td>Do you have access to intranet?</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Do you receive important information through email or intranet?</td>
<td>45%</td>
<td>55%</td>
</tr>
</tbody>
</table>

Figure 5.1.1. A total summary of the interview result presented in percentage.

The result of the interviews shows the operators view of the manufacturing situation today. Most of them seem to have some kind of previous experience of welding before beginning to work at the station. And those who does not have experience then they will be provided with education and training by the company. Most of the operators feel motivated, but there are still small things that could motivate them more like credit from the managers when doing good work, stricter policies about the working time, overlapping between shifts and
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communication. Furthermore there should be variation or rotation in the process area, more understanding from the managers like a closer contact and of course a higher salary. There are a lot of ideas for improvement, but many of the operators do not know who to give the ideas or if the ideas will ever be considered, as the feedback is not so good. When it comes to communications with the managers and the rest of the company a weekly meeting is held. Other information about future situations and changes and the production flow could be gained through e-mail or intranet (internal network). However most of the operators do not even have the account that gives them access, even if many of them would like to have that. Also the equipment is not new and is usually not functional.

When talking about the introduction before starting to work at the company or at the station, 40% of the operators have not received any introduction, quality education or understanding of the process flow. They also feel that it is very important that all operators understand and can read drawings as these are the standards that should be followed when working with the objects and welding. This problem occurs mostly among the new employed welding operators that do not yet have enough working experience in welding. Different situations affect the work process such as rebuilding, higher production speed, missing material and machine failures that of course affect the quality outcome and the quality of the welding. 50% of the operators feel like there are missing material, objects or extra material, in order to give a good production flow. The raw material has problems with keeping a good quality level. This creates more correction work for the operators which lead to a longer process time. At present the quality is tested through a revision and controllers, but the operators see his own work through the philosophy that he does “right from the beginning”. Even though they all understand that the quality level could be higher just by having a lower production speed, by using standards that gives the object the right quality from the beginning, more quality checks and more understanding regarding quality and its affects. The MIG/MAG welding method used by the company today is good, but it can still be improved, by having new machines, better standards for the welding techniques and choice of tread/wire.

The largest problem in the process seems to be the machine failures, usually the operator tries to fix the problem up to the point that he can, but then a service man have to be contacted. The operators perform weekly maintenance on the machines, like cleaning and testing pressure and refilling of water, but most of them think that the machine are causing problems and affecting the quality of the work and the product.

Finally the operators feel that the working area is not safe enough, which is a factor that most importantly must be improved.

When analysing the amounts of contributions from the ten main causes in the interview a Ishikawa diagram can be developed showing that most of the contributions comes from the causes; material, machine, introduction, information and situation. See the result in figure 5.1.2, causes and contributions affecting the quality.
5.2 Quantitative measurement

The quantitative measurement gives the information from the company’s point of view according to the data collected from August 2006 up till April 2007.

The presented data in figure 5.2.1 shows the variation of disturbance in the manufacturing that affects the objects caused by failures or rework, during a chosen period. The highest variation of affected objects is in October 2006 with 32% more disturbance than usual and then the number decreased to the lowest measured point in December 2006 with 36% less disturbance than usual. Comparing the months of the highest variation with the lowest variation of failures, the deviation between those two is the double in October comparing to December the same year, 2006. When looking at the total period it seems to be usual for the manufacturing area to have some kind of variation of failure, rework or disturbance at ± 10% of the usual disturbance per month, which of course leads to higher costs than necessary.
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Figure 5.2.2 Disturbance within the manufacturing area between August 2006 and April 2007.

According to the measurements made by the company, there are failures, some kind of rework or extra work appearing on a number of objects each month. The cumulative frequency which is the curve in the figure 5.2.2 shows the greatest frequency to the smallest where the 80% of the problem is caused by 20% of the activities. According to those measurements 25% of the activities cause 87% of the problems. As the Pareto diagram gives the possibility to identify the most critical activity or problem that the focus should be on. The result of this is to give the robot welding, tack welding and use of the traverse some extra attention.

