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Design of manufacturing cell in the company BOS Klášterec nad Ohří

Diplomová práce

Studijní program: N2301 – Mechanical Engineering
Studijní obor: 2301T049 – Manufacturing Systems and Processes

Autor práce: **Vignesh Babu Kuduva Gopinath**
Vedoucí práce: Ing. František Koblasa, Ph.D.

Liberec 2019

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Faculty of Mechanical Engineering

Design of manufacturing cell in the company BOS Klášterec nad Ohří

Master thesis

Study programme: N2301 – Mechanical Engineering
Study branch: 2301T049 – Manufacturing Systems and Processes

Author: **Vignesh Babu Kuduva Gopinath**
Supervisor: Ing. František Koblasa, Ph.D.

Liberec 2019

Technical University of Liberec
Faculty of Mechanical Engineering
Academic year: **2018/2019**

DIPLOMA THESIS ASSIGNMENT

(PROJECT, ART WORK, ART PERFORMANCE)

First name and surname:	**Vignesh Babu Kuduva Gopinath**
Study program:	**N2301 Mechanical Engineering**
Identification number:	**S17000474**
Specialization:	**Manufacturing Systems and Processes**
Topic name:	**Design of manufacturing cell in the company BOS Klášterec nad Ohří**
Assigning department:	**Department of Manufacturing Systems and Automation**

Rules for elaboration:

Specification of the graduation thesis is design and implementation of optimised manufacturing cell. The main goal of the project is to design manufacturing cell together with assembly process definition taking in account production volume, ergonomic and quality of product. Following goal is to implement designed manufacturing cell in to current layout in the company BOS Automotive Products CZ s.r.o.

It is recommended that thesis will follow classical project based methodology:

1. Introduction in to design and optimization of manufacturing systems (e.g. Lean Six sigma methods, Ergonomics, rules of designing material and information flow, Process analysis, 5S.
2. Analysis of current state and requirements (job data analysis, avaiable layout analysis,proces analysis).
3. Design of manufacturing cell and assembly proces options.
4. Evaluating and selecting best solution e.g. expected ROI.
5. Conclusion and final evaluation.

Scope of graphic works:

Scope of work report
(scope of dissertation): **50-60 pages**

Form of dissertation elaboration: **printed/electronical**

Language of dissertation elaboration: **English**

List of specialized literature:

[1] KARWOWSKI, W., G. SALVENDY. Ergonomics in manufacturing: raising productivity through workplace improvement. Norcross, Ga.: Engineering and Management Press, c1998. ISBN 9780872634855.
[2] PYZDEK, T., P. A. KELLER. The six sigma handbook. Fourth edition. New York: McGraw-Hill Education, [2014]. ISBN 9780071840538.
[3] BRITTON, G. A., S. TORVINEN. Design synthesis: integrated product and manufacturing system design. CRC Press, 2013. ISBN 9781138073746.
[4] GROOVER, M. P. (2007). Automation, production systems, and computer-integrated manufacturing. Prentice Hall Press. ISBN 9780133499612.

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Date of dissertation assignment: **15 November 2018**

Date of dissertation submission: **15 May 2020**

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Liberec, dated: 15 November 2018

Declaration

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At the same time, I honestly declare that the texts of the printed version of my master thesis and of the electronic version uploaded into the IS STAG are identical.

26. 3. 2019 Vignesh Babu Kuduva Gopinath

ACKNOLEDGEMENT

I would like to express my gratitude to the following people who were very instrumental in making of this thesis work a reality. I am thankful for the precious time they dedicated to guide and motivate me towards the successful completion of this project.

Ing. František Koblasa, Ph.D. – Department of manufacturing systems and automation, for his expert guidance, utmost patience, motivation and inspiration to complete this project.

Ing. Lucie Heligar Svobodová, Ph.D. – Manufacturing Engineer at BOS Automotive Products CZ s.r.o. for the expert guidance, tour of the company and help with practical work at the company.

Ing. Petr Zeleny, Ph.D. – Head of the Department, Department of manufacturing systems and automation, for his support and encouragement.

Last but not least, I would like to thank my family and loved ones for their continuous support, trust and help in the process study.

Abstract

The work presented in this thesis is the design of a manufacturing cell for the company BOS Automotive Products CZ s.r.o. in Klasterec and Ohri. The main goal of this thesis is to design new universal manufacturing production cell for the company. Using some suitable tools such as process analysis, Moment analysis, Product family matrix, the current state processes that takes place in BOS Automotive has been analysed. with some literature review from the research works. Based on the requirements of the company BOS Automotive s.r.o. work consists of design of a new Universal manufacturing cell. The new design of the manufacturing cells is represented in the form of CAD models as well as with a process flow diagram, multi-criteria analysis and spaghetti diagrams.

Keywords

Design of manufacturing system, Layout, Process flow.

Abstrakt

Tato práce se zabývá návrhem výrobní buňky pro firmu BOS Automotive Products CZ s.r.o. v Klášterci a Ohří. Hlavním cílem této práce je navrhnout pro společnost novou univerzální výrobní buňku. Pomocí některých vhodných nástrojů, jako je analýza procesu, momentkové pozorování, matice produktové rodiny a s některými dalšími na základě literární rešerše byly analyzovány aktuální stavy procesů, které probíhají v BOS Automotive. Na základě požadavků společnosti BOS Automotive s.r.o. je pak navržena v nové univerzální buňky. Nový design výrobních buněk je reprezentován ve formě CAD modelů, stejně jako vývojovým diagramem procesů, multikriteriální analýzou a špagetovým diagramem.

