CHALMERS

Assembly line design and balancing

Designing and balancing the Audi B9 Mirror assembly line at SMR Automotive Mirrors Technology, Mosonszolnok, Hungary

Master of Science Thesis in the Master's programme Production Engineering

RANJITH RAJA

Department of Product and Production Development
Division of Production Systems
CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: Assembly line of Audi B9 exterior mirror at SMR, Hungary

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ABSTRACT

This thesis work presents the designing and balancing the Audi-B9 exterior mirror assembly line in SMR Automotive Mirrors Technology, Hungary. The purpose of the project is to develop an efficient and effective way of assembling the parts in order to meet the customer demands. The whole project contains investigation work, workshops and literature studies to find and develop an optimized assembly line based on the current requirements of the company provided.

To accomplish the goals, firstly analyses of balance losses and to find the ergonomic risks at the similar Audi-Q7 line was performed. Meanwhile, the requirements, data, problems definition from the company were gathered, analyzed and converted into prerequisite description in order to fully understand the purpose of the goals. Based on the prerequisites, first a deep analysis of B9 mirror design was made to find the different possibilities of assembling the mirror. With the help of tooling engineers, team leader and the collected data the fixtures and tools are designed for the workstation. During the development phase of line layout, tools and fixtures different concepts and were generated based on benchmarking or combined with each other and finally the best solutions were selected. Considering the difficulty of the tasks involved in designing the automatic workstation the whole responsibility was taken on the company side. The part involved on my side in that station is allocating the work tasks and suggestion of ideas. Later on, setting up ergonomic standards for the position of part holders, tools, working postures and picking position of materials on the assembly line were done. After all the implementation of the solutions, -the line is optimized to have a well-balanced cycle time.

At last, the evaluation of the proposed new line in different circumstances were performed and described in detail. Along with the conclusion of results, a recommendation is provided to the company for the future work.

Keywords: Assembly line design, Assembly line Balancing, Ergonomics, Assembly complexity, Poke-yoke

PREFACE

This report is the result of a Master's thesis project carried out at SMR Mosonszolnok in Hungary from August 2014 to November 2014 as part of the Master of Science programme in Production Engineering at Chalmers University of Technology.

It was excited and challenged task to do a master's thesis project in a big company. Initially to a certain extent applying knowledge to the subject was challenging, but once the focus and dedication are influenced the lack of knowledge won't last so long.

First of all, I would like to express my gratitude to my examiner Roland Örtengren for his patience and support during the thesis work. His guidance and feedback of the short reports motivated throughout the project and was crucial to the success of the thesis.

I would like to extend a special thanks to my supervisor Kónya Tamás at SMR Hungary for his trust, recommendation in my ability to do this thesis work. There are number of process, kaizen and manufacturing engineers to whom I am grateful for the help and support.

A special mention for the B9 line team leader Kodaly Zoltan for all valuable input data, guidance and understanding throughout the thesis work.

Gothenburg, February 2015

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Ranjith Raja

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1 Introduction

This chapter includes corporate presentation of the company and the background of the problem that constitutes the motivation of the project. Furthermore, the scope, objectives and organization of the project are presented along with a brief outline of the report.

1.1 About SMR

Samvardhana Motherson Reflectec (SMR) is one of the largest manufacturer of exterior rearview mirrors for passenger cars in the world and a subsidiary of Samvardhana Motherson group.

SMR develops, produces and distributes exterior mirrors, interior mirrors, blind spot detection system and a wide range of other automotive components. SMR is a global corporation with world class engineering capabilities, state-of-the-art manufacturing facilities and a global customer base. Its broad customer base includes all major car makers in North America, Europe, Asia and Australia.

SMR's competitive edge stems from ongoing innovations, contributions from a worldwide network of experts, and the use of latest design and manufacturing technologies. These are the reasons why numerous leading car makers choose to partner with SMR for the development of innovative and cost-optimized solutions.

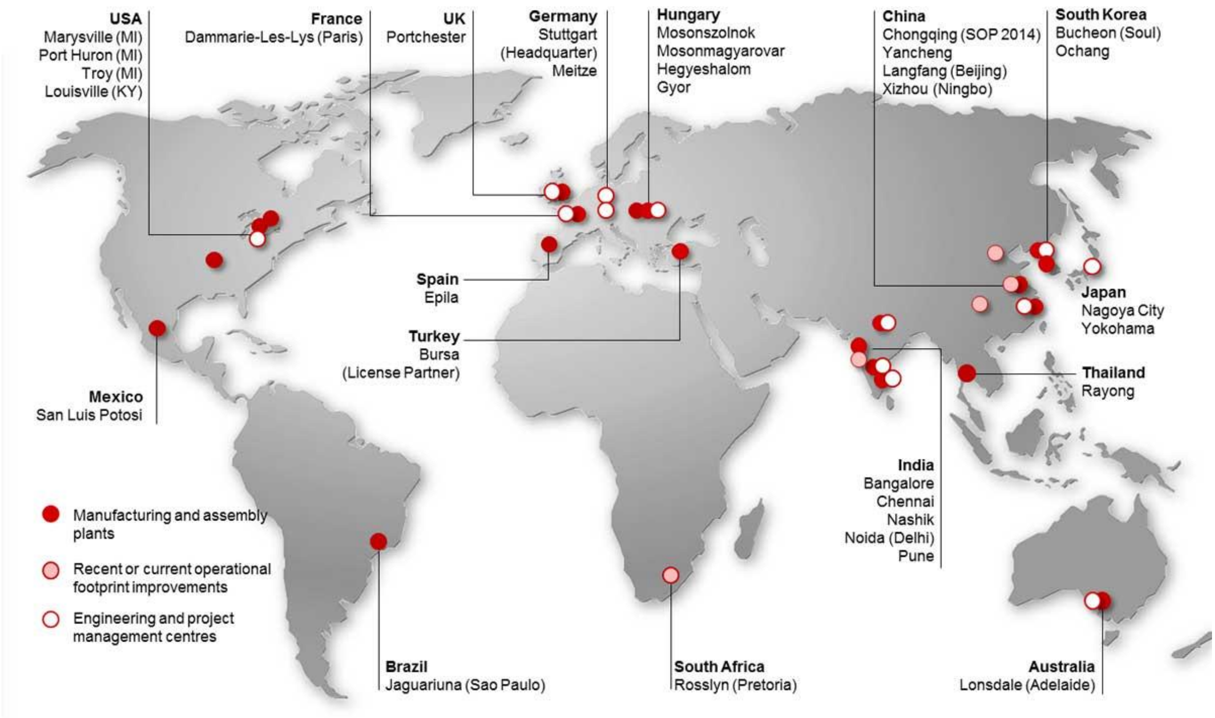

Figure 1.1 Global Production Sites of SMR

With world-wide network of manufacturing plants, SMR holds 22% of global market share with annual (2012-2013) sales of € 1.08 billion and about 8000 employees worldwide. SMR has 20 company sites worldwide that are distributed to 14 countries: Hungary, India, USA, Germany, UK, France, Spain, Brazil, Mexico, China, Australia, Japan, South Korea and Thailand as seen in Figure 1.1.

Figure 1.2 SMR Hungary, Mosonszolnok

SMR Hungary has two production sites plant 1 located in Mosonszolnok and plant 2 located in Mosonmagyaróvár. The plant 2 located in the Mosonmagyaróvár is the largest production site of SMR. The name was established in 1995 as Mosonszolnok Sapu Bt. SMR Automotive Mirror Technology Hungary. SMR Hungary produces 7 million mirror pairs per year. The company plays a key role of holding 34 % of Europe's market share.

Table 1.1 Company profile of SMR Hungary, Plant 1

Area	Open	21300 m^2
	Closed	12907 m^2
	Offices	24
	Total	34207 m^2
Employees	White collar	200
	Blue collar	900
	Total	1100
Production 2014	Volume	5200 000 mirrors

1.2 About the product (Exterior Mirror)

SMR is also a technology leader with a variety of market launches of new functions and technologies in exterior mirrors. It provides both customized tailor-made to the specific needs of its customer and standardized platform solutions providing the paybacks of low complexity and high volume.

The products are offered for different sizes of vehicles and in different price segments. The product variants are composed of different segments: cost-driven segment, medium segment, performance and premium segments and commercial vehicle segments. These segments encompass dynamic effects and safety equipment according to the law regulations.

1.2.1 New features in Audi B9 exterior mirror

The newly designed Audi B9 mirrors have a new trend. The mirrors are to be fixed in the doors and gives a greater field of vision compared to the triangle mirror float.

1.2.2 Other products of SMR

SMR also produces and distributes interior mirrors, blind spot detection systems and a wide variety of other automotive components.

1.3 Background

Production at SMR Hungary is done in a main assembly building and completed in 5-8 assembly stations that vary from mirror to mirror. The steps of exterior mirror production at SMR can be summarized as follows. The production of the mirror starts at the molding department. The ground plate, lower cover, aperture, etc. are molded in this section. The molded parts that require painting are taken to the paint shop and the rest of the molded components are sent directly to the assembly line or warehouse. The paint shop is an automated line, where the components are loaded to a paint stem and after several stages the components comes out as a painted part. After the completion of painting, the parts are stored in an after paint area for the cure time of paint. Then these parts are taken to the assembly line or warehouse according to the scheduling. Some parts of the mirrors are directly bought from the suppliers and stored in the warehouse. These parts are directly delivered to the assembly line if there is no action required to be done in molding or the paint department. When the assembly is done in the production department then the final part is packed and stored in the warehouse for shipping. Lean, and Kaizen principles drive SMR's assembling technology.

The company is currently developing a new exterior mirror design for the Audi B9. The current status of this project is that design of the mirror is in the final phase and the process engineers are working on the possible assembling methods. This is the background why the -company now asks for a thorough analysis of the mirror design and an assembly line with shortest takt time. This thesis will go deeper in the case regarding the balanced assembly line.

1.3.1 Area of focus

The emphasis of this thesis work is only the assembly line that is in the assembly department buildings. The location of buildings and factory layout of interest can be seen in Figure 1.3.

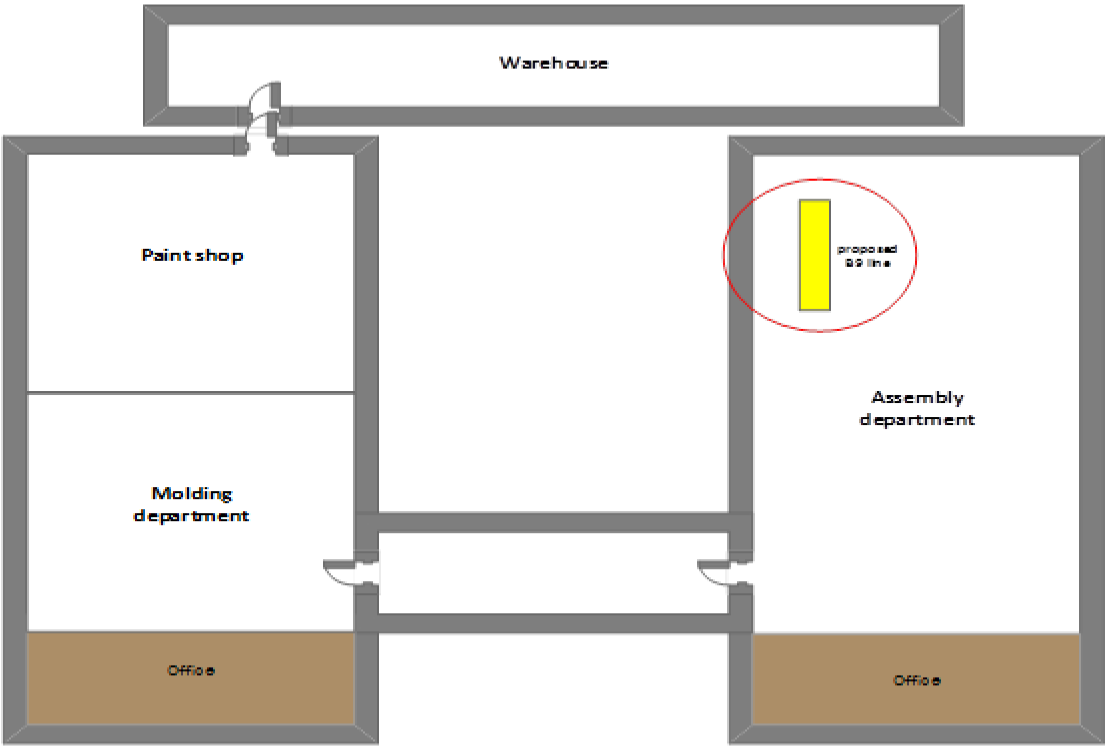

Figure 1.3 SMR Hungary –plant 1, facility layout

1.4 Problem definition

A study at SMR Hungary, shows a clear idea that there is a relationship between conditions related to production related ergonomic and the output of assembly quality. This indicates that if the ergonomic conditions get poorer, the assembly quality errors will increase. With the purpose of motivating investments for improvement, the company needs to value this aspect and how it improves the quality of the work and the product. In order to measure these aspects, the tools can be chosen from an already existing one to obtain the necessary data.