5.3 Qualitative measurement
Based on the measurement questions and observations in the process following data was collected regarding reasons of failure and decision of failure.

Figure 5.3.1. The usual source to quality failure according to the operators.

When analysing the usual sources to quality failures that occur according to the operators can be viewed by the measurements in the figure 5.3.1 a percentage of most common sources to quality failures at the manufacturing area can be found in three types of stations: tack welding,
robot welding and final welding for respectively the rear and front frame. In the tack welding area the usual sources are the purchased raw material and manual handling. The operators at the robot welding station are affected by the previous station and the manual handling. Also in the final welding station operators are affected by the same sources of failures, mostly previous station, but also the manual handling.

Which is the most common problem affecting your work and the quality?

![Graph](image)

Figure 5.3.2. The most common problem affecting the operators work.

The most common problems that affect the operators work and the quality are presented in the figure 5.3.2. According to the diagram the tack welding station is affected by machine errors and defects in the material. In the robot welding station the operators have problems with the machine and the fixtures that are used to fixate the object during the welding process, that does not fit for the object or is not in a proper condition. The work and quality in the final welding station are mainly affected by machine problems.

How do you act when you notice a quality failure?

![Graph](image)

Figure 5.3.3. Action made due to failures, according to the operators.

When looking at how the operators act after having a failure, it is clear that they either correct it by themselves if possible or, depending on the failure, the object can be sent forward to the next station so that the failure can be corrected in the final welding. The object can also be
sent backwards to previous station where it is classified as error or out of work. Figure 5.3.3 shows the distributed actions taken by the operator when failures occur. According to the robot welding operator in the rear frame line actions such as pushing the object forward to the final welding could happen as well, where the problem can be taken care of.

In figure 5.3.4 a summary is made showing the total values from all control areas: tack-welding, robot welding and final welding both front and rear frame, giving a holistic view of the measured data. The first bar in the diagram indicates that the most usual sources to quality failures are previous station and manual handling, but even the raw material could be a problem. In the second bar it is shown that the most common problem is the machine, but also fixture problems occur. In the third bar it is presented that operators are mostly correcting the failures by themselves and sometimes they return the object as error to previous station and rarely the object is sent forward to next station without any correction or notice.
5.4 Introduction, education and existing quality work

According to the interviewed production technician the newly employed operators should be provided with the introduction that should include the information about the company, the work instructions, supervision and fundamental information such as welcome sheets, welding instructions and other specially developed sheets. The responsibility to deliver this information on the introduction days lays on a particular production leader in this particular working area. However, not all operators received an introduction before they started the work or some even got the introduction, but it did not include all important parts. It was twelve out of twenty interviewed operators that received the introduction and sometimes the introduction did not include any information about quality. Those operators that did not receive or get a complete introduction felt a need for a round tour in the company which they would have appreciated because it would have made their work easier by having a holistic view of the process flow and made them more familiar with the produced product. It is stated that a developed programme exists for the introduction and it is decided that it should be followed, but since not all operators got an introduction there is a gap in communication and performance of this task which may be affected also by how the planned time for the introduction is created.

The welding operator should show his own skills in welding before starting the work and if there is a need of extra knowledge an education will be done during 1-4 weeks to learn more. Also a repetition of the welding drawings should be done by quality-responsible persons, but according to the interviewed operators they did not get any repetition in the beginning of the work nor have they been tested by the company to see how good they can read the welding drawings. This is directly affecting the quality of the object and also the operator’s work. In order to prevent this kind of mistakes there should frequently be a repetition of reading the drawings.