Klíčová slova

Projektování výrobních systémů, rozmístění pracovišť, Procesní tok

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1. INTRODUCTION

Increase in the industrial competition has made the companies to improve the levels of output, quality and efficiency which can be achieved only by designing a better production system that that of a greater control over existing ones. A set of wide range of activities and some problems regardless of technology and process are to be considered before design of a manufacturing system. Some separately emerged specific needs such as concepts, techniques, solution procedures are rarely presented within a single volume using a common framework. The materials related to production and operation management which broadly covers the general concepts of the design of production system. Design of production system will provide a focus on the design aspects of production as opposed by planning and control or more general issues. Which leads the industry in a better way to do the production of products and controlling them in a right manner. A better design of a production system will increase the productivity will elimination some Non-value-added items such wastes in the industries, unwanted motion, unwanted production time, etc.

A production line in a manufacturing process is a traditional method, in which the product is moved and stopped in the line for performing some operation on it. The movement of the product in the production line can be done either manually by a staff or by using some conveyor, it may vary depending on the product being manufactured. More often production lines are used for the manufacturing of some similar products in higher number of volumes. For example, if a product is being produced in multiple production lines because of the capacity of the product it may occupy a lot of space of the work floor, in such case "**UNIVERSAL PRODUCTION LINE"** plays a major role. Universal production lines are used to produce more type of products with higher capacity. The aim of this diploma thesis is to design a Universal line for luggage cover production for BOS automotive products CZ, s.r.o.

The aim of this thesis work is therefore to:

- Analyse the current layout at BOS automotive products CZ, s.r.o including the process flow in the production line.
- Finding out the bottleneck.
- Finding out a possible solution.
- Designing a new universal line for the production and evaluating and selecting a variant to implementation.

2. MANUFACTURING

Making of good and services to satisfy the needs of mankind is called as Manufacturing. By applying some physical and mental labour it creates value to the process. Manufacturing system will lead to a production of some economical products and helps them marketing at a right possible time by means of some chain of interrelated activities such as processing, product design, manufacturing of tools, jigs and fixtures, etc. Manufacturing is not a single man activity; it should be done by a large group of people. Many activities few independent and interrelated are grouped together to form a Manufacturing System. By considering future competitions the products are manufactured economically and qualitatively based on the demands of the customers. Manufacturing systems with the interactions of many activities got enhanced with computer and hence paved a way for CIM-Computer Integrated Manufacturing. For producing high quality products, the plant layout plays an important role in it. The plant layout should provide all the data about the timely movement of the raw materials, availability of jigs and fixtures, adequate safety for the workers in the job shop, adequate space for the machines and tools, etc. Different activities in the actual manufacturing is called as management functions. Roll of engineers are more important in the manufacturing concern of an organizations.

2.1. Plant AND shop Layout

It is necessary to have a proper plant layout and scheduling procedure, because in manufacturing most of the time spent by the job was in waiting and moving. The overall arrangement and positions of all equipment's, machine, manpower and everything must be mentioned in a plant layout. Designing of the shop layout forms an integral part in plant layout of the manufacturing plant.

2.2. TYPES OF LAYOUT

The manufacturing layouts are classified into four types namely fixed or position layout, line or product layout, process or functional layout and combination or group layout as per the production requirements and their product types.

2.2.1. Fixed OR Position Layout

Fixed or Position layout is sometimes called as project layout. The major part of the assembly remains fixed and all other equipment's and machines tools for processing is brought towards

the fixed part or to the work site. Until the dispatch the assembly of the product remains in a fixed position without any disturbance. This type of layout comes in action when the products to be produced is bulk in size. This type of manufacturing of bulk products requires only simple machines and tools. The products that are manufacture are in very small numbers maybe one or two because of the size of the product. The products that are manufactured in this type of layout are ships, aero planes, etc. This type of layout id highly flexible. The below figure shows the typical layout of a fixed or position layout.

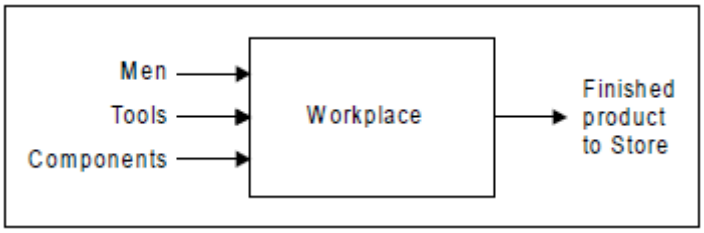


Figure 1: Fixed or Position Layout[1]

Merits

- This type of layout is highly flexible for large number of products.
- During manufacturing process, the movement of material, men and machines will be less.
- Very high skilled operators are required for operations.
- Each personal is responsible for their work.

Demerits

- Equipment handling cost is very high.
- Difficult utilization of labours and equipment's.
- Only large items are manufactured.