1.5 Purpose and goals

To propose/develop a new assembling ways for Audi B9 mirrors in the corresponding workstations at SMR Automotive mirrors, Hungary, the objectives of this study are,

- Product line and process design
- Cycle time analysis on the pre series process

- Apply error proofing methods on the product line using poka-yoke (fool proofing) principles
- Balance the line using the cycle time analyzing methods
- Improve the assembling process regarding efficiency and quality requirements
- Set up the ergonomics work standard for the assembly operator
- Solve the various problems occurring during the assembling

1.6 Delimitations

Delimitations have been made to focus and clarify the boundaries of the project

- The company wants to maximize the usefulness of its floor space by keeping it utilized efficiently.
- The method should ensure that correct combination of parts is assembled, identified and controlled to satisfy the needs of aftermarket requirements.
- The assembly method should be carried out with consideration of ergonomics standards.
- Material handling such as flow rack is to be considered during the assembly line design with ergonomics standards, but it does not consider the material supply method, i.e. the feeding of material to the workstation for refilling of stock levels.

1.7 Project organization

This Master's thesis project is carried out with the contribution of the following persons.

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Master's Program coordinator
Anders Skoogh, Director of Chalmers' Master's Programme in Production Engineering, Chalmers University of Technology

2 Theory

This section contains explanation of common terminology and concepts, and the theoretical background of this project.

2.1 Line assembly

Line assembly is the assembly method where the product is going to number of workstations for assembly one piece at a time. The work is divided between each station in order to complete the total work which means each station makes one small assembly.

2.1.1 Types of line assembly

The line assembly varies based on the production strategy and depends upon the product variants whether the product is single variant or of different variants. According to the variety; in product variants, the assembly line is separated into three different categories: single-model line, mixed-model line and multi-model line.

A single model, assembly line is used for manufacturing a product that does not have any variants. The work at all stations remains same for all the work-pieces, and the outcome product of the line is the same. The mixed-model line usually copes with products that have different variants. In the mixed-model line operations are similar for different variants, so it does have any resource constraints for assembling, but may have different operation times for different variants.

In the multi-model lines, the product variants are produced in batches. In the multi-model assembly line, the operation varies for the different variants that require setup for change of tools or another equipment. In order to reduce setup time cost or change over cost, the products are produced in batches.

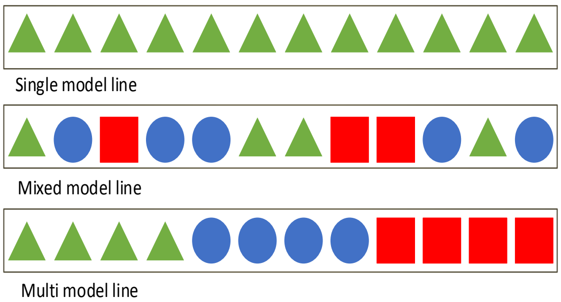

Figure 2.1 Different assembly methods

2.2 Assembly line balancing

Balancing an assembly line is a procedure in which tasks are distributed evenly to each assembly station in the line so that each workstation has the same amount of the work. The significant thing is to balance the workload of the operator at every station, reducing the operator idle time over the takt time which means the decrease of unused idle station capacity.

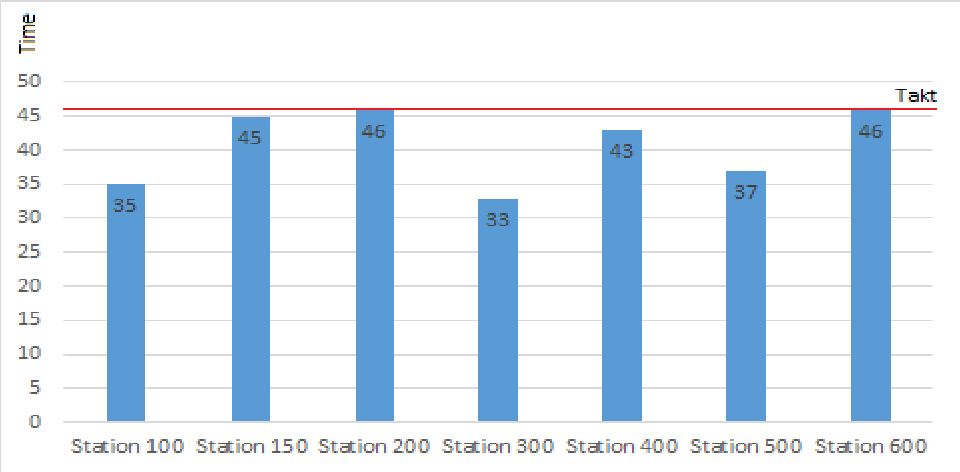

Figure 2.2 Example of poor balance

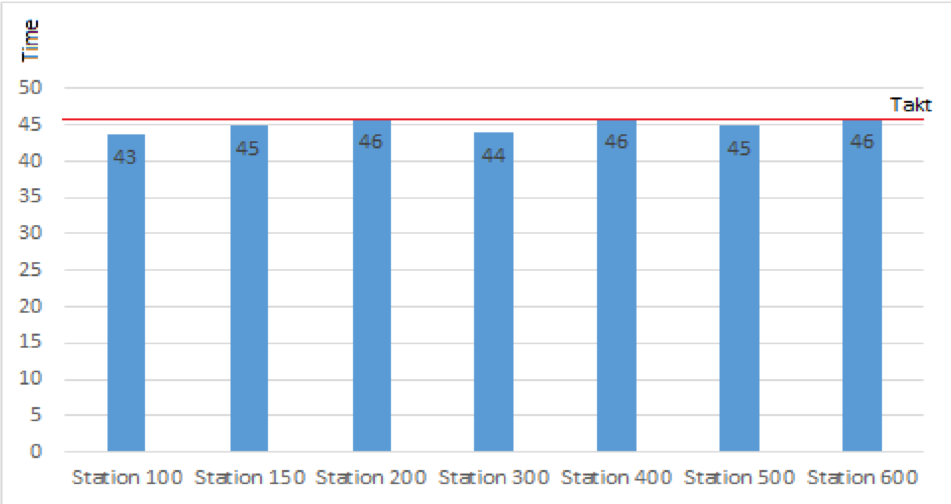

Figure 2.3 Example of good balance

A well-balanced workstations give various advantages in reducing wastes, such worker idleness, and need of changing operator, faulty product and stocks. It also allows the company to reduce the price of their product by through the decrease in production cost of the unit.

2.2.1 Precedence

The precedence diagram is a very significant structure in balancing the assembly line. It gives the information of order flow of the tasks must to be done. It specifies order and priority relationship of operations. The precedence avoids the risks of dismantling of a part for assembly or rework with the accurate creation of precedence relation of the tasks or activity.

In the precedence diagram, the operations are classified as parallel and series operation. The parallel operations can be done in at same time without disturbing each other, and the series operations are done one after the other with respect to the precedence. In the precedence diagram below (Figure 2.4): Operation T1 is predecessor of all the operation. After T1 the operation T2 and T3 can start in parallel. Operation T3, T8, T9 are serial operations. Operation T7 can only be done after T4, T5, T6 are accomplished.

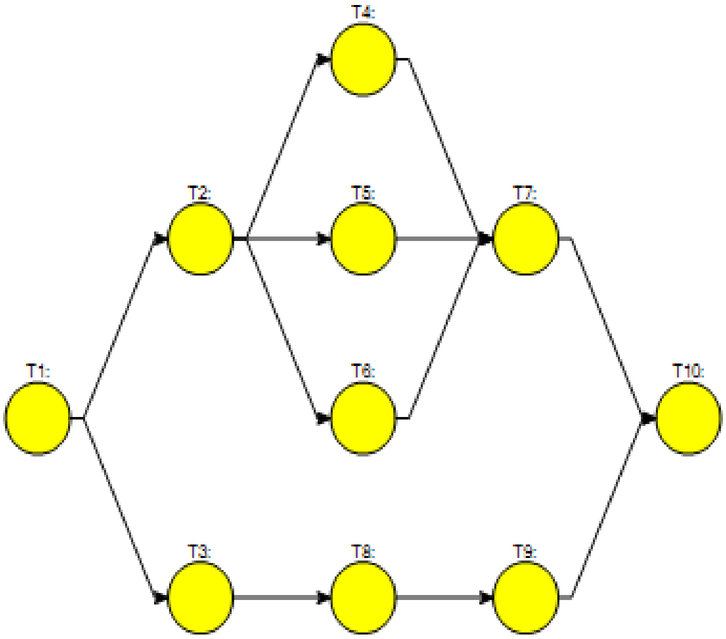

Figure 2.4 Example precedence diagram

2.2.2 Bottleneck

According to (Schroeder, 2007), "*a work center that is fully utilized at a specific point in time while at least one task is waiting to be processed*". *A bottleneck work center will constrain the capacity of the entire shop and an hour added at the bottleneck will add an hour of capacity to the entire factory. An hour added to a non-bottleneck work center will not help the schedule at all, since excess capacity exists there.*

A bottleneck in a production line causes the entire line to slow down or stop. It affects the capacity of the whole production line. For instance, in a balanced five station assembly line, if 30 sec of work is added to the station 1, the remaining stations have to wait for 30 sec for all assembled products. This shows that, station 1 is the bottleneck on the line, and it is of vital importance to eliminate the balance loss, i.e., to have a balanced line that maximizes the capacity (Baudin, 2002).

2.2.3 Balancing losses

Balance loss at an assembly line is unavoidable, because it is hard to divide the task evenly to all the workstations. There is only a very slight possibility to attain and preserve a well-balance of workload at the line flow production. Hence, balance loss is an effect of line production (Engström et al, 2004).

2.2.4 System losses

In general, it is obvious that each operator requires a different amount to time to accomplish the task; by this a distribution of the assembly time is created. Hence, these distribution are losses. Handling losses is also related to the system losses, such as handling the tool, getting material or reading the work instructions. In addition, the outer disturbance also causes losses, e.g., lack of material or tool, equipment failure, bad fitment and more (Engström et al, 2004).

2.3 Time constraints

The following sections describe, different time concepts that occur in a production system.

2.3.1 Operation time

The time between the start and the end of an operation at a station is known as operation time. The operation time can be measured by time studies either by stopwatch, video or image processing techniques (Scholl, 1999), or calculated using a predetermined motion time system such as MTM.

2.3.2 Cycle time

Cycle time is a time measured from the initial moment a work-piece delivered to the station, the required time to complete all the operation of the work-piece on that station. The cycle time is a function of the total operation time and number of operators at the station (Scholl, 1999).

2.3.3 Takt time

Takt time is defined as the time a work-piece stays at a station. It is a function of available production time and product volume (Scholl, 1999). In this project, it is used to understand the rate at which we need to produce the product in order to satisfy the customer demand. It can be determined with the formula:

$$\text{Takt time} = \text{Net available production/Demand}$$

From the definition, the takt time should not be mixed up with cycle time. Takt time is the same for all stations on an assembly line, i.e., the time for which work piece stays at a station. Cycle time is operation time of work that is completed while the work-piece is at the station.

2.3.4 Takt overdue

Takt overdue means that the takt time is not well enough to complete all the operation in a workstation.

2.3.5 Idle time

In general, the idle time is the difference between the cycle time and the station (takt) time. The idle time is waiting time, since the operator is idle after performing the all the operations and the work piece is not being moved to the next station. The sum of all idle times for all stations in the line is termed as balance delay time (Scholl, 1999). The idle time can be expressed as,

$$\text{Idle time} = \text{Takt time} - \text{Cycle time}$$

In this project, the idle time is the difference between highest cycle time and the cycle time of the respective station.

2.3.6 Tolerance time

Tolerance time is defined as the time required for work-piece to complete all operations in the current station and to be delivered to the next station (Scholl, 1999).

2.3.7 Throughput time

The throughput time is equal to the total process and waiting times of the assembly line. Besides, it is defined as the total time required for a work piece to enter and leave the assembly line as completed product (Scholl, 1999).

2.4 Poke-yoke

Poke-yoke is a Japanese term which means "mistake proofing" commonly referred to "error-proofing". It delivers a visual or other signals which represent a characteristic state of the work task. It is a manufacturing practice of preventing error by designing the production process, tool and equipment so that the operation cannot be performed inaccurately (David, 1986).

2.5 Work station

A workstation is a section in a production line where are certain amount of work is performed. The workstation is characterized by dimensions and is set up with machines, materials, equipment, tools, fixtures and operators needed to perform the assigned operation. The workstation can be further sub-divided into manual or automatic stations depend upon the performing of work (Scholl, 1999).

2.6 Operator

A person who accomplishes the operation or work in an assembly line is an operator. The operator can do their work either manually, by means of hand tool or semi-manually by automatic tool or task specified machines. To perform all tasks in an assembly line by a minimum number of operators required is calculated by:

$$\text{Minimum number of operators} = \frac{\text{Total assembly time}}{\text{Takt time}}$$

Though, this is based on a theoretical calculation due to some restrictions in most of the cases, the calculations does not give a reliable result (Baudin, 2002).

2.7 Material flow

Material flow is the description of the continuous transportation of raw materials, components and parts to the production system from their source of location, i.e., warehouse, supplier, sub-assembly, kitting, etc. In the production, the material flow is the significant aspect that can affect the whole production system if a problem occurs during this process. Sometimes it may stop the work of whole production system until the necessary part is received.

2.8 Productivity

In general, the productivity is a relationship between input and output and is usually measured in terms of:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

In this thesis work, the productivity of line is measured through OEE (overall equipment effectiveness) that identifies the how the assembly line is truly productive. The OEE is calculated from three factors: Availability (A), Performance (P) and Quality (Q). The OEE can expressed as (Braglia et al, 1986):

$$\text{OEE} = \text{Availability} \times \text{Perfomance} \times \text{Quality}$$

2.8.1 Availability

The availability is calculated taking account of downtime loss by dividing actual operation time by the planned production time. It can be expresses in a formula as:

$$\text{Availabilty} = \frac{\text{Actual operation time}}{\text{Planned production time}}$$

where, the planned production time is the time without the paid break times. The actual operation time is calculated by planned Production time minus sum of all the downtimes while operating i.e. breakdown and changeovers.