It was stated by the production technician that the number of failures reported from the operators in the compilation form are not the same as the actual number of detected failures found in the end of the welding process. According to the operators they correct the failures as much they can, otherwise depending on the failure type they ask for help from production manager, send the object to the error area or send it forward to final welding area where it will be corrected. The operators might miss some mistakes depending on how well they follow stated standards, read the drawings, instructions and how conscious operators are about meaning of their quality work for the end product. The failures can in this way pass through instead of being directly corrected and later be detected in the end of the process. The existing standards should be clear to each operator as well as the drawings and the understanding of the total production process, in order to avoid failures that pass through, which indicates that a control of quality and work is needed after every finished part of the welding work.
5.5 Quality control and control of the process

Before a control of the process can be done it is important to understand, define and manage the flow and all its parts. The first phase is definition of the process station and ownership, which must be clear. Who works at the station, who has the responsibility and which boundaries and limitations does this person have? What is he allowed to do and what decisions is he allowed to make? The second phase is to define the process flow, the goals for the process, which standards are to be followed and whether the standards and drawings are available for all people involved? The third phase is to control the single process within the production flow. Which is the best control point for the single station, before the work starts, after the work is done or during the work, using a second operator for doing the control? When the control point is defined measurements should be performed, giving information about; amount of failure, needed extra time, cause of failure and state the actual problem. Now the quality control can start with a pilot case, evaluating the measurements, coming up with improvements and making necessary changes to gain a more effective process flow, see the flow in figure 5.5.1.

![Figure 5.5.1. How to define and manage the process within the company.](image)

When all single stations within the manufacturing process are defined an overview of the flow and all its control points can be shown. To gain a good flow the control points should be placed before every station, this in order to affect the flow as little as possible, see figure 5.5.2. The operator approves the quality of the object received from the previous station and thereby takes over the responsibility of the quality of the object. The object should follow the standards and drawings of the previous station in order to make the work easier for the next station and to follow his own stations standards and drawings. If the object does not have the right dimensions, quality or standards, this should be noted:

1. What kind of failure.
2. The amount of failures.
3. The causes for the failure.
4. Which action is taken to fix the failure.
5. The extra time it takes to fix the failure.
6. Person noticing the failure.

If the notice of failure is forgotten the operator who approves the quality of the object in his quality control will be responsible for this.
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

The information and measurements from the operators should be sent to management and presented in a control chart and histogram showing; the noticed failures, amount of failures, causes of failures and extra time needed, during one week or month. This information must then be available for the operators giving information about the situation.

When the situation is clear the results should be evaluated and ideas for improvements defined. Also the changes for the improvement should be made in the process stations and continuous control and feedback must be performed.

![Figure 5.5.2. Quality control points for the company’s specific manufacturing process.](image)

It is very important that the information from the operators is collected and evaluated so that their work is useful and meaningful to the company.

Through the analysed data and information received, a manual for implementation of quality control is developed in order to quality assure the process, see appendix 2.
6 Results

This part presents the results achieved in this study, based on the data connected with methodology and theory in the analysing part.

The result of this project is to give answers to the problem discussion and the questions asked by the researchers. The present outcome of the evaluated process is that the fundamental components (objects) of the product are affected by a lot of disturbance in the process flow. According to measurements made by the operators, the main problems for re-welding or extra welding are caused by the robot cell, the tack-welding or waiting time for extra equipment like the traverse. These disturbances are causing 87% of the failures, where as they are only 25% of the activities. According to the qualitative measurements the most common problem for the operators are the machines used and the fixture holding the object in a right position. If a problem occurs the operators usually fix the failure themselves. If not then they give the object an error mark and put it aside or push it forward to the final welding station.

To gain a good quality control, control points must be established within the process. Each operator has his own control point where he has to approve the passing objects according to the standards and drawings. If failures occur he must report: the kind of failure, amount of failure, causes, action taken to fix the failure, time needed and who made the notification.

The measurements should be made on the objects before the working process starts on each station giving a special focus on the manual handling, raw material and the work made at the previous station.