2.2.2. Process OR Functional Layout

In this layout, according to the functions of the manufacturing operations machines and production facilities which are similar are grouped together. Machines with similar operations are grouped in a place where parts with similar operations can be done in one place. For example, all milling machines are grouped in one place for milling operation. Job order type

of production and maintenance activities of non-repetitive production uses this type of layout. There won't be any change in the layout when there is a change in component or product. The production in these types of layout will be affected when there is any breakdown. These types of layout play an important role in batch production. The below figure shows a typical layout of process or functional layout.

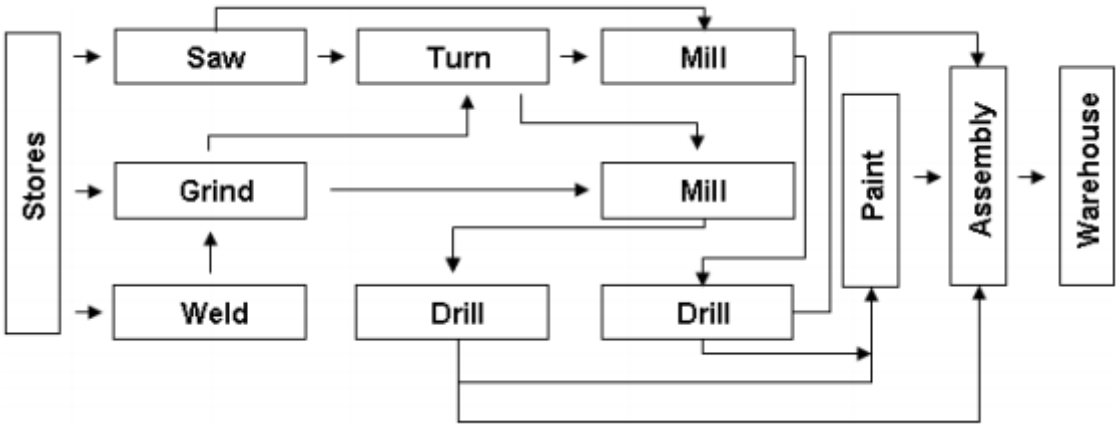


Figure 2: Process or Functional Layout[2]

Merits

- These types of layout are widely flexible in allocating work to both equipment and workers.
- Better utilization of equipment.
- Product quality is improved because of the work of workers in one machine.
- Varieties of jobs can be done.
- Operations done by workers in one section cannot be affected by another sections.

Demerits

- More space is required to produce the products.
- Difficult production control.
- More efficient co-ordination and inspection is required.
- Queue is created because of more material.
- Larger inventory is required.
- Takes more time to complete similar products.

2.2.3. Line or Product Layout

Based on the product flow line the machines with various operations are placed in a sequence where a raw material is fully converted into a product. No machine in the line will have the same operation. The operation of the line sequence starts with raw material and moves it to other operations accordingly in a sequential path. Line layout play an important role in continuous-production system in which the product has smaller end-product and highly standardized and interchangeable parts of the product. Products having steady demand falls under this category. For mass production of products this type of layout can be used where there will be reduced material handling and material flow will be smooth. Stoppage of production may occur where there is some breakage in a machine. The below figure shows a typical Line or Product layout.

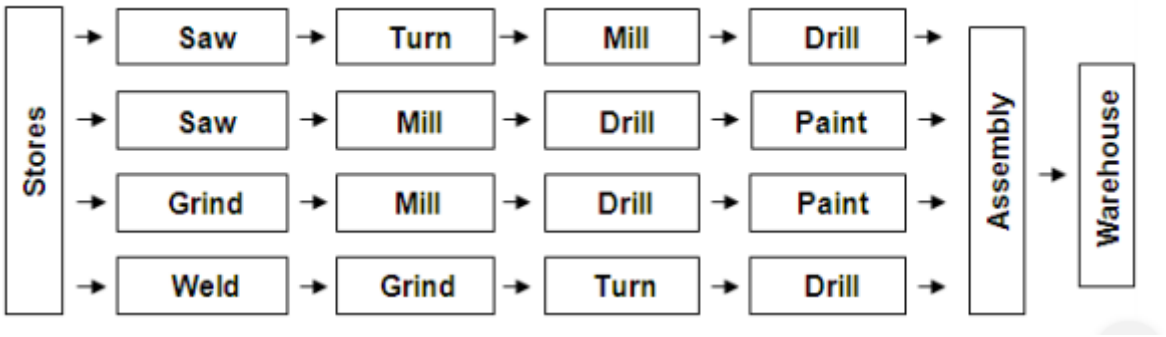


Figure 3: Line or Product Layout[2]

Merits

- Smooth and continuous flow of work.
- Less skilled labour is required.
- Inventory is reduced.
- Reduces the production time.
- Simple planning and control and better coordination is achieved.
- Reduced processing time of the product.
- Requires less production space.
- Movement of material and material handling is less.

Demerits

- Increasing the production beyond the production line capacity is very difficult.
- Inspection becomes very difficult with single inspector.
- When the product is changed this layout becomes less flexible.
- Stand by machines are required, if a machine in the line gets breakdown then it needs to be replaced.