2.8.2 Performance

The performance is calculated by taking account of speed losses in the system. The performance can be expresses in the formula as:

$$\text{perfomance} = \frac{\frac{\text{Total pieces}}{\text{Operating time}}}{\text{Ideal Run rate}}$$

where, ideal run rate is the inverse of ideal cycle time.

2.8.3 Quality

The quality is calculated by taking account of quality losses in the system. It can be expressed as:

$$\text{Quality} = \frac{\text{Good Pieces}}{\text{Total pieces}}$$

2.9 Production process

The production process is generally based on the customer-oriented. According to the demand of the customers, the manufacturers outline the "what's" and "how's" to produce a product. By this, the manufacturers plan the production process. The three main production strategies are:

- Make to Stock (MTS)
- Make to Order (MTO)
- Assemble to Order (ATO)

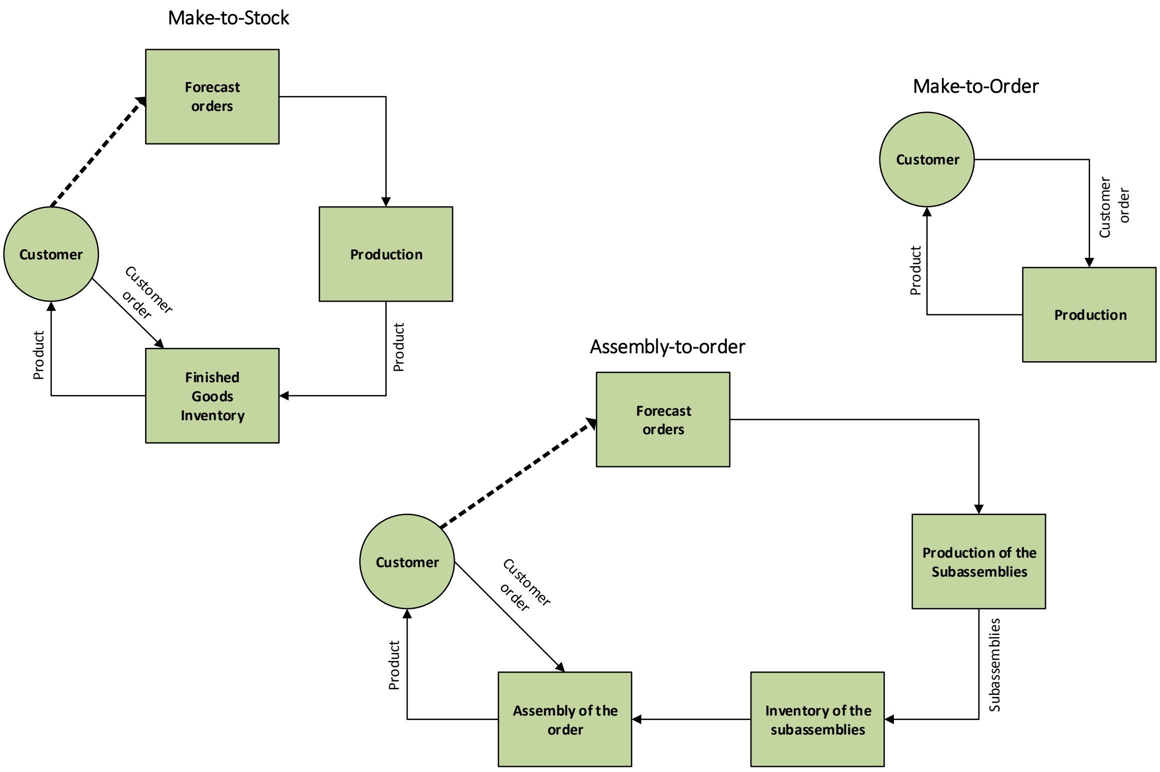

Figure 2.5 Comparison of MTS, MTO and ATO production processes (Schroeder, 2007)

The make-to-stock (MTS) production process is a production strategy used by the producers to match the customer demand forecasts. The focus of the MTS is stock the product based on the customer demand and deliver the products immediately on demand. Inventory management, capacity planning and forecast are the key roles in the MTS. Inaccurate forecasts lead to excess inventory or stocks and cause losses. MTS system can delivers quick service with low production cost (Schroeder, 2007).

In the MTO, manufactures or assembly processes starts the production after the products are designed according to the customer's specification and order. In the MTO production process, the production costs are greater than the MTS, but it provides high flexibility for product customization (Schroeder, 2007).

The Assembly to order (ATO) is a mixture between MTS – where the products are produced in advance and MTO – where the products are produced after the order from customer. The ATO strategy combines both, the sub-assemblies that form the products that are MTS, and the product specification of the customer's order which is MTO makes the final product. The strategy in ATO is to, once the order is received, assemble the parts and sent to the customers (Schroeder, 2007).

2.10 Lean production

Lean Manufacturing is a manufacturing technique derived from the word "*muda*" from the Japanese word means "*waste*" – human action that absorbs resource, but creates no value. *Lean thinking provides a way to more work with less human effect, less time, less equipment and less space* (Womack and Jones, 2003).

The lean production system seeks the total elimination of waste. *It is the philosophy of attaining the cost reduction through elimination of waste* (David, 1986). There are many types of wastes:

(David, 1986) highlights waste into the following seven categories:

- Overproduction
- Time on hand (waiting)
- Transporting
- Processing itself
- Unnecessary stock on hand (Inventory)
- Unnecessary Motion
- Defective goods (rework)

Overproduction is the excessive progression of work. This work creates wastes such transportation, conveyance and inventory. It raises need for additional storage space, parts, materials and energy to operate machines. It also needs additional workforce to handle all the additional tasks.

Time on hand (waiting time) is created when a worker stands idly in an automated machine as a watchman or when he cannot do anything constructive manually because the machines is running. This waste also arises when the preceding process fails to deliver the parts needed in the present process, thus avoids workers to do their work.

Transportation is referred to the waste caused by an item being moved a distance unnecessarily, being stored temporarily or being rearranged. Another example of waste due to the transportation occurs when parts are moved from the warehouse to the factory, from factory to the machines and from machines to the hand of workers.

Process waste occurs when the process does not go smoothly, and time is wasted or more time required to do the work than the needs of the customer.

Inventory the unnecessary stock on hand is in the form of raw materials, work in progress (WIP) or finished goods. Excess inventory requires additional storage, containers, handling requirement and time. Also, excess inventory cause extra carrying cost.

Motion is referred to the non-value added work. It mainly causes time losses within the production process. It is typically a result of the physical design of the system.

Defective goods (rework) is the correction of the faulty operation, which means that the work takes twice the time for the same operation. This results in labor cost, rescheduling production etc. (Womack and Jones, 2003) (David, 1986)

2.10.1 Value added and non-value added operation

An operation in a production, that adds or not adds value to the product, is called as value added and non-value added activity correspondingly.

In the production line the cost of all resources such as operators, raw material, transportation, storage, etc. which determines the final product cost. It means every work tasks are assessed for the value that enhances to the final product. Therefore, the each operation is significant for which the customer is willing to pay for is expressed by,

$$\text{Operation value} = \text{Product value after operation} - \text{Product value before operation}$$

2.11 Layout planning

Principles for systematic layout planning (SLP) were published by Richard Muther and John D Wheeler in early 60’s. Today, most factories and other industrial facilities are using this method when making their layout planning. In order to get an optimal layout, the method consists of six steps (Muther and Wheeler, 1994):

- Step1: Map dependencies between resources
- Step2: Create resource needs (Electricity, space, water etc.)
- Step3: Make graph of the dependencies
- Step4: Draught different possibilities
- Step5: Assess and choose the best
- Step6: Plan a detailed layout

2.12 Assemblability

Assemblability (ease of assembly) is defined by ease of gripping, positioning and inserting parts in the assembly complexity (Fujimoto and Ahmed, 2001). The assembly complexity of operators can be evaluated under time pressure, such as e.g. picking the right material, the right tool, making the things right order, choosing the right method, etc. Several study results show that the outcome of the assembly quality was based on the degree of complexity. Also, the assembly errors are higher due complex assembly, than the non-complex assembly (Falck et al, 2012).

2.13 Ergonomics

Ergonomics is a very wide concept that comprises all the factors that affect humans. In the workplace, the ergonomics are about to designing for people, to make the workplace comfortable and efficient. It includes everything from physical loads, environmental condition (temperature of the room, lighting and noise) and to the social relationship with the colleagues. On the other hand, such all comprehensive term is not very practical to work with. Hence, the ergonomics have been separated into specific areas such as physical and cognitive ergonomics. The physical ergonomics concerns with human body's response to physical and physiological work demands whereas cognitive ergonomics concerns mental processes, such as perception, stress and psychological perspective. It is hard to separate between physical and cognitive ergonomics, because in some respects they are closely related (karlsson et al, 2009).

In this project, the main focus is on the physical ergonomics but the relationship with the cognitive ergonomics cannot be neglected.

2.13.1 Physical ergonomics

Physical ergonomics has been additionally separated into two areas: physical loads and environmental aspect. Certainly, they affect each other to a great extent. However, in the workplace the environment (lighting, noise, air pollution and temperature) is often organized and enhanced. The physical load is a combination of three factors: posture, force and time factors. The ergonomic situation of the workplace is jointly based on these three factors (Laring et al, 2002).

Posture

The posture is the working position of the body during the operation of the work. The posture is based on the different factors: space, stress, vision, safety aspects and body space. It is impossible to perform a task in another position rather than doing it in the easy way (karlsson et al, 2009).

Force

The force in the ergonomics is the external force exerted in pushing/pulling/lifting or in manual material handling. If the load is too large, then there will be immediate damage to the body. Likewise, if the load is small but repetitive the force can cause injury to the musculoskeletal system (karlsson et al, 2009).

Time

The most vital aspect dealing with the ergonomics is time. Time factors influence the occurrence of work- related musculoskeletal system. If a tiresome work is only performed for a less frequent time, it may not be very harmful, but if the work is repeated at short intervals, it will cause pain, fatigue and the body would not be able to perform the task.

Recovery time is most essential for heavy task, and it has to be considered as part of the activity time, it gives time to the body to recover and before performing the operation again. Repetition is not harmful when there is sufficient recovery time. The performance will be extremely reduced if the recovery time is taken away (karlsson et al, 2009).

3 Methodology

The methodology is used to reach out the definite goals in the project. A short description of the procedure is shown below, followed by the visualization of methodology which is given in the Figure 3.1, where each process is further described in detail.

3.1 Description of procedure

To achieve the objective of the project, as a first task a similar assembly line (only the first three station 100, 150 and 200) was chosen to identify the losses and to evaluate the ergonomics risks. The procedure was to collect the time studies, then analyzing the work tasks by isolating the value adding, the non-value adding and the waiting time to identify the losses. The time studies used (video analysis) and onsite evaluation was done for identifying the ergonomics risks. The results were used to evade those losses and ergonomics risks in the new assembly line for the B9.

The next procedure in the project was to design and balance the new assembly. First, the precedence analysis was made with discussion with company supervisor and project coordinator of the line and the selection of the tools/fixtures with consideration of the poke-yoke (Foolprooofing) principle. Then, the time studies had done and used for balancing and optimizing the line. Finally, the implementation of ergonomics standards was been done.

3.2 Visualization of methodology

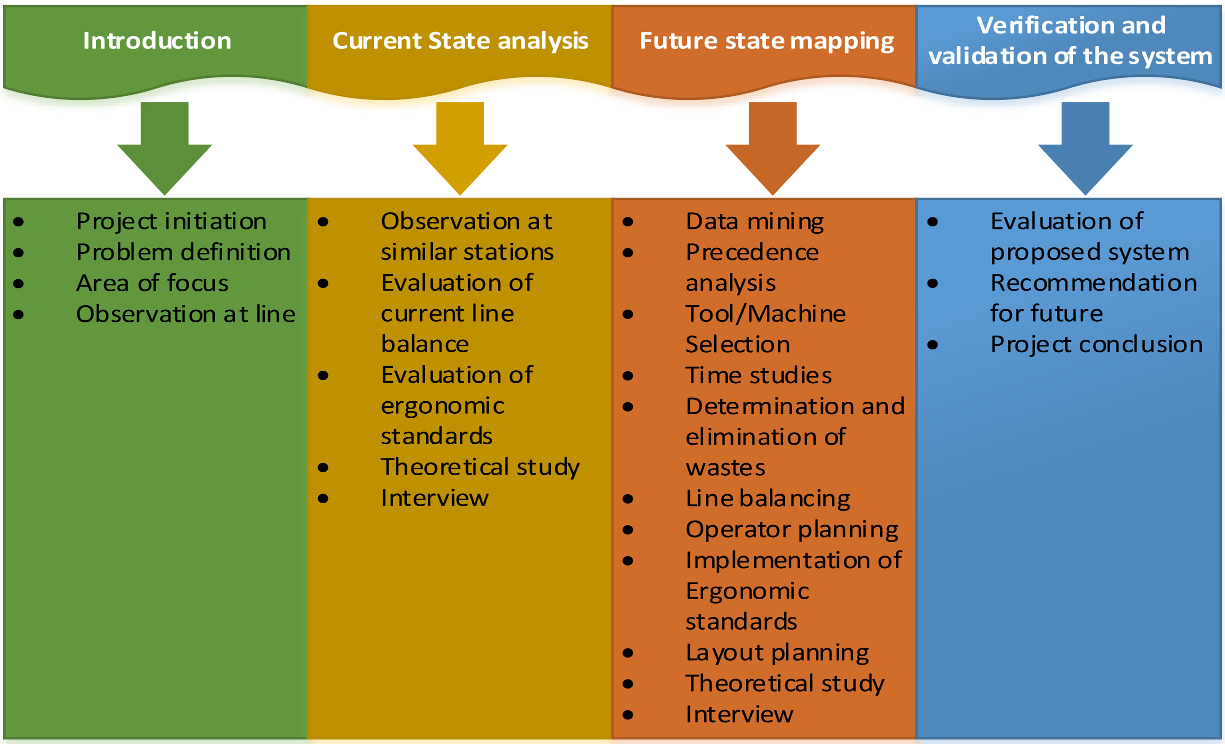

Figure 3.1 Project steps and flows

The first section of the project introduces the essential things of the project that includes the focus of the project. The second section shows the current evaluation of the project that is the things that have to do before the designing the new assembly. The third section is the main focus objectives of the project for the reliable results, and the final section is evaluation of the final results and recommendation for the future. In the following sections, the different process of the project procedure will be described more in detail.