The measurements should be collected by the operators and given to the management that evaluates the data and presents the result in an understandable diagram viewable for the operators. The diagram should present causes of failure, which and amount of failures, time of adjustment and corrective actions.

There are a lot of factors affecting the quality within the manufacturing station, the most common and most affecting once are the material, machines, introduction, information and company’s situation.

The most affective way to control the processes is by defining the process station and ownership, the operator’s boundaries, limitations and authorities. Then the process flow should be defined, stating the standards and drawing that should be understood and followed. Finally each station should establish a control point where which data to measure should be clear. A pilot case should be performed and the result evaluated to give information about improvements and changes needed. This process should be regularly used, to gain continuously improvements. The manufacturing process can be quality assured by having continuous quality controls and making them a part of the system.

By using the developed manual in appendix 2 where the strategies and methods are combined with the data and information collected at the company will make it possible to implement the quality control in an actual process.
Implementation of quality control in order to assure the quality of a manufacturing process within a production line

7 Conclusions
So how can quality control and assurance be implemented in the early state of a process by analysing, measuring and standardising the manual and automatic handling within the manufacturing area?
Quality control and assurance can be implemented in a manufacturing process by first define the present situation of the process in order to determine the quality outcome today. Then control of the process should be performed to identify the work flow within each station, the operator authorities and standards that should be followed when performing the work. When the process is defined a quality control point should be placed before each station, giving information about the quality level before further processing. The result of the control points are measurements of quality failure, rework time, failure causes etc. By continuously performing the quality control for each station and using the information for improvements and necessary changes, the quality of the process will be assured.
8 Recommendation
Based on interviews and analyses of the collected data the recommendations to the company will be to focus on introduction, education and quality work. Every new employee should receive an introduction, which includes; information about the company and product, a round tour of the production in order to understand the process flow. To eliminate quality problem work instruction and understanding of standards and drawings should be included. The instruction time should be well planned and include information about safety, environment and quality.

The operator should be tested in welding before performing the work and in case of the need for extra knowledge they should be provided with necessary education. Frequent repetition of standards and understanding of drawings should be performed. If an operator is given a particular responsibility within the group, like quality responsible an extra education should be included. The quality controls must be performed as required by the manual on regularly bases and the communication flow between the operators and management should be continuously.

8.1 Future work
To gain a better view of the present situation a more detailed quantitative measurement should be performed, giving exact information about the causes of quality failures, such as how often they occur and what kind of failures there are. Also a pilot case of quality control should be performed to evaluate the implementation process and choice of control points.

8.2 Evaluation of the work presented
In order to get a better view of the situation today, more people should be interviewed both managers and other operators from the night and weekend shift. The measurement data is based on quality measurements and quantitative measurements, where the qualitative data is collected and evaluated by the researchers. While the quantitative data is collected by the company and then evaluated by the researchers, which means that the researchers do not know if the information is valid and affected by other factors. The information received through interviews with the operators gives opportunity to identify the gaps in communication between operators and managers, however the perspective of the operator could have been affected by the production situations and manufacturing changes made due to a increasing demand of the product.
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Mahoney and Thor (1993), The TQM trilogy: using ISO 9000, the Deming Prize, and the Baldrige Award to establish a system to total quality management. AMACOM, Amerixan management Association, New York.
Patel and Davidson (2003), Forskningsmetodikens grunder, 3ed. Studentlitteratur, Lund.

Company information and Contact persons:
Production development manager: Joakim Carlborg
Production leader (manufacturing): Tommy Abrahamsson
Production technician: Rasim Toptas and Henrik Törnblad
TQM manager: Lars Klinthäll.