2.2.4. Combination layout

This type of layout is also called a group layout. It takes the combined advantages of process and product layouts. Manufacturing lines with process layout is arranged in sections and get scattered according to the condition. This type of layout is adopted in manufacturing industries. The machines and equipment's are grouped in order to perform similar operation to produce family of products. When a product is produced with different shapes and size this type of layout can be used. Because of this some machines are arranged according to the process layout and some are arranged according to the product layout. There will be no change in the layout when there is a change in size and type of the product. This layout helps in elimination of changing time of products from one machine in one section to another. When the products being produced do not justifies the individual and independent production then combinational layout can be used to perform the operations on the production of the product. The below figure shows a typical Combination layout.

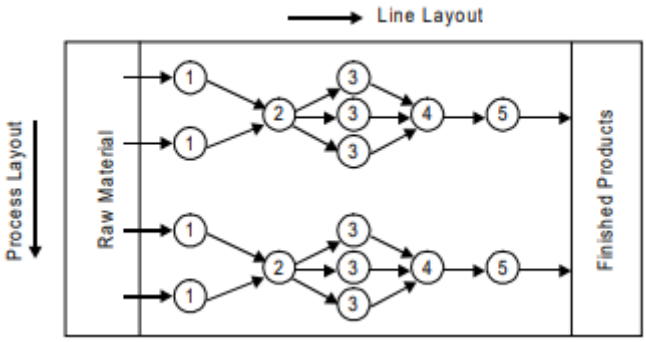


Figure 4: Combination Layout[1]

Merits

- Cost of material handling of metals and machine setup time is reduced.
- Production planning function has been simplified.

- Excess work in progress inventory is eliminated.

Demerits

- Changing of batch size leads to changing the number of machines.
- Structure of the layout needs to be changed completely when there is a change in input component mix.
- Changing of existing layout will be time consuming and costly.

When a new component is introduced in the line a thorough analysis is required.[1]

2.2.5. Cellular Layout

In this layout according to the process requirements of the part families the machines are grouped. The machines which are grouped together according to their part families is called as cells. By using a technique called as group technology (GT) the processes are grouped by identifying similar design and process characterised parts. The operators inside the cell should be trained to operate all the equipment's in the cell. Cells can be used in assembly lines. Flexible Manufacturing System (FMS) is the automated version of cellular manufacturing which can be controlled by using a computer. By using FMS, the controlling of parts becomes much easier which helps in maintaining the flexibility of product layout of small batch production. The below figure shows the image of a cellular manufacturing system.

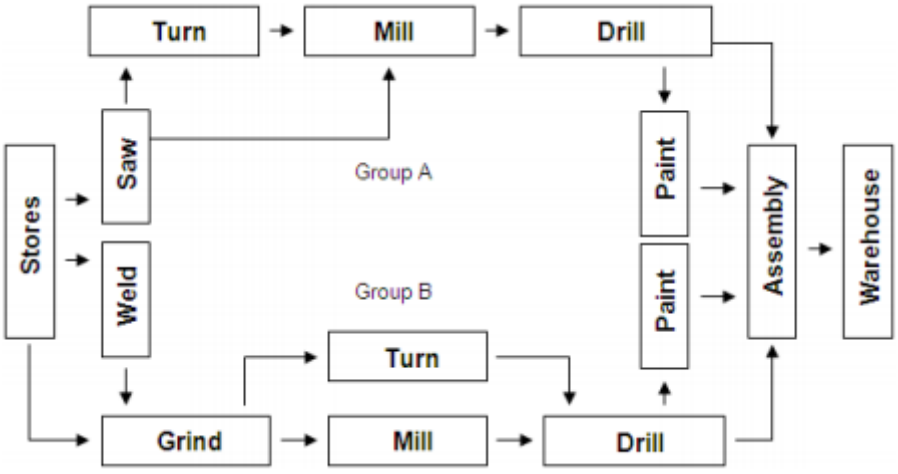


Figure 5: Cellular Layout[2]

Merits

- Faster processing time.
- Less material handling.
- More flexible.
- Less Work-in-process inventory.
- Reduce setup time.[3]

2.3. Methods of Analysis

In-order to design a manufacturing layout some analysis must be carried out to find out what needs to be added in the new layout from the current one. Some of the analysis methods are discussed below.

2.3.1. Process Analysis

Transforming of an input into an output is known as Process. The major element of the process can be presented with the help of "**process flowcharting**". Process flowcharting consists of some basic elements such as operations, customers, decision points and storage areas. The analysis of the process begins with the help of these elements.[4]

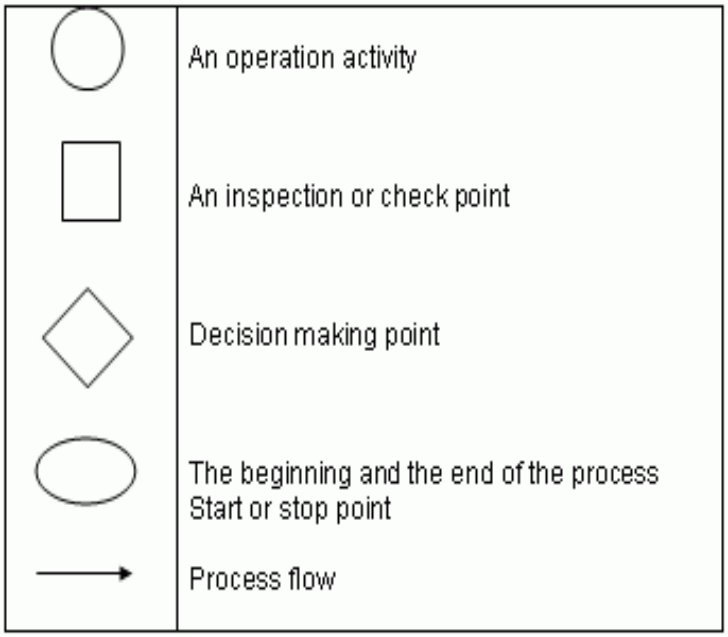


Figure 6: Process analysis symbols[3]