3.3 Data Gathering

The parts regarding the data gathering will be described more in detail in the following chapter:

3.3.1 Time studies

The times studies of the assembly process were undertaken in terms of video analysis with the help of a company supervisor and operators. In those case, that video analysis is used to analysis the task times and ergonomics standards, and to enhance it.

3.3.2 Interview

The most vital information that was collected during the interview was the adjustment time took for a specific task and the frequency of errors at the section. The interviewed functions at 'SMR Hungary' and intend of the interviews are listed below:

Production engineer and the project coordinator

During the interview, more general questions asked about the production systems such as production schedule of mirrors as it was required for the base assessment. Information regarding the specific work task are also gathered to some extent. Further, data about the ergonomics situation and assembly complexity of the current state was collected.

Assembly workers

Information regarding assembly instructions, error types and adjustment times and procedures was gathered. Besides, an overview of ergonomics in terms of physical and environmental aspects information was collected. The information was vital and used to evade and improve these things in a new assembly line.

3.3.3 Error collection

From the interviews and studies the screw related errors are common and frequently occurs in the assembly line. Thus, the screws related errors are classified into categories:

- Not performed – screw tasks have not been performed
- Performed incorrectly – screw tasks were performed in the wrong place
- Removal of dropped screws – Screws fallen over the mirror and not been removed

3.4 Line balancing

In order to level the workload and achieve a well-balanced assembly line, the factors that cause losses and; wastes have to be eliminated. The production system was analyzed to define wastes and factors that cause losses before performing the balancing procedure.

3.4.1 AVIX® line balance

The tool that was used in this project for the static balancing on the production line is the AVIX® line balance (v4.4.11) software by Solme AB. The color system in the software isolates the productive work from the non-productive work, and gives unambiguous details. Furthermore, the tool helps to optimize the production line with the best balance results.

3.5 Evaluating the ergonomics and complexity conditions

The evaluation of the ergonomics and assembly complexity can be performed by either directly on the sight or by a film. For this study, it was decided to film the work tasks to get an explicit condition of every task and respective movements for the assessments. The filming and the ergonomics assessment was performed and certified by the company's ergonomist. The assembly complexity was achieved using the same film by the method (Falck et al, 2012). Filming the assembly task for the assessments has a numerous benefits:

- The film can be reviewed for infinite times for the assessment.
- Filming the work tasks assists to get an unambiguous view of the working position.
- The evaluated assessments can be shown.
- For the future examination, the film can be stockpiled.

3.5.1 Ergomics assessment

The ergonomics assessments in this study were performed by the two ergonomics methods namely:

- REBA – Rapid Entire Body Assessment
- RULA – Rapid Upper Limb Assessment

In this project, the REBA was used for the work tasks that need entire body moments in order to complete the tasks. The RULA was used for the work tasks that doesn't require the leg moments, i.e., performing the tasks by upper body movements in a standing position.

The assessment is divided into three main sections and consists of arm and wrist analysis, neck, trunk and leg analysis, and muscular force. Variables, to consider, are weight of the relevant part, time and tool and the number of repetition per hour. Every section was graded distinctly and summed up to get the final score. The final score of the assessment method represents a risk level and a color, which represents the ergonomics evaluation. The table 3.1 and 3.2, shows the risk levels represents the action needed to be taken for the ergonomic score. The REBA and RULA assessment worksheets can be found in Appendix I and Appendix II.

Negligible: No action is required.
Low: Working situation may be necessary revised.
Medium: Working situation should be revised.
High: Working situation should be revised as soon as possible.
Very High: Working situation should be revised immediately.

Table 3.1 REBA score and risk levels

REBA score	Action level	Risk level	Action
1	0	Negligible	None
2 to 3	1	Low	May be necessary
4 to 7	2	Medium	Necessary
8 to 10	3	High	Necessary soon
11 to 15	4	Very High	Necessary Now

Table 3.2 RULA score and risk levels

RULA score	Action level	Risk level	Action
1-2	0	Negligible	Acceptable
3-4	1	Low	Investigate further
5-6	2	Medium	Investigate further and change soon
7-8	3	High	Investigate and change immediately

3.5.2 Assembly complexity assessment

To get a high system performance in terms of quality, quality and productivity the assembly line must be designed to adapt to the product variety of customer needs (Falck et al, 2012). A study by (ElMaraghy et al. 2010), shows more complex manufacturing atmosphere may affect the system performance. The aspects that included in the model of complexity are high product variance, assembly instructions, experience and capability of the assembler and visibility and accessibility of the assembly operations. In addition, the mounting position, fitting and self-evidence of the of assembly operation are considered (Falck et al, 2012).

Evaluating the assembly complexity of the process supports assembly - oriented product design and guides the product designers in designing low assembly complexity products. Assembly complexity supports the product line designers in the selection of the best suitable assembly process. (Falck et al, 2012).

The assessment of assembly complexity is based on 16 criteria, from the study made by (Falck et al. 2012) to measure the tasks in a convenient way. The corresponding achieved criteria number summarized, and the total score gets a color grade in the table: 4 that represents the complexity level of the tasks. The assessment in this project focused on the aim of the measure how high assembly complexity there is. It also can done in opposite way where there is an aim of measure low assembly complexity.

Criteria for high assembly complexity tasks considered as “tricky and demanding” operations:

1. Many different ways of doing the task
2. Many individual details and part operations
3. Time demanding operations
4. No clear mounting position of components
5. Poor accessibility
6. Hidden operations
7. Poor ergonomics conditions implying risk of harmful impact on operators
8. Operator dependent operations requiring experience/knowledge to be properly done
9. Operations must be done in a certain order
10. Visual inspection of fitting and tolerances, i.e. subjective assessment of the quality results
11. Accuracy/precision demanding
12. Need of adjustment
13. Geometric environment has a lot of variation (tolerances), i.e. level of fitting and adjustment vary between the products
14. Need of clear work instructions
15. Soft and flexible material
16. Lack of (immediate) feedback of properly done work, e.g. a click sound and/or compliance with reference points

Table 3.3 Degree of fulfillment of the high complexity

Fulfilment of criteria	Degree of complexity	Complexity level
0-3 (0-19%)	Low	Green
4-7 (44-25%)	Rather low	Yellow-green
8-11 (50-69%)	Moderate	Yellow
12-14 (75-88%)	Rather high	Yellow-red
15-16 (94-100%)	High	Red

3.6 Statement of Approach

With the aim of designing and balancing the assembly line, it is required to all know all knowledge of the assemblies their sequence, precedence and operation times.

The line that was analyzed as precedence for the new line is Q7, the first three stations are decided to analyses that have similar operations to the new proposed line. Even though, the operations are similar, there is some process change in assembling and operation times for all mirror types. For this reason, it was significant to clarify and consider these reasons before designing the new mirror line.

The method applied to perform the design and balance the new B9 line are stated below:

1. Stations 100, 150 and 200 of Q7 line were determined.

2. The operations in the Q7 line were crosschecked with the process list of the B9 line prepared by the process engineer group.

3. Operation time and number of operators in all process of each station were calculated. This was done by the stopwatch and video analysis studies. The operation times were checked with the estimated historical operation time of proposed line.

4. Investigation of balance losses and ergonomic risk at the current line was made with the video analysis by using AVIX and respective ergonomic tools. In addition, interviews the line team leader, process engineer and line operators had been done to identify the problems in the existing line.

5. In order to achieve a well-balanced and optimized new line the, source of wastes and ergonomic risk were determined.

6. Improvement potential to removal of waste, ergonomic risks and quality problems was created and analyzed with line team leader and engineers.

7. With the analysis of the current station and improvement solution, the new assembly line was designed considering correct combination of parts are assembled, balanced line and ergonomic standards.

8. As a first step in designing the proposed line, the fixtures and tools were designed for the estimated number of workstations with the help of historical operation times (MTM) and design of the mirror.

9. A new time study analysis was done with the designed line for eliminating the balance and system losses. Then the cycle times, idle time etc., are calculated. A few Kaizen workshop has been done to optimize the line as well-balanced.

10. In view of the new number of stations, the available factory space, and other constraints, a layout proposal was prepared.

11. Evaluation of line were done to check the Balance loss, productivity, assembly complexity, ergonomic risk and quality related issues.

4 Current state analysis

This chapter contains the current state analysis of the Exterior mirror assembly line which was done by focusing certain features such as production process and operations, workload of operators, current layout and balance of the line.

For the Productivity analysis a Hierarchal task analysis was performed and the evident losses were identified. The ergonomic analysis was done using different ergonomic methods and the worst situations were identified.

4.1 Pre – condition of the project

A prerequisite for this project was to make it manageable and focused. The assembly lines for various mirrors were similar to each other depending on the design of the mirrors. The new Audi B9 mirror design was similar to the existing of Audi Q7 mirror, which was in the production phase.

The similarities between the B9 and Q7, presents an opportunity to do a case study on Q7, in order to find the evident losses, ergonomic perspective of the work stations and significant measurements of importance. The information gathered from this analysis was used as a base for designing the first three stations of Audi B9 mirror.

Thus, station 100, 150 and 200 from Q7 were chosen for analysis.

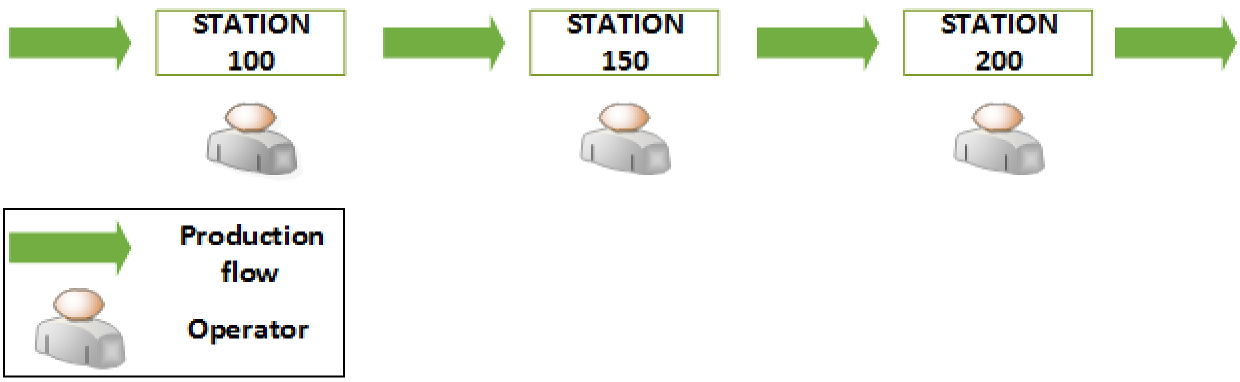

Figure 4.1 Visualization of the Chosen workstation in the AUDI Q7 line

4.2 General Information

Production in the exterior mirror assembly lines were based on a single piece flow system. The whole assembly line in Q7 consists of 5 stations, 3 of which are used for the analysis for the Audi B9 line. The production of the mirrors was controlled by 3 main sections in the factory.

- Molding
- Painting
- Glass assembly

The total Production of the company is about 700 million pairs of mirror per year. There is a low level of automation throughout the production process. All tasks – including the movement of the parts to the next station are performed manually by the operators. However, in the current setting, the number of workers is fixed for the station.

KANBAN system is used for the material flow within the factory. The purchased and outsourced parts from the suppliers are placed in the warehouse and then distributed to the assembly lines by the internal logistics unit just in time (JIT).

4.3 Hierarchal Task Analysis (HTA)

The current work tasks in the Audi Q7 exterior mirror assembly line structured in to HTA with the help of the video recorded during time study and analyzed using AVIX software. The HTA chart shown in Appendix: A classified into value adding, supporting, and loss. Design of HTA involved splitting of work tasks in a sequence as found in sequence of operation column, the colored arrows represent the classification such as value added in green, supporting in yellow, and losses in red. Detailed HTA can be found in Appendix III.

4.4 Productivity - Identified obvious losses

After analysis of the assembly line Q7, the current losses were identified. The major loss was due to the movements for fetching the materials and fixing the product in the fixtures. There were also some quality issues which lead to rework mainly on screwing. By the analysis of the AVIX it was found that 19% of assembly time was spent on the losses and 47% for the supporting tasks.