Amra Jusufagic and Johanna Skoog
### Appendixes

**Appendix 1 – Interview result with comments**

<table>
<thead>
<tr>
<th>Working time at Volvo CE in Braås:</th>
<th>Less than 2 year:</th>
<th>2-4 years:</th>
<th>More than 4 years:</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manpower:</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Do you have earlier experiences of welding?</td>
<td>8</td>
<td>1</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Are you permanently employed by the company?</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Do you have a higher education than high school?</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Did you have enough technical or specialised knowledge in order to do your work as requested?</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Have you received any extra education in order to be able to do the work?</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

**Introduction:**

| Did you get an introduction before starting to work at the frame manufacturing station? | 6  | 3  | 4  | 3  | 2  | 2  | Some introduction was two weeks late, after starting the job. |
| Did the introduction include quality? | 6  | 3  | 1  | 6  | 2  | 2  | The introduction did not included round tour for all operators, which would make it easier to be involved in the company and it working area to get a holistic view. |
| Did you receive any special education from the company? | 2  | 7  | 4  | 3  | 2  | 2  | - |
| Do you feel like you are missing some education or learning in order to do a qualitative work? | 4  | 5  | 0  | 7  | 1  | 3  | It would be appreciated with more safety in the production. To understand drawing is important which some operators has difficulties with and also to know which the standards. |
| Do you feel that the introduction should have included more things? | 4  | 5  | 3  | 4  | 2  | 2  | A repetition of reading and understanding drawings would make it easier for the operator before he starts his job. The introduction was not always planned in a good way, too intensive or long introduction according the operators. An round tour in the company and production area is desired to get an understanding of the flow and the total production and product. |

**Motivation:**

| Are you motivated in your work? | 7  | 2  | 6  | 1  | 3  | 1  | Some operators are not particularly motivated for their work, they work for the salary. |
Could some things make you more motivated? | 6 | 3 | 7 | 0 | 2 | 2 | The operators would be more motivated if they got a credit for good work, cake or recompense, to hear from managers that they are doing a good job, more care and help from the managers, keep the overlapping of shift times and communicate more with colleagues, extra activities outside of work time, and variation in the work area. The management could be more involved in the operators work and understand it more.

Does the work you perform feel meaningful? | 6 | 3 | 6 | 1 | 2 | 2 | -

### Material:

Are there always material available (or do you have to wait for it in order to be able to work)? | 6 | 3 | 2 | 5 | 2 | 2 | The material is available 98% of the time. Sometimes when the operators have to wait for material then it is often that the material is not ordered in time.

Does the raw material have the right quality? | 6 | 3 | 2 | 5 | 1 | 3 | The quality is okay, but sometimes very bad. When the material does not have the right quality it is often because of bent metal sheets or plates and lot of sand in the castings. The laser misses and makes a hole that has to be polished. Also previous work by the robot and pores in the material affect the quality. Even suppliers make their own failure when making the material. Sometimes the material is dirty and oily.

Is there a lot of scrap? | 2 | 7 | 2 | 5 | 3 | 1 | Return it.

Does failure affect the end product? | 5 | 4 | 5 | 2 | 4 | 0 | It takes time to adjust the failure. No effects are on quality if the failure is corrected in time. If the metal sheets are bent it affects the tack welding and creates pores and makes longer time to finish the object.

Are standards followed? | 7 | 2 | 6 | 1 | 4 | 0 | They follow drawings, Volvo- standard and EU-standard.

Is the buffer and storage system working? | 8 | 1 | 5 | 2 | 1 | 3 | Sometimes it is good and sometimes bad condition depending on if there is need for waiting for the frames or of there is a lot of things staying in the way.

Do the demands of the market affect the work of the process? | 6 | 3 | 6 | 1 | 2 | 2 | Production speed increases.