2.3.2. Moment Analysis

Moment analysis is used to find activities which add value and helps in eliminating the activities that do not add value which are considered as waste. This helps in increasing the productivity and efficiency by calculating the capacity of the manufacturing product, which leads to produce products with better quality and at lower price.

It is used for developing a better way for the operation of process. By finding out some standard motions and assigning time for each process they can be made better which get some good results in the market.

There are three steps are followed in the data processing for the standard time calculation:

- Sample size calculation.
- Finding of normal time by multiplying observed times with rating factor. The determination of rate factor is done by the observer, where 1. V>100% (Rating above normal), 2. V=100% (Normal rating), 3. V<100% (Rating below normal).
- Further allowance factor of each operations are to be multiplied with normal times.[5]

2.3.3. Capacity

Capacity is called as the upper limit on a load which can be handled by an operating unit, which is the rate of productive capability of a facility. Inputs or outputs of a system is specified as load.

When an organization decides to manufacture a new or existing product then it must do a capacity planning. The selection of technology for the production process and location for the machines are done once the capacity is evaluated. The following activities involves in capacity planning:

- Assessing of existing capacity.
- Forecasting the needs of the capacity.
- Identification of alternative ways for modifying the capacity.
- Evaluating the alternatives.
- Selection of the right capacity alternative.

Assessing of existing capacity: measurements takes place in assessing, in which the measurements are a blend of different approaches and it is not from a single technique which is customized for decisions. For a effective system two systems of measurements are used namely: efficiency and utilization. The ratio actual output to the effective capacity is called as efficiency and the ratio of actual output to design capacity is called as utilization.

Forecasting the needs of the capacity: the requirements of the capacity can be evaluated from two extreme perspective.

- **Short-term Requirements:** the short-term workloads which a facility must handle are done by managers of the company by forecasting the demand of the product. The requirements for different product and services are made by looking ahead up to 12 months. The adjustments are made by comparing the results with existing capacities and applied when it is needed.
- **Long-term Requirements:** it is more difficult to make long-term requirements because of the uncertainty in the demand and technology. The forecasting of a product is done for almost five to ten year which is the most difficult task. Depending upon the marketing plans, product development and product life cycle the long-term requirements are made. The methods in the production process changes even when there is no change in the product.

Identification of alternative ways for modifying the capacity: once assessing both existing and future capacity requirement the identification of alternative ways of modifying capacities either short-term or long-term must be made. In this the optimization of existing resources are to be considered instead of expanding the existing resources. The future alternatives may have some disadvantages like incorrect demand forecast, some financial investments, etc. it may result in no return for several years. Since the alternatives must be selected with much care.

Evaluating the alternatives: different modelling alternatives are available for evaluating the capacity planning. They are:

- Present value analysis.
- Aggregate planning models.
- Breakeven analysis.
- Decision tree analysis.

Selection of the right capacity alternative: the most appropriate alternative can be selected by means of decision tree analysis, linear programming and computer simulation. Good understanding of the organization environment is required for selecting the alternatives for the capacity.

2.3.4. Spaghetti Diagram

Spaghetti Diagram also popularly called as spaghetti chart, spaghetti model or plot is a method which in an organization to view the movement of the objects with the help of lines. The object in motion may either be a worker, material and so on. It helps in tracking the path around the production area. Different colours are used for indicating different products at a same time. This analysis helps in the identification of crossing between workers, overlapping, length of the movement and other aspects and they can be eliminated for better production. A sample diagram is shown in the below figure.

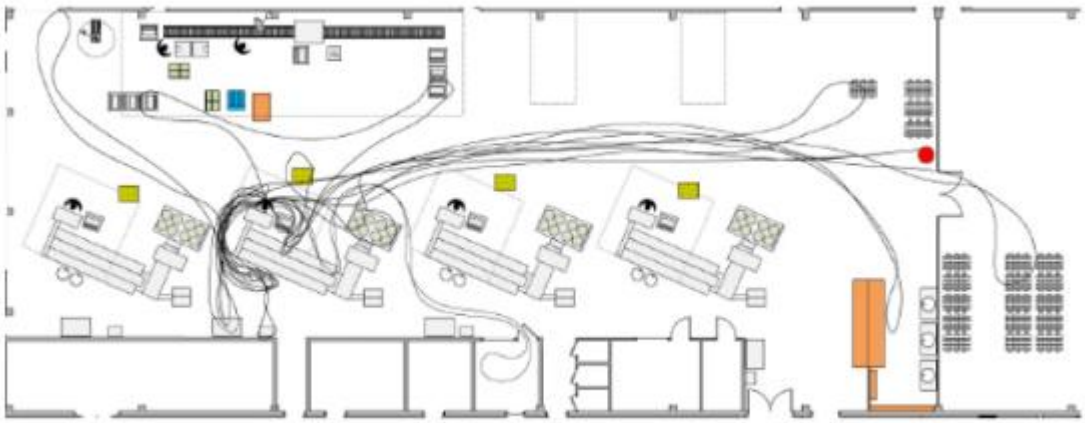


Figure 7: Spaghetti Diagram[5]

3. LEAN MANUFACTURING

Lean can be denoted by several names such as Lean Management, Lean Manufacturing, Lean Enterprise or Lean Production. Generally, Lean Manufacturing is defined as a set of principles, tools and techniques which are opted by many companies or industrial organisations for eliminating the waste to enhance the efficiency of the level of the production of products being produced.