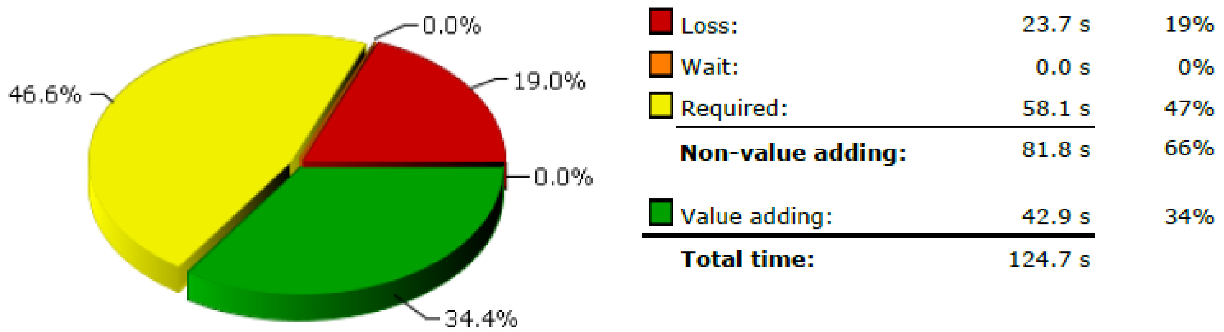

Figure 4.2 Identified losses in Q7 line

4.5 Balancing the station

From the video analysis of the assembly line Q7, it was found that process time of station 100 took 40.4 sec to complete the work. Likewise, the Station 150 holds 39.2 sec and last station 200 holds 45 sec. From the AVIX, it was found that all stations were well balanced.

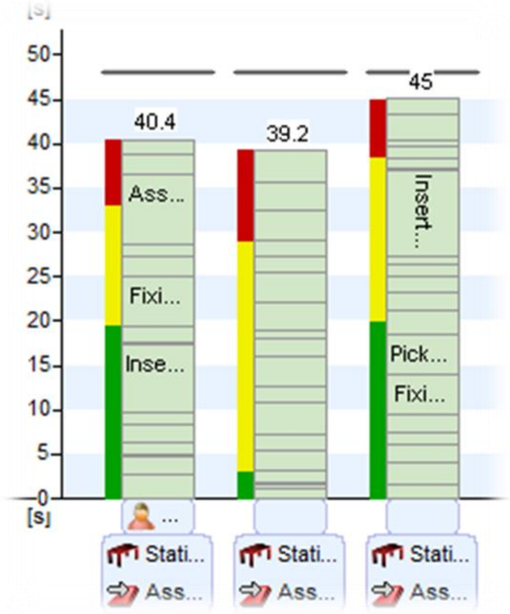

Figure 4.3 Balanced result of Q7 line

4.6 Ergonomics, environmental and Physiological risks

In order to improve the ergonomics in the new assembly line an evaluation was been done in the old assembly line Q7. The ergonomic, physiological and environmental risks were identified by studying a video and by on site investigation. The evaluation was carried out in assembly Stations 100, 150 and 200, to identify the ergonomic impact. From the video recording of assembly line cycles and the onsite review, the largest ergonomic and physiological risks are identified.

4.6.1 Ergonomic evaluation for the three stations

This section contains the ergonomics evaluation sheets of three stations with the ergonomic risk level which were considered as potential risks.

4.6.1.1 Station 100

In the first station [100], the first situation was identified and targeted. The analysis of picking parts such as cable and fixing the cable in the fixture was done, as can be seen in the movie at *Q7Analysis.* The posture of these tasks was analyzed by using the REBA and the results are presented in the below table 4.1.

Table 4.1 Assessment result of Station 100(1)

Trunk Score	3
Neck score	2

Legs Score	3
Table A	5
Upper arms score	3
Lower arms score	1
Wrists Score	2
Table B	4
Loading score	0
Coupling score	0
Activity score	1
Score A	5
Score B	4
Score C	5
REBA final score	6

REBA score	Action level	Risk level	Action	
1	0	Negligible	None	
2-3	1	Low	May be necessary	
4-7	2	Medium	Necessary	<--------
8-10	3	High	Necessary soon	
11-15	4	Very High	Necessary Now	

The study got a score of 6 which represents a medium level. This working situation should be revised to improve the ergonomic handling of the parts.

The second situation was identified and targeted for the further analysis. Fixing the cable in the fixture was analyzed, as can be seen in the movie *Q7Analysis*. This posture was analyzed by using the REBA and the results are presented below in the table 4.2.

Table 4.2 Assessment result of Station 100(2)

Upper arm Pos.	5
Lower arm pos.	2
Wrist Pos.	2
Wrist twist	1
Table A	6
Muscle use score	0
Force/Load score	0
Neck pos.	1
Trunk pos.	1
Legs	1
Table B	1
Muscle use score	0
Force/Load score	0

Final A score	6
Final B score	1
Table C	4
RULA final score	4

The result is a low risk level with a score of 4 for this operations, but the situation is to investigate further.

4.6.1.2 Station 150

In the second station [150] the first situation that was identified and targeted. The analysis was done on fastening the big screws, as can be seen in the movie *Q7Analysis*. This posture was analyzed by using the REBA and the results are presented below in the table 4.3.

Table 4.3 Assessment result of Station 150(1)

Trunk Score	3
Neck score	3
Legs Score	2
Table A	6
Upper arms score	3
Lower arms score	1
Wrists Score	1
Table B	3
Loading score	0
Coupling score	1
Activity score	1
Score A	6
Score B	4
Score C	7
REBA final score	8

This situation got a score of 8 which represents a high risk level. This working situation should be revised as soon as possible as it possess a high risk.

The second situation was identified and targeted for the further analysis. The fastening of the small screws for base part was analyzed, as can be seen in the movie *Q7Analysis*. This posture was analyzed by using the REBA and the results are presented below in the table 4.4.

Table 4.4 Assessment result of Station 150(2)

Trunk Score	1
Neck score	2
Legs Score	2
Table A	2

Upper arms score	4
Lower arms score	2
Wrists Score	1
Table B	5
Loading score	0
Coupling score	1
Activity score	1
Score A	2
Score B	6
Score C	4
REBA final score	5

This situation got a score of 5 which represents a medium risk level. This working situation should be necessary revised.

4.6.1.3 Station 300

In the third station [300] the first situation that was identified and targeted. The analysis was done on fetching the base cover, as can be seen in the movie *Q7Analysis*. This posture was analyzed by using the REBA and the results are presented below in the table 4.5.

Table 4.5 Assessment result of Station 200(1)

Trunk Score	3
Neck score	2
Legs Score	2
Table A	5
Upper arms score	5
Lower arms score	2
Wrists Score	2
Table B	8
Loading score	0
Coupling score	0
Activity score	0
Score A	5
Score B	8
Score C	8
REBA final score	8

This situation got a score of 8 which represents a high risk level. This working situation should be revised as soon as possible.

The second situation was identified and targeted for the further analysis. The analysis was done on fetching the cover, as can be seen in the Figure 4.4 and movie at *Q7Analysis*. This posture was analyzed by using the REBA and the results are presented below in the table 4.6.

Table 4.6 Assessment result of Station 200(2)

Trunk Score	4
Neck score	2
Legs Score	3
Table A	7
Upper arms score	4
Lower arms score	2
Wrists Score	2
Table B	6
Loading score	0
Coupling score	1
Activity score	0
Score A	7
Score B	7
Score C	9
REBA final score	9

This situation got a score of 9 which represents a high risk level. This working situation should be revised as soon as possible.

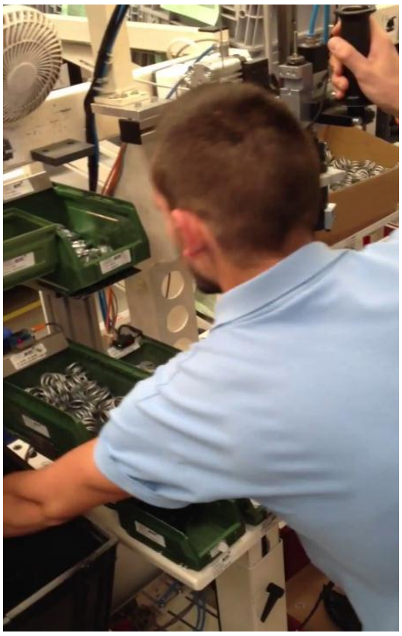

Figure 4.4 Fetching the cover

4.6.2 Ergonomic analysis

From the ergonomics analysis, it was clearly found that the body parts related to the highest ergonomics risks identified were the shoulder, neck and wrist/forearm and legs. These ergonomics risks are explained below

Shoulders

The shoulders are experiencing an active load almost throughout three assembly stations. The shoulders are slightly raised during several operations while punching the wire or spring, fetching the parts and fastening the screws. Especially the operator's right shoulder is raised when fastening the screws and for punching works.

Neck

The existing three workstations are exposing the neck for an ergonomic risk. The risk tasks are identified to be the fastening of the screws. Also, the neck is bent sideways and slightly twisted while picking the materials. These sustained work posture can lead to fatigue problems with the neck-area.

Wrists/forearm

The wrists/ forearm are experiencing a risk mainly due to fetching the materials. For this task, the operator needs to extend their wrist/forearm from the normal work posture. According to (Salvendy, 2012) working with a flexion/extension wrist will reduce the volume of the carpal tunnel which will increase the tendon friction, causing disorder like carpal tunnel syndrome.

4.6.3 Environmental risks

During the assembly, the operator was not directly exposed to any heat related or vibration problems. However the operators experience minor lighting and noise problems. The lighting problem mainly occurs when performing precision task work. The above results were identified by interviews with operators and using the noise measurement meters.

5 Future state mapping

This chapter includes the analysis of designing and optimizing the new Audi-B9 assembly by balancing, structuring, eliminating the waste, ergonomics standard and layout planning.

5.1 Analysis of operations that need correction

The operations in the new B9 assembly line are similar to Q7 line which was examined. To design and balance the new line without considering the problems in a similar line which would be a wrong approach.

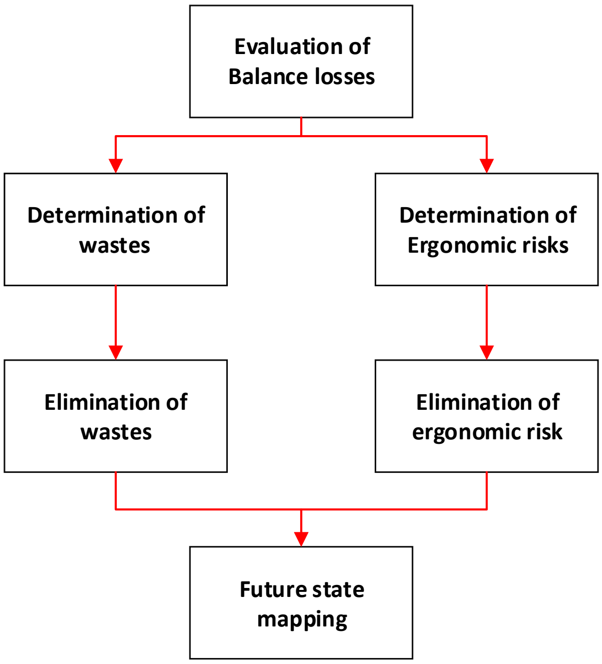

Figure 5.1 Preceding task of future state mapping

A thorough analysis of every operation in all three stations in the existing Q7 was conducted. The quality of information which was collected in this line was the most crucial aspect, since the outcome of data directly affects the design of the new line. The analysis was focused on three main issues: waste identification, ergonomic risks and quality related errors.

5.1.1 Wastes

From the profound analysis of each operation, high frequency non-value added activities were detected in the assembly line. The tasks such as picking the material, moving the part to the next station and picking the tools were identified as wastes. In order to eliminate these wastes, continuous improvement tools were used to shorten the distance, to grab the parts or tools and to place the finished product to the next station, instead of using a WIP table.

5.1.2 Ergonomic risk

The ergonomic assessment of each operation at all three stations shows the condition of physical ergonomics, as poorer in all stations. In addition, there is a high-risk work activity in two stations. For instance, in the station 300 the operator need to bend down to retrieve a cove. These actions could cause the operators severe shoulder pain. In order avoid these risks; a study was done to set up ergonomic standards to the new workstation.

5.1.3 Quality issues

In addition to the wastes and ergonomic risks, the current state analysis provides further details about quality related issues. In the station 200, due to improper precise fasting and dropping of screws by the operators in the mirror part, a quality related error was identified. A fixture design was suggested to avoid the drop-in of screws.

5.1.4 Valuation of solution proposals

The solution proposals were discussed with the B9 line team leader, tool engineers and the process engineers. Respective workshops and studies were done to find the appropriate solutions. Finally, outcome solutions were accepted by the engineers and team leader.

5.2 Precedence diagram

In the AUDI B9 assembly line, total number task that involved making the final product is 38. The precedence uses circles to represent the task activity (For instance: T1) and connects them with arrows that show the dependencies. A deep analysis of mirror design was done based on the possible assembly ways and thus the precedence was created as shown in the below Figure 5.2.