### Methods:

Is the working method used today a good method? | 9 | 0 | 7 | 0 | 3 | 1 | -
Could the methods be improved? & 5 & 4 & 3 & 4 & 2 & 2 & The welding methods could be improved by new machines, standards of welding techniques, choice of wire in the welder. To take away media posts where the welding piece sits. Everything is good for better development. \\
<p>| <strong>Machines:</strong> |  |
|---|---|---|---|---|---|---|---|---|---|
| Do you have all machines needed for the process? | 9 &amp; 0 &amp; 7 &amp; 0 &amp; 2 &amp; 2 &amp; The tools are available and there are all necessary tools but sometimes when someone borrows it is hard to get them back. |
| Do you have all tools necessary? | 5 &amp; 4 &amp; 6 &amp; 1 &amp; 4 &amp; 0 &amp; The usual problem with the machines is robot problem, wire problem, pressure, and problem with the tube package every two weeks. The problems occur for someone almost every day and for some one per week. |
| Do you often have problems with the machines? | 6 &amp; 3 &amp; 6 &amp; 0 &amp; 4 &amp; 0 &amp; As long as it is possible the operators fix the problem by them self, otherwise asks for help from managers or others operators. |
| Do you fix the problem by your self? | 3 &amp; 6 &amp; 4 &amp; 3 &amp; 2 &amp; 2 &amp; If the quality is affected then it is less quality product. |
| Do the machines or the tools affect the quality of the frame? | 7 &amp; 2 &amp; 6 &amp; 1 &amp; 3 &amp; 1 &amp; A daily maintenance is performed by the operators and fills the weld with the water and changes the mouthpiece. Every Friday the service is done on welding pistol. |
| Do you measure you equipments, calibration, readability, error detection? | 7 &amp; 2 &amp; 5 &amp; 2 &amp; 2 &amp; 2 &amp; The electrician does measures the equipment and not the operators. The welding values are adjusted by the operators and calibration. |
| Do you maintain your equipment? | 5 &amp; 4 &amp; 4 &amp; 3 &amp; 3 &amp; 1 &amp; It is not so safe, mostly noisy, toxic gases dirty, smoky air, too hot on the summer. |
| <strong>Environment:</strong> |  |
| Is the safety good? | 4 &amp; 5 &amp; 4 &amp; 3 &amp; 0 &amp; 4 &amp; Is the social environment good? | 8 &amp; 1 &amp; 5 &amp; 2 &amp; 4 &amp; 0 |</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there any extreme situations affecting the manufacturing today?</td>
<td>5 4 6 1 3 1</td>
<td>There are some situations and factors that affect the manufacturing as rebuilding of the manufacturing area can make it harder for operators to work. Pores in the welding piece, robot breaks down, the metal sheet can end run out. The heat on summer makes the production speed slower/decreases. When the manufacturing is still operators has to wait for material, max 30 min. Sometimes there are a lot of reports of sick workers.</td>
</tr>
<tr>
<td>Does it affect the quality?</td>
<td>4 5 4 3 4 0</td>
<td>The extreme situation affects the quality in form of less time to manufacture and perform controls.</td>
</tr>
<tr>
<td>Do you test the quality today?</td>
<td>7 2 1 6 2 2</td>
<td>The quality is not tested enough! There is an inspector or controller that test the quality, not the operator by him self. The control is at the final welding and control of the robot weld. Revision is done on the frames. The quality control that the operators looks through what they have done and if their work is correctly performed.</td>
</tr>
<tr>
<td>Could something be done to gain a higher quality level?</td>
<td>7 2 5 2 4 0</td>
<td>More time, to manufacture and not so high production speed, more checking and training for new operators as well better understanding of drawings would increase the quality. Also that everybody does the tack welding in the same way and that all operators are more quality conscious.</td>
</tr>
<tr>
<td>Management:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do the management affect your way of working with quality?</td>
<td>7 2 5 2 4 0</td>
<td>The management can affect the operators work by increase the production speed which makes it harder for them to manufacture higher quality products and makes the operator more stressful.</td>
</tr>
<tr>
<td>Do they support you if you have any ideas or improvements?</td>
<td>3 6 4 3 3 1</td>
<td>There is a lot of talk from the management but nothing seems to happen or it takes a lot of time. Money can be handed out to groups if they have come up with some good ideas to realise in the production.</td>
</tr>
<tr>
<td>Do you receive the information needed from the managers, group leader, and production leader?</td>
<td>6 3 6 1 3 1</td>
<td>The information is forwarded on weekly meetings. The information could sometimes be bad or more information is desired to be provided from the management and that they does not only say what they want to be told, instead what concerns the company and more widely information about Volvo's situation.</td>
</tr>
</tbody>
</table>
Is there any information missing in order for you to do a better work? | 2 | 7 | 2 | 5 | 1 | 3 |
|---|---|---|---|---|---|