Lean concept is widely used in manufacturing sectors and in supply chain management. But Lean is a philosophy where it can be used in the entire industry organization.

Lean Manufacturing helps the manufacturers to supply products with better quality and with low piece to lot of customers. It is an enormous process to create an organization based on Lean Manufacturing. The main aim of Lean Manufacturing is:

- Elimination of waste.
- Building of quality products.
- Production of products with low cost.
- Creating of some value adding tools for the better functioning of the organization.[6]

3.1. Types of Waste

Lean Manufacturing is meant for the elimination of waste in an organization. Elimination of waste helps to reduce the human efforts, reduces the production time to develop a product and leads to have less inventory which in turn reduces some space in company. Typical wastes in Lean Manufacturing are as follows:

3.1.1. Overproduction

Producing a product before it is needed, and more than the customer demand is said to be overproduced. It occupies a lot of space by means of storage. Some of the main causes of overproduction are:

- Long setup.
- Not having a proper scheduling.
- Improper inspection.
- Not using the automation properly.
- Just-in-case logic.

3.1.2. Waiting

The higher processing time of a machine may lead to waiting. It can be eliminated by increasing the efficiency of the human than that of machines. Some of the main causes of waiting are:

- Workload unbalance.

- Not planning the maintenance properly.
- Long processing of machines.
- Quality based problems.

3.1.3. Work in process

Work in process generally happens when there is large production with lot of materials between operations, which is because of the long cycle times. Some of the main causes of work in process are:

- Complexity of the product.
- When the market forecast is poor.
- Not getting the timely shipments from the suppliers.
- Communication misunderstanding.

3.1.4. Transportation

Transportation is a one of the most non-value-added process. Transportation can be eliminated by means of introducing manufacturing cells. Some of the main causes of transportation are:

- Poor plant layout design.
- Poor process flow.
- Size of the batch.

3.1.5. Motion

Due to some inappropriate location of tools and parts there will be some motion of workers and machines in the job floor. It can be eliminated by improving the operation of the machines. Some of the main causes of motion are:

- Poor efficiency of the machines and human.
- Poor layout of the job floor.
- Unwanted movement during waiting.

3.1.6. Defects

Defects of parts happens due to the unconsciousness of the worker and by the delivery of some wrong products. It cannot be eliminated completely but it can be prevented by finding the defects in the earlier process of manufacturing. Some of the main causes of defects are:

- Design of the product.
- Not understanding the customer need.
- Inadequate training/education of the worker.
- Poor quality of the parts.
- Poor process control.

3.1.7. Over processing

Over processing of a product is done when something is made beyond customer demand in the product. It can be eliminated by eliminating all unnecessary processing of products. Some of the main causes of over processing are:

- Change of product without the change in process.
- Communication gap.
- Excessive information.
- Customer requirements are not well defined.

3.1.8. Underutilization of people

In this case some people's abilities are not considered. Some of the main causes of underutilization of people are:

- Hiring of people with poor practices.
- Low investment in training.
- Low pay in return of high turnover strategy.

By eliminating all these wastes the entire process flow can be improved apart from improving individual operations in an organization. Lean Manufacturing helps in eliminating of these above-mentioned wastes.[7]

3.2. Methods of Lean Manufacturing

The methods used in the Lean Manufacturing are explained below:

3.2.1. 5S Method

5S method is used in the production process for the continuous improvement. 5S is the basic for the implementation of Lean Manufacturing. The name 5S is derived from the first letter of five Japanese letters. 5S is meant to be the five Stages of the work organization.

- **Seiri (Sorting)**

  Sorting of all the unnecessary items from the workstation. It leads to a better use of workspace by reducing the inventory. It can be done by marking all the unnecessary items and placing them in a designated area.

- **Seiton (Systematics)**

  It helps to arrange all the tools in their respective places in the workstation. This helps the worker to pick the right tool at right time without any search for it. It removes unnecessary traffic between employees, which in turn helps in the production of better-quality products.

- **Seiso (Cleaning)**

  Seiso helps to keep and maintain the workspace neat and clean by proper cleaning. It helps in eliminating the pollution around the workspace.

- **Seiketsu (Standardize)**

  Seiketsu helps in standardizing the first three stages of 5S. in this stage, instructions are created which defines the responsibilities of employees. It provides a systematic procedure which repeats the previously entered changes.

- **Shitsuke (Discipline)**

  This is the last stage of 5S which is the most difficult stage. In this stage, it forces both the employees and the management to change their habit in the production area.

No large financial investments are needed for 5S method. It makes the organization to create a clean, governed and maintained working environment.