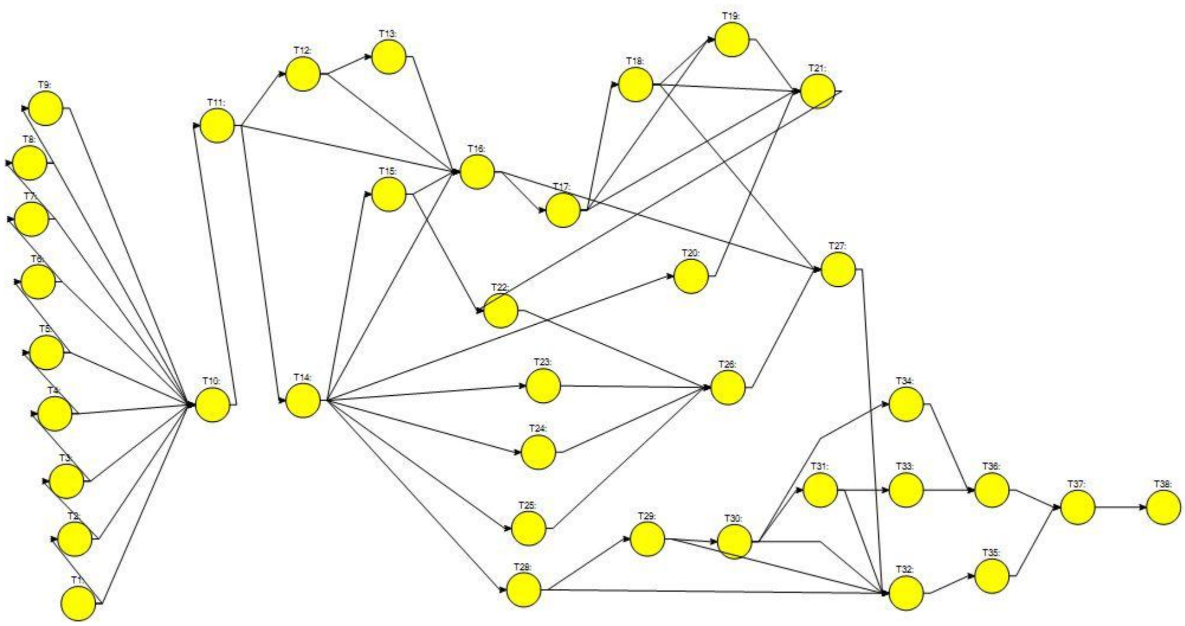

Figure 5.2 Precedence diagram of B9 Mirror assembly

5.3 Structuring the proposed assembly line

With the data of precedence, operation and known operation times, the desired balance assembly line has to be designed. For this purpose, the number of workstations, expected number of operators in the line, organizing the tool, fixture and material handling setup was considered. The layout planning procedure with the desired number of stations, positioning of the stations in the assembly section department regardless was also considered.

At the beginning of the layout concept generation ideas were discussed in relationships of a black box with the input function - output terminology. For this, this simple problem-solving tools such as 5W1H and brainstorming were used. By this creative manner, several alternative plans were developed. Importance of various design factors was identified and weighted. The main design constraints related to the B9 line are precedence constraints and capacity constraints.

To achieve a better efficient assembly line more data are required. To collect all assembly line data, several performance and workstation indexes are considered as shown in table 5.1.

Table 5.1 Performance and workstation indexes for assembly line layout

Performance Index	Workstation index
Variance of time among product versions	Operator skill, motivation
Cycle time	Tools/ fixtures required
No of stations	Tools/ fixtures change necessary
Station space	Buffer and material allocation
Traffic problems	Setup time
Task complexity	Ease of assembly and Ergonomic values
Reliability	Working place
	Need of storage
	Worker absenteeism during operation

With this strategy and data, the utmost challenge was to handle the different resources together with layout options and balancing, which made it very difficult to come up with reliable solutions. By this, it became essential to establish the assembly layout prior to line balancing.

5.4 Layout planning and material handling

The new assembly line is placed in the assembly section department of SMR Hungary Plant 1. The layout was designed based on the assembly line flow and the available space in the building. Other aspects such as space required for the operators, material handling, material flow for the molding and the painted components to reach the line, access to the fork-lift for the purpose of sending and receiving goods from other departments were all taken into consideration.

The proposed Audi B9 line consists of six stations: Station 100, 200, 300, 400, 500 and 600. The first five stations were based on line assembly criteria and the sixth station is based on the sequence operation. The stations 100 to 500 are semi – automated and the station 600 was fully automated, expect the initial setup and the final packaging operation.

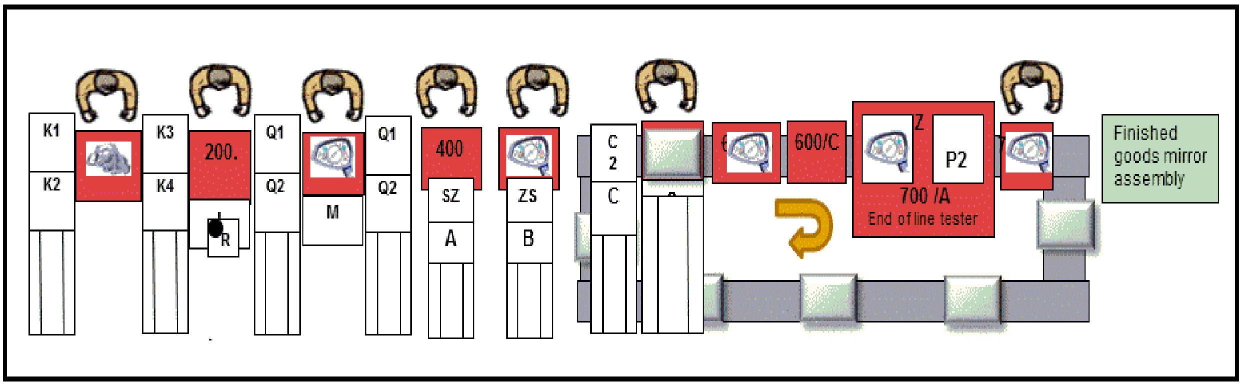

Figure 5.3 Layout of Audi B9 assembly line

On the topic of material handling, the materials are placed on the either side of the station. In stations like station 100, 200, 300 and 400 the material is placed in front of the assembly area due to smaller components, this in turn helps the operators to pick up the parts with easy access and precise manner.

By using the Richard Muther and John D Wheeler layout planning method, the new Audi B9 assembly line is generated. The primary concerns during designing of layout has been,

- Using the available space in the department while planning the layout of new assembly line stations
- Considering the positions of monumental resources for positioning near the workstations

5.5 Operator planning

The efficiency of the assembly line was based on assigning the assembly operators to the assembly stations. While planning the required number of operators to complete entire operations, balancing of the line was considered for avoiding system losses.

In order to eliminate the idle times of the operators at the stations, the number of operators required should be kept minimum. This would cause Takt overdue that can be overcome by having maximum number of operators at the stations. In this perception, the best approach in terms of efficiency of line would be having an optimum no. of operators which would not create a Takt overdue.

Table 5.2 Number of operators per station in B9 line

	No. of operators
# 100	1
# 200	1
# 300	1
# 400	1
# 500	1
# 600	2
Total	7

The total number of assembly operators in the Audi B9 line is 7. The first five stations has one operator per station and in the final sequence operation station two operators has been assigned to do work tasks without any takt overdue.

5.6 Supporting tool and fixtures

In SMR dedicated tools and conventional fixtures were commonly used in the assembly workstations. Known for its name, the conventional fixtures are designed as a 'work holding' device used for holding and positioning the parts during the assembly operations. With consideration of the parts flow in the assembly line, the fixtures were designed. Each station has different types of fixtures due to the addition of parts and to have a better assemblability (ease of assembly). For instance: The workstations 100 and 300 both have different fixtures as shown in the figure 5.4 and 5.5.

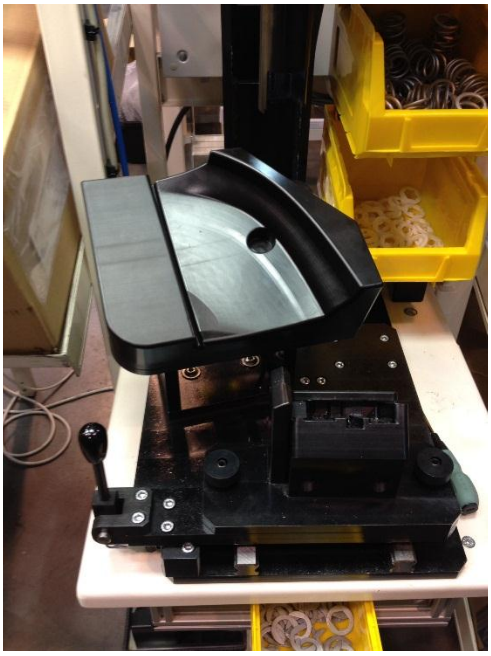

Figure 5.4 Fixture in Workstation 100

Figure 5.5 Fixture in Workstation 300

As a first task in the workstation 100 the 2k aperture and lower cover had to assemble together. To do this and to follow up with the other sequence of workflow the fixture 1 was designed. In station 300 the fixture was different because the task here was to assemble the blinker screws. With respect to the previous add-on parts in the product and to have a better ease of assembly the fixture 3 was designed. Likewise, each station has different fixtures depending on the add-on parts in the previous station and task to be done in their respective station. With addition to work holding fixture, a special fixture was designed for screwing in the station 300 to avoid dropping of screws and to have precise fastening.

The tools needed for B9 assembly line are grease lever, screwdriver and the wire cutter. With the consideration of ergonomic standard and assemblability, the grease lever was designed. The new screwdriver contributes a more efficient productivity with enhanced grip ability and fastening speed, so as the wire cutter.

5.7 Balancing of the proposed assembly line

The general framework of balancing the assembly line was related to the no. of tasks that will be performed. The other main parameters for balancing the line are: precedence, cycle time, time units and the given takt time. The takt time is formulated below with the demand rate and available time.

$$\text{Takt, C[s]} = \frac{\text{Avaliable time}}{\text{units per day}} = \frac{8 * 60 * 60 - (30 + 10\,) * 60}{600} = 44 \text{ seconds}$$

In this project, the takt time is only used to find out within how many seconds has to be used to produce a part in order meet the daily demand rate. The balancing of tasks are based according to the sequence of work and their operation time. The balanced assembly line are shown in the below figure with individual station cycle times.

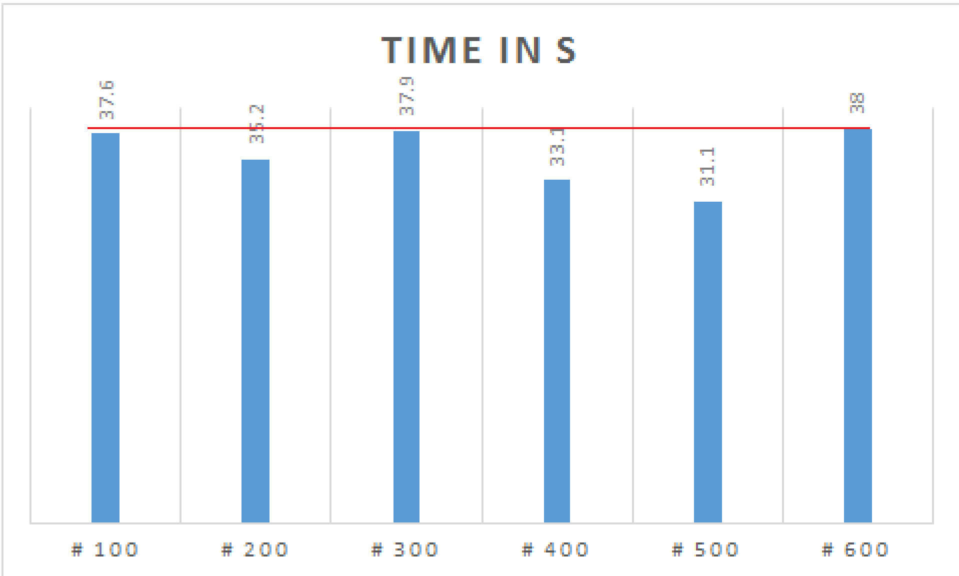

Figure 5.6 Balancing graph of AUDI B9 line

The first five stations of the assembly line were balanced on the assembly line criteria and the sixth based on sequence operation. The stations are well- balanced with a cycle time of 37.6, 35.2, 37.9, 33.1, 31.1 and 38. The tasks allocated to each stations are shown in table 5.3:

Table 5.3 Task allocation of each workstation in B9 line

Stations	Task allocation
#100	Spring package assembly, grease dosing and securing fork assembly
#200	Cover fastening and screwing, and wire harness
#300	Blinker assembly and screwing, and cable tying
#400	Cable set and connector pins assembly
#500	Cable set and actuator assembly
#600	600 /A: Damper frame assembly
	600 B/C: Damper frame and actuator screwing/ repair
	700 /A: End of line tester
	700 /B: visual checking, labelling and packaging

The main problem in balancing these stations was to provide 8% of flexibility to the operators for the purpose of the fatigue factor which was one of SMR policy. The operators in the stations 400 and 500 have the highest idle times. The reason behind this was to add the extra tasks to these stations when an advanced B9 mirror type arrives at the production line after 6 months, which is currently in the developing phase. The new camera type model would have some tasks like screwing, plugging in the cable which will be assigned to the stations 400 and 500.

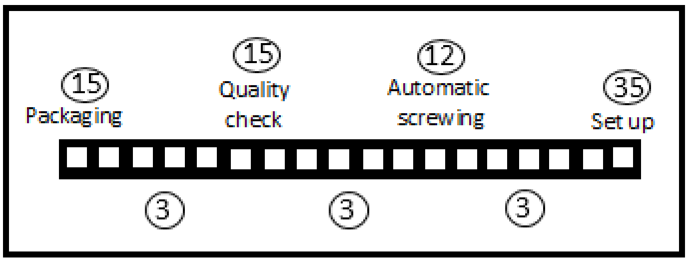

Figure 5.7 Operation time of each section in workstation 600

The station 600 was a sequence operation station. The station was fully automated, except the initial set-up and the final packaging operation. In this workstation, two operators were assigned in order to balance the line and to avoid the task overdue. The first process in this station is setup which includes the setting up of screws, friction spring and plug in the connector for the quality check. The fixtures then moved to the conveyor which travels at a velocity of 0.82 feet/sec to automatic screwing followed by quality check. Finally, in the end mirror is packed.