**Information:**

<table>
<thead>
<tr>
<th>Question</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have a Volvo email?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have access to intranet?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you receive important information through email or intranet?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Possibly more information of what would the future plans are and if there is any rebuilding in the production and also if there are coming new operators.

Log in name and password is missing for some operators. One computer is too little for all operators per shift, and the place where the computer is should be more private.

Does not know.
Company quality policy
The company corporate value of quality shall be received through three important factors, costumer focus, leadership commitment and participation by everybody. As quality is a measure of the company’s performance experienced by the customer. To be successful on the market the company have to understand and satisfy the costumers need, that is why it is important for the product to exceed the costumers expectations. To gain higher quality the leadership should communicate clear objectives by realise the plans in to action; Quantify-Measure-Deliver. Increase the motivation among the employees by delegating authority and responsibility to make it possible for them to reach their goals. Every employee must understand his role in the process and be willing to actively contribute to the group and the company’s objectives.

Process objectives
To meet the objectives of the company, the production process should be defined, measured and continuously improved by producing zero defects and meet the costumers need.

Manage and control the process
1. Define the process station and ownership:
   Define the responsibilities, authorities, limitations and boundaries for the operator at the station. It is very important that this information is understood by the operator.
2. Define the process flow:
   The process flow of the production should be defined, by understanding the process goals and the standards for the product. This information should be available for all people involved.
3. Control the processes within the production flow:
   Choose a control point within the each station and measure the input before processing the object (product). The measurements should be evaluated and presented as the present situation, usable for future changes and improvements. This process should be regularly used to gain continuously improvements.

Measurement routines
A quality control should be continuously performed by the operator before processing the object. The operator approves the quality of the object received from the previous station and thereby takes over the responsibility of the objects quality level. The object should follow the standards and drawings of the previous station in order to make the work easier for the next station to follow his own stations standards and drawings. If the object does not have the right dimensions, quality or standards, this should be noted.
Following measurement should be performed:
1. What kind of failure.
2. The amount of failures.
3. The causes for the failure.
4. Which action is taken to fix the failure.
5. The extra time it takes to fix the failure.
6. Person noticing the failure.

If the notice of failure is forgotten the operator who approves the quality of the object in his quality control will be responsible for this.

The information and measurements from the operators should be sent to management and put in a control chart and histogram showing the noticed failures, amount of failures, causes of failures and extra time needed, during one week or month. This information must then be available for the operators giving information about the situation.

When the situation is clear the result should be evaluated and ideas for improvements defined, changes for the improvement should be made in the process stations and continuous control and feedback must be performed.

Important aspects

Introduction:
Every new employee should receive an introduction, which includes:
- Information about the company, the production flow and product
- A round tour of the company and the production processes
- Work instruction and understanding of standards and drawings
- Supervision
- Fundamental information

The instruction time should be well planned and include information about safety, environment and quality.

Education:
The operator should be tested in welding before performing the work and in case of the need for extra knowledge they should be provided with necessary education. Regular repetition of standards and understanding of drawings should be performed. If an operator is given a particular responsibility within the group, like quality responsible an extra education should be included.

Quality work:
The quality controls must be performed as required by the manual on regularly bases and the communication flow between the operators and management should be continuously.