Figure 8: 5S Cycle[8]

3.2.2. SMED – Single Minute Exchange of Die

SMED helps in shortening the changeover time to a single minute. Four stages of process improvement changeover equipment have been developed by Shingeo Singo:

- Current state workstation analyzation.
- Separation and changeover operation both internal and external.
- Transform internal operation in external.
- All aspects of the changeover must be improved.

The minimization of changeover time is done by transforming the operation of internal external. The performance that take place during the machine downtime is said to be the internal operations. Performance of some activities before and after the stoppage is said to be external operation. Decreasing the time of the changeover will leads the worker to spend more time in production.

3.2.4. Standardized Work

In Lean Manufacturing the standardized work helps in improving the work and sustainability of the production process. It allows all the workers to work in a same way, in a same order and

time, at a fixed cost. It helps to adapt to the constantly changing customer requirements to produce new, better standardized products.

3.2.5. TPM – Total Productive Maintenance

The waste associated with the technological machines can be eliminated using TPM. TPM makes all employees to maintain production continuity. The main aim of TPM is to increase the productivity and efficiency of all machines and equipment's by reducing the failures, retooling time, reducing the defects in product quality and decrease the time spent on the start-up of production.

3.2.6. Kanban

Kanban is a production control method, which says that the control is not from the production schedule, it is directly from the events occurring on production. By using Kanban, the stock in the workstation can be eliminated. It helps the suppliers to supply the raw materials at right time and helps in the increase of productivity of products.

3.2.7. Kaizen

In Japanese Kaizen means continuous improvement. Kaizen always search for new possible things in terms of development of organization. Kaizen can only be achieved from the cooperative work of high-level managers to low level workers. The main aim of Kaizen is to eliminate all non-value- added time and change them into value-added time in an organization. The ideas from low level employees to high-level managements are collected for the continuous improvement of the organization.

3.2.8. Poka-Yoke

Poka-Yoke helps in prevention of errors that occurs from mistakes. The main aim of Poka-Yoke is to eliminate errors. Any error in the process can be solved using Yoke method. It helps in reducing the training time of employees, many quality control operations can be eliminated, increases the control process to 100% by eliminating errors.[9]

3.2.9. Takt time

Takt time is used to meet the customer demand at a right pace. The Takt time can be calculated by dividing the total working time (for a shift) by the customer demand. The Takt time helps

in continuous improvement of an organization. The Takt time changes according to the customer demand, so it is hard to maintain the same pace of production in a manufacturing.

Takt Time = working time available/customer demand[10]

3.3. Six Sigma

Six Sigma is said to be the implementation of quality principles and techniques which are highly effective, rigorous and focused. The main aim of Six Sigma is an error free business performance. Sigma is derived from a Greek word which is used to measure the variability of processes. Usually company works on the norms of three or four level Sigma which means the standard of processes are created between 6,200 and 67,000 problems per million opportunities. But Six Sigma increases the expectation of the customers and increases the complexity of products by the standard of 3.4 problems per million opportunities.

For decades Six Sigma relies on some tried and true methods. The complexities that are characterized Total Quality Management (TQM) was discarded by Six Sigma by using some measures. The tools of Six Sigma are from a simple performance improvement model known as Define-Measure-Analyse-Improve-Control which is popularly known as DMAIC. DMAIC is briefly described as follows:

Define

This phase is used to define the goals of the improvement activities. The main objectives of the Define phase are:

- Developing of the project charter. (It can be done by 1. Defining the scope, objectives and schedule of the process. 2. Defining the process and its stakeholders. 3. Selecting team members for the project. 4. Obtaining the authorization from the sponsors.)
- Assembling and training the team for the project.

Measure

This phase is used for the measurement of the existing system. The main objectives of the Measure phase are:

- Process definition: it measures whether the process in investigation is clearly defined or not.
- Metric definition: it measures the relative means of the process.
- Establishing of the process baseline: for verifying the previously defined business needs the current operating results are to be measured and quantified.
- Evaluating the measurement system: for drawing some meaningful conclusion the reliability of the data must be validated.

Analyse

This phase is used to find ways that eliminates the gap between the current performance of a system by analysing them. The main objective of the Analyse phase are:

- For existing processes, the value stream must be analysed for eliminating the gap between current and desired performance.
- The sources of variation are to be analysed which contributes to the design performance.
- Similar products can be analysed by using some benchmarking techniques.

Improve

This phase helps in the improvement of the system. The main objectives of the Improve Phase are:

- Implementation of new design.
- Prioritizing of opportunities in case of multiple proposals.
- Establishing of optimal setting for the new design.
- Steps are repeated for better evaluation.

Control

This phase helps in the control of the new system. The main objectives of the Control phase are:

- It statistically validates the objectives and benefits of the new design.
- A control plan is developed and implemented for the new design.[11]

3..4. Lean Six Sigma

For improving the quality of the product Lean Six Sigma method is approached by a combination of reducing the variations and elimination of wastes in an organization. This approach combines two ultimate concepts of improvement program, Lean Manufacturing and Six Sigma. .[12]

4. BOS Automotive Products CZ s.r.o

BOS Automotive Products was established in 1910 by Wilhelm Baumeister. It is an international company which has its locations in Europe, North America and Asia. BOS plays an important role for many automotive industries by developing, manufacturing and distributing innovative systems and components. They satisfy their customers by continuous innovation and improvement, cost optimization development and production process with high quality.