5.8 Poke-yoke (fool proofing)

In the designed B9 assembly line, three different poke-yoke principles were used in four stations 100, 200, 300 and 600. The poke-yoke terminology was designed with the help of the tooling designers and suppliers.

In the station 100, a poke-yoke was developed to ensure and verify the amount of grease that was applied to the ground plate through the grease lever. The poke-yoke used here shows the operators whether the grease lever is ready for action to perform greasing (Green) or not (red) and also to verify the correct amount of grease was delivered (green light) and if not shows (red light). The poke-yoke functions are shown in the figure 5.8.

Figure 5.8 Grease lever poke-yoke in Workstation 100

In the station 200 and 300, a poke-yoke was developed for the screwing operations. The main purpose of this poke-yoke is to resolve the already existing screwing errors and to have accurate screwing. In both the stations there are two screwing operations. The poke-yoke function shows the operators whether the screwdriver is ready for the operation (green), if not (red). A green light appears in the respective screw numbers 1 or 2 if the screws are fastened with precise accuracy. In the case of error or the screw not fastened properly then the red light appears. The screwing poke-yoke are shown in the Figure 5.9.

Figure 5.9 Screwing poke-yoke in Workstation 200

In the final station 600, the poke-yoke was developed along with camera detection principle. The operation done in this station is fully an automatic process. Due to this, the operator only has operation of initial setup, and to review the result of the poke-yoke and take remedy action if something went wrong. Here, in this station a numbers of screws are fastened. As shown in the Figure 5.10 the results of CAM 1: friction spring, frame screws, actuator screws and friction spring screws are OK. Likewise, the CAM 2 in this section shows the working condition of an actuator and turn blinker.

Figure 5.10 Automatic quality check in the workstation 600

5.9 Setting up ergonomic standards

The development of ergonomic standards was carefully planned before the implementation on the new line. To identify the ergonomic risks, two ways of method was performed in the current line. As a first step in the development of the ergonomic standards, a study was been done in the company to focus on the major area of concern associated with work conditions, as well as the potential for developing musculoskeletal illness were also identified. During the study, the relationship between the musculoskeletal illness and ergonomic risk factors was recognized. The risk factors are awkward positions, force, repetition of work and vibration. The tools used to analyze these risk factors are: Rapid Upper Limb Assessment (RULA) and Rapid Entire body assessment (REBA). An interview has been done as a second with assembly operators to find out the ergonomic problems in the line.

With the identified risk factors, the workstation design was reviewed. The potential area of the risk factors was identified and their measurement of standards has been done. To eliminate these risk levels and enhance the design a literature study and workshop has been done to set up new ergonomic standards.

Based on data collected throughout the workshop and study, the new ergonomic standards are based on the following factors

- Work posture risk levels
- Mountability
- Working height
- Working distance
- Material handling

6 Results

In this chapter, the result of the new Audi B9 line in form of several different ways: layout, productivity, balance loss, operator utilization, assembly complexity assessment and ergonomic complexity assessment. The assessment of assembly complexity and ergonomic are evaluated to the each individual tasks.

6.1 Line layout

The layout of the new Audi B9 assembly line is planned in the given available space. The key notion of line layout provides enough space for the operators, material handling, material flow for the molding and the painted components to reach the line, access to the fork-lift for the purpose of sending and receiving goods from other departments.

6.2 Balance loss

The Balance loss is one of the critical factors that play a pivotal role in determining the productivity of the line. So we had to keep the balance loss to a minimum, so that we could increase the productivity from the line. With the individual cycle times starting from station 100 to station 600 recorded at 37.6, 35.2, 37.9, 33.1, 31.1 and 38 sec, the balance loss was well under 7%.

6.3 Productivity

The most important objective of this project was to meet the demand from the customer. In order to achieve that, our cycle time should be less than 44 sec (Takt. time). After the line balance, we achieved a max cycle time of 38 sec, which was well under 44 sec. A 20 min interval break and 20 min lunch break is given by SMR to its employees. The line does not have any planned downtime, in rare circumstance there might be a 10 min of unplanned time. Operator efficiency of the line is considered to be 92% since SMR gives 8% fatigue factor to the operators.

The SMR uses OEE calculation for the measurement of Key performance Indicators (KPI) of the Audi B9 line. The three main factors make up the OEE calculation are availability (A), Performance (P) and Quality (Q). The OEE calculation sheet of B9 line shown in the Figure 6.1

	Overall Equipment Effectiveness Report							
Project Number	Name of the Project		Performed by		Verified by		Date	
2105	AUDI B9		Kodaly Zoltan & Ranjith Raja		Konya Tamas		25.02.2014	
Production Data								
Shift length	8	Hours =	480	Minutes				
Short Breaks	2	Breaks @	10	Minutes Each =		20	Minutes	
Meal Break	1	Breaks @	20	Minutes Each =		20	Minutes	
Down Time (planned)	0	Minutes						
Ideal Run Rate	1.578947368	PPM (Pieces Per Minutes) @ 38 sec per part						
Total Pieces	694	Pieces						
Reject Pieces	7	Pieces						
Support Variable	Calculation		Calculated Data			Result		
Planned Production Time	Shift Length - Breaks		480	-	40	=	440	Minutes
Operation Time	Planned Production Time - Down Time (planned)		440	-	0	=	440	Minutes
Good Pieces	Total Pieces - Rejected Pieces		694	-	7	=	687	Pieces
OEE Factor	Calculation		Calculated Data			OEE %		
Availability	Operation Time / Planned Production Time		440	/	440	=	100	
Performance	(Total Pieces / Operation Time) / Ideal Run Time		1.577273	/	1.578947	=	99.89393939	
Quality	Good Pieces / Total Pieces		687	/	694	=	98.99135447	
Overall OEE	Avalibility * Perfomance * Quality					=	98.88636364	

Figure 6.1 OEE sheet of B9 line

The three productivity factors are calculated by the different formula. From the calculation, the product of availability, performance and quality gives 99 % of overall OEE. The final OEE percentage is an Excellent, because, above 85% of OEE is better as per World class OEE table.

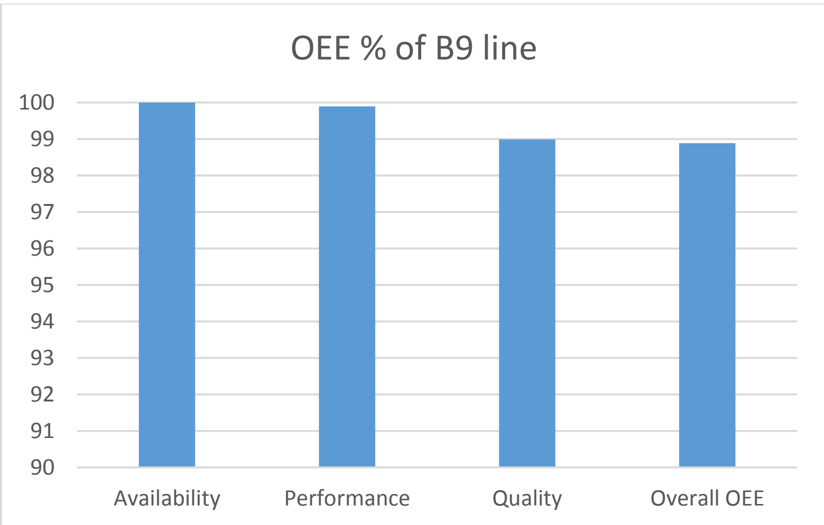

Figure 6.2 Graphical representation of OEE

6.3.1 OEE Time loss

OEE is a great tool for identifying the biggest time loss during the production in the assembly line. The time loss are shown in downtime losses, speed losses and quality losses. From the OEE sheet, the time losses are calculated as shown in the Figure 6.3.

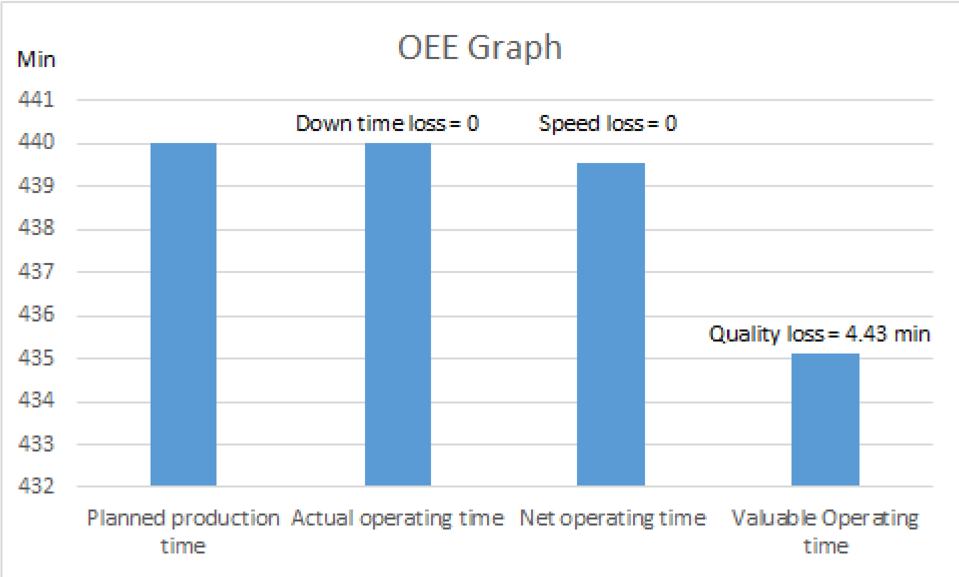

Figure 6.3 OEE graph showing time losses in minutes

6.4 Results of Ergonomic risks

One of the core objective of this project was to eliminate the ergonomic risks that exists in the similar production lines in the plant. In order to eliminate these risks the new ergonomic standards are implemented in the new Audi B9 line based on certain criteria as discussed in the *chapter 5.9: Setting up of ergonomic standards*. The ergonomic assessment is done for 36 works tasks out of 38, the remaining two tasks are automatic process.

As seen in the below table 6.1, a complete ergonomic assessment on 38 work tasks of the Audi B9 line are done. The work tasks is evaluated by two methods RULA and RUBA.

Table 6.1 Ergonomic assessment results

# sequence of the work tasks	Ergonomics method	Risk level	Final score
1	REBA	Negligible	1
2	RULA	Negligible	1
3	REBA	Low	3

4	RULA	Negligible	1
5	REBA	Negligible	1
6	RULA	Negligible	1
7	RULA	Negligible	1
8	REBA	Medium	5
9	RULA	Negligible	1
10	REBA	Negligible	1
11	REBA	Low	2
12	REBA	Negligible	1
13	REBA	Negligible	1
14	REBA	Low	2
15	RULA	Negligible	2
16	REBA	Negligible	1
17	REBA	Negligible	1
18	RULA	Negligible	1
19	REBA	Negligible	1
20	RULA	Negligible	2
21	REBA	Negligible	1
22	RULA	Low	3
23	RULA	Negligible	2
24	RULA	Negligible	2
25	RULA	Negligible	2
26	REBA	Negligible	1
27	RULA	Negligible	1
28	RULA	Negligible	1
29	RULA	Negligible	1
30	REBA	Negligible	1
31	REBA	Negligible	1
32	REBA	Negligible	1
33	RULA	Negligible	1
34	RULA	Negligible	1
35	RULA	Low	1
36	--	--	A
37	--	--	A
38	RULA	Negligible	1

From the results, 31 work tasks was at negligible risk levels, four work tasks as at low-risk levels and one work task was with medium risks level. There is no high ergonomic risk task in the entire process. The blue color in the table and graph represent automatic process which had non-manual work task.

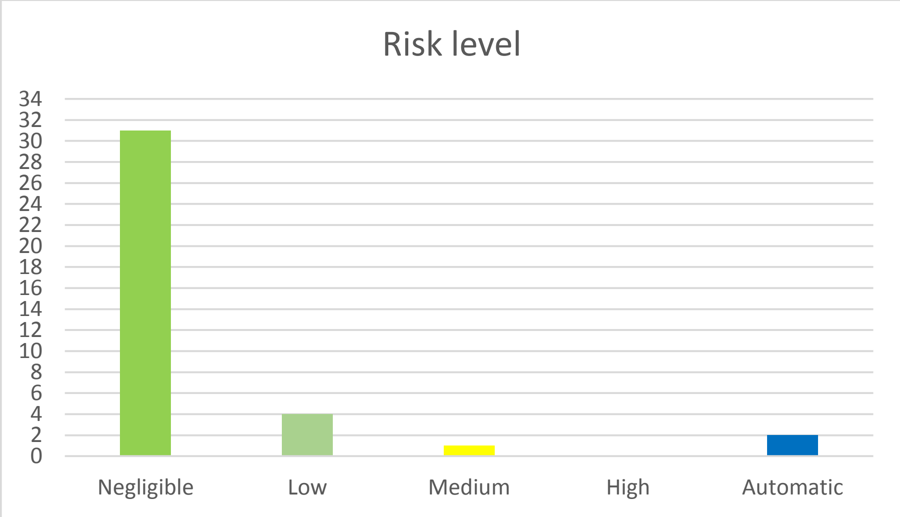

Figure 6.4 Ergonomic risk levels of all 38 tasks

As for the ergonomics result, the information from the table also shown in the Figure 6.4 which indicates how many ergonomic risk are fulfilled to be represented in each ergonomic risk level.

6.5 Results of assembly complexity

The objective of this assessment in this project is to give the feedback and guidelines to product designers and process line designers in terms of designing low assembly complexity products and suitable assembly process.

The assembly complexity assessment is done based on the 16 criteria which discussed in the *chapter 3.5.2: assembly complexity.* The criteria have been evaluated for all 38 work tasks as fulfilled. The assessment results are shown in Figure 6.5.

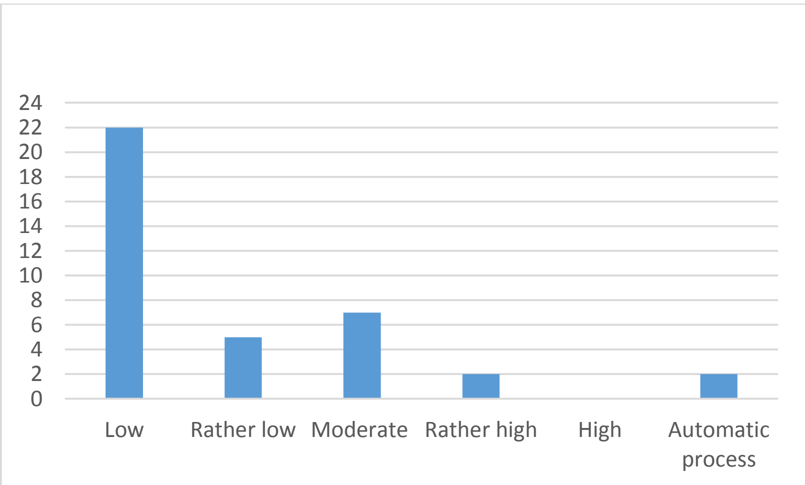

Figure 6.5 Assembly complexity assessment results

Out of total 38 tasks, 22 tasks is at low complexity level, 5 rather low, 7 moderate, 2 rather high and none of the work tasks is considered to be a high assembly complexity level. The major part of the results (28 of 38) is considered to be on a low or rather low complexity level.

7 Conclusion

The proposed Audi B9 line in the SMR Hungary has given most essential answers with the best possibility of assembling the parts of the mirror.

Here follows a list of conclusion achieved from the project:

- The line can meet the current demand of 600 mirrors per shift. In addition, the line can produce more than the demand rate.
- Balanced cycle time of each workstation have 8% flexibility time to operators that is one of the SMR strategies. Additionally, two stations 400 and 500 were balanced with high operator idles times. This gives room for the tasks of the camera type model which is to be added in these two stations in near future.
- The Audi B9 line layout is designed according to the available floor space in the assembly department
- The solutions meet better standards in terms of assembly complexity and ergonomic-related problems.

According to the SMR team, the solution implemented on the ergonomic and quality issues is a strong potential way for the upcoming new projects in addition to the exciting production line. The company who ordered the work tasks within this project is satisfied with the outcome results.

8 Future recommendations

By meeting most of the requirement specification, the end result satisfied the goal of this project. However, due to time and resource limitation of this project, there are some more areas that could be further improved.

8.1 Recommendation concerning ergonomic risk

The condition of the ergonomic standards has made improved a lot better but still have some room for improvements and solution suggestions. The new line has only one medium ergonomic risk level in the operation task 8 fixing the retaining fork in the black washer. The problem concerned with bending down (due to unclear view) to fix the fork in the black lever with use of punching lever. To improve this situation, a new punching lever design has been suggested which contributes the operators a better visibility instead of bending.

8.2 Recommendation concerning assembly complexity

The first operation task fixing the 2k aperture in the workstation 100 of B9 line is a complicated one in term of assembly complexity. Reason behind this issue is that the two parts can only be fixed with a precise angle of accuracy. It takes too much time to assemble these two parts. To solve this issue, a DFM (Design for Manufacturability) idea has suggested to the product designers in such a way they are easy to manufacture.

The other problem on the assembly line is connecting the purchased components wire in the wire-harness connector. The current wire harness-connector does not have any locking system once purchased components wires are fixed. Due to this there are possibilities of chances of unplugging. A new idea in wire-harness connector design has been suggested to have a better holding position of wires after it connected.

8.3 General recommendation for the continues improvement work

Additionally, there are recommendations for how SMR Hungary, can continue the work with assembly complexity and production ergonomics. Due to the time limit and new production line the adjustment costs related to assembly complexity and ergonomic are not known. In order to accomplish this, the SMR needs to collect data on adjustment costs on the assembly line. The cost of adjusting errors occurring on the assembly line should be examined, in order to visualize a total view of all costs.

Production ergonomics should be an incorporated part of SMR to a greater extent than it exists today. As soon as a change is made in the product design or production environment ergonomics should be included as a significant factor in the consequence analysis. The knowledge of ergonomics in the product development process must be momentously improved. The product is the basis for all assembly work, if the product does not assist an ergonomic assembly then no measure can be taken on the assembly line to ensure a satisfactory ergonomic situation. To solve this issue, increased cooperation with the product development department during the development of product and process will enhance a better working condition in terms of ergonomic and assembly complexity in the assembly line.

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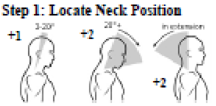
Appendix I: REBA assessment work sheet

REBA Employee Assessment Worksheet

based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

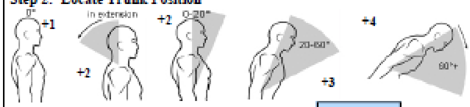
Step 1: Locate Neck Position



Neck Score

Step 1a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

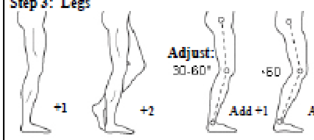
Step 2: Locate Trunk Position



Trunk Score

Step 2a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs



Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

Posture Score A

+

Step 5: Add Force/Load Score
If load < 11 lbs : +0
If load 11 to 22 lbs : +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

Force/Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find Row in Table C.

Score A

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

SCORES

Table A	Neck	1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B	Lower Arm	1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C

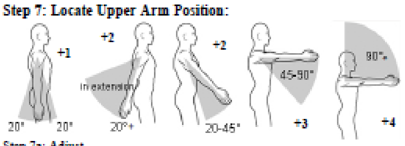
Score A (score from table A +load/force score)	Score B, (table B value +coupling score) 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score

Final REBA Score

B. Arm and Wrist Analysis

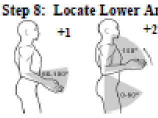
Step 7: Locate Upper Arm Position:



Step 7a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:

Wrist Score

Step 9a: Adjust…
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B

+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, *good: +0*
Acceptable but not ideal hand hold or coupling
acceptable with another body part, *fair: +1*
Hand hold not acceptable but possible, *poor: +2*
No handles, awkward, unsafe with any body part,
Unacceptable: +3

Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain
Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Task name: ____________________ Reviewer: ____________________ Date: ____/____/____

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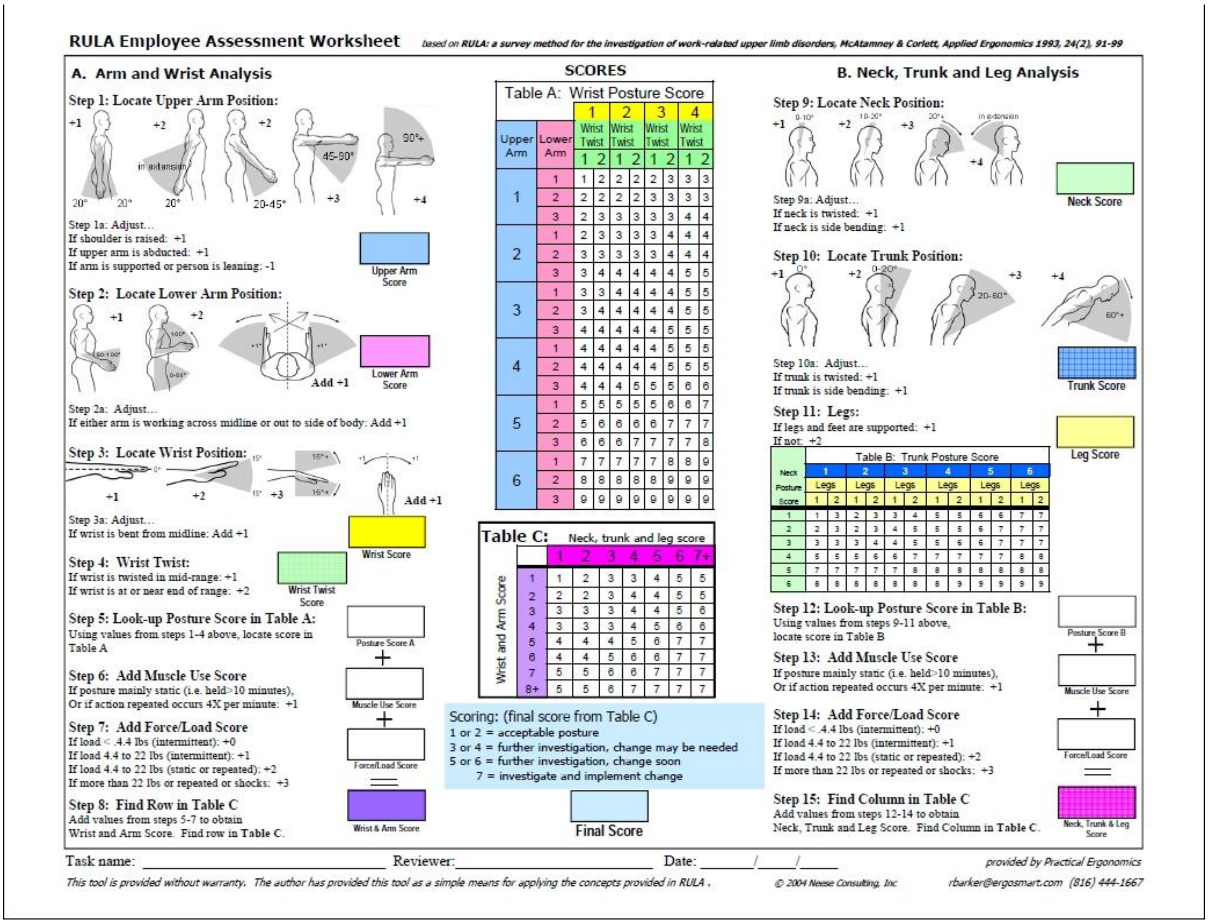
Appendix II: RULA assessment work sheet



RULA Employee Assessment Worksheet *based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99*

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

Step 1a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:

Lower Arm Score

Step 2a: Adjust…
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust…
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A
+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 7: Add Force/Load Score
If load < .4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score
=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	Wrist 1, Wrist Twist 1	Wrist 1, Wrist Twist 2	Wrist 2, Wrist Twist 1	Wrist 2, Wrist Twist 2	Wrist 3, Wrist Twist 1	Wrist 3, Wrist Twist 2	Wrist 4, Wrist Twist 1	Wrist 4, Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

Step 9a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Step 10: Locate Trunk Position:

Step 10a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score

Neck Posture Score	1, Legs 1	1, Legs 2	2, Legs 1	2, Legs 2	3, Legs 1	3, Legs 2	4, Legs 1	4, Legs 2	5, Legs 1	5, Legs 2	6, Legs 1	6, Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above, locate score in Table B

Posture Score B
+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 14: Add Force/Load Score
If load < .4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score
=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk & Leg Score

Task name: ____________ Reviewer: ____________ Date: ___/___/___

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Appendix III: HTA Analysis Q7 line

Hierarchical Task Analysis			
Station	Sequence of peration	Operation	Work Classification
Station 100	Picking the cable	10-10	⇨
	Joining the cable	10-20	⇧
	Picking the plate	10-30	⇨
	Assembling the plate to the cable	10-40	⇧
	Picking the lower cover	10-50	⇨
	Inserting the cable in the lower cable	10-60	⇧
	Placing the product in the fixture	10-70	⇨
	Fixing the cables in the fixture	10-80	⇩
	Picking and placing the washer	10-90	⇨
	Puncing the washer	10-100	⇨
	Assembling the turn sign connector and cable	10-110	⇧
	Picking the wire connector	10-120	⇨
	Moving the part to station2	10-130	⇩
Station 150	Locking the product in fixture	20-10	⇩
	Picking the tool	20-20	⇨
	Picking the Big screw1	20-30	⇨
	Fastening the big screw 1	20-40	⇨
	Picking the big screw 2	20-50	⇨
	Fastening the big screw 2	20-60	⇨
	Picking the big screw 3	20-70	⇨
	Fastening the big screw 3	20-80	⇨
	Moving the part to next fixture	20-90	⇩
	Picking the part	20-100	⇨
	Fixing the part	20-110	⇧
	Picking the small screw 1 and the tool	20-120	⇨
	Fastening the small screw 1	20-130	⇨
	Picking the small screw 2	20-140	⇨
	Fastening the small screw 2	20-150	⇨
	Marking the part by marker	20-160	⇩
	Moving the part to station 200	20-170	⇩
Station 200	Fixing the part in the fixture	30-10	⇩
	Picking the base cover	30-20	⇨
	Fixing the base cover	30-30	⇧
	Punching the cable	30-40	⇨
	Picking the case	30-50	⇨
	Fixing the case	30-60	⇧
	Picking the spring, 2, 3	30-70	⇨
	Fixing the spring, 2, 3	30-80	⇧
	Moving the fixture	30-90	⇩
	Picking the part	30-100	⇨
	Punching the part	30-110	⇨
	Moving the fixture	30-120	⇩
	Inserting the wire in the base cover	30-130	⇧
	Picking the turn indicator lamp	30-140	⇨
	Fixing the turn indicator lamp	30-150	⇧
	Picking the tool	30-160	⇨
	Inseting the wire deep	30-170	⇨
	Moving the part to next station	30-180	⇩