BOS Automotive products CZ s.r.o located in Klasterec and Ohri produces different products. The products include Luggage Cover Systems, Sun Protection Systems, Panoramic Roof Systems, Armrests, Cargo Management (intelligent Trunk Storage, Fixation and Organization Systems), Safety Restraining Nets, Innovative Door Handle Systems, Carrier Systems, Plastics in the engine components for different automotive industries. All these above mentioned produced in an area of 3,600 sq.m production plant with a total number of almost 726 employees.

Figure 9: BOS Automotive s.r.o[13]

4.1. Luggage Cover

The luggage cover is used in the trunk area of the car to cover the items that are stored in the trunk. By hiding the items in the storage, it can provide added security and it also provide shade cover. The luggage cover can be opened by simply extending it from the rear seats, after extended, the cover is attached to the hooks which is on the both sides of the trunk. The luggage covers can be retracted by simply detaching them from the hooks. BOS Automotive s.r.o produces luggage cover for hatchback vehicles, station wagons, vans and modern SUV's.

Figure 10: Luggage Cover[13]

5. CURRENT STATE ANALYSIS

This state consists of current layout of the manufacturing cell, its process analysis and moment analysis, product family matrix, capacity requirement of each production cells and Sankey diagram which explaining the number of products flows in a line and how it flows.

5.1. Current layout of manufacturing cells

The layouts that are currently in use are explained below along with their processes and issues in them.

5.1.1. HARDO

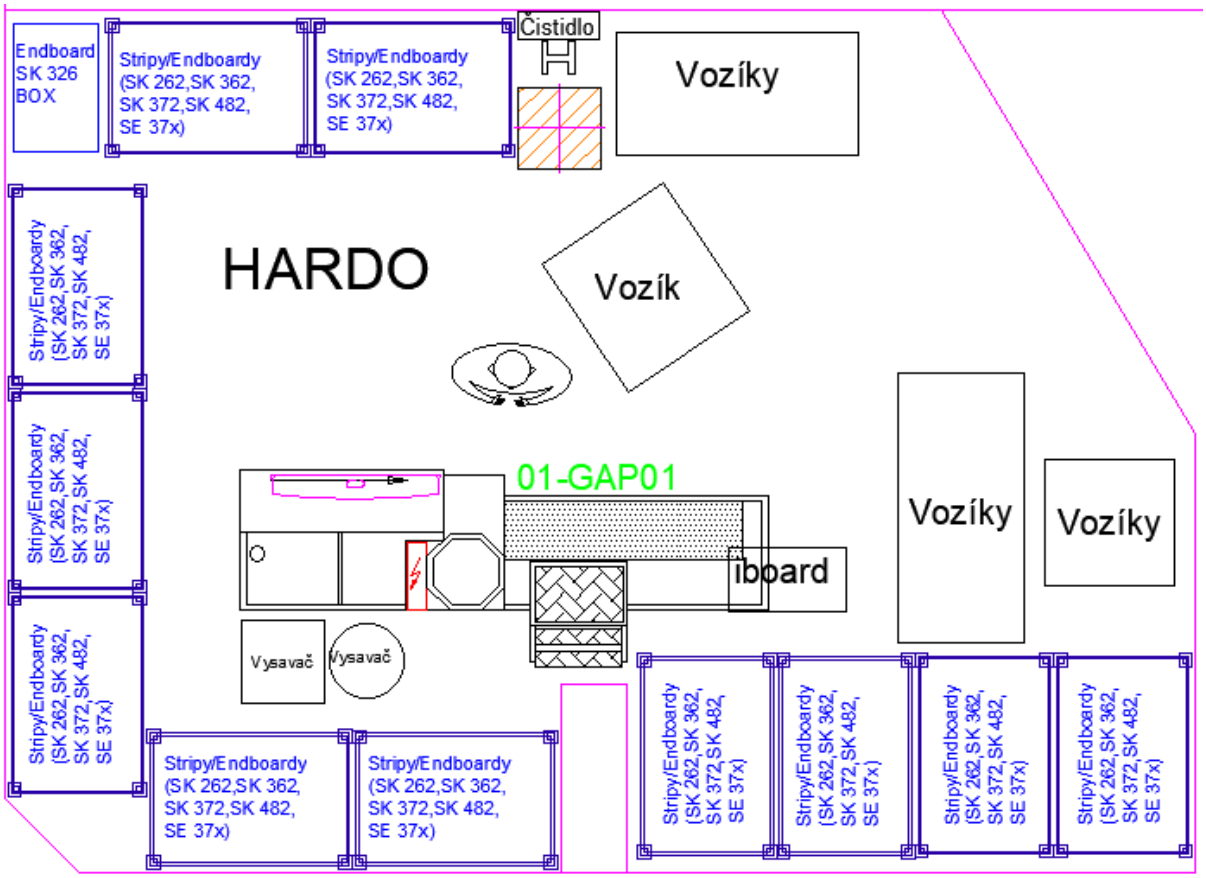


Figure 11: HARDO[13]

This is the place where the wooden boards are made. This is the first step after the raw material is arrived. From this place the wooden boards are send to each production cells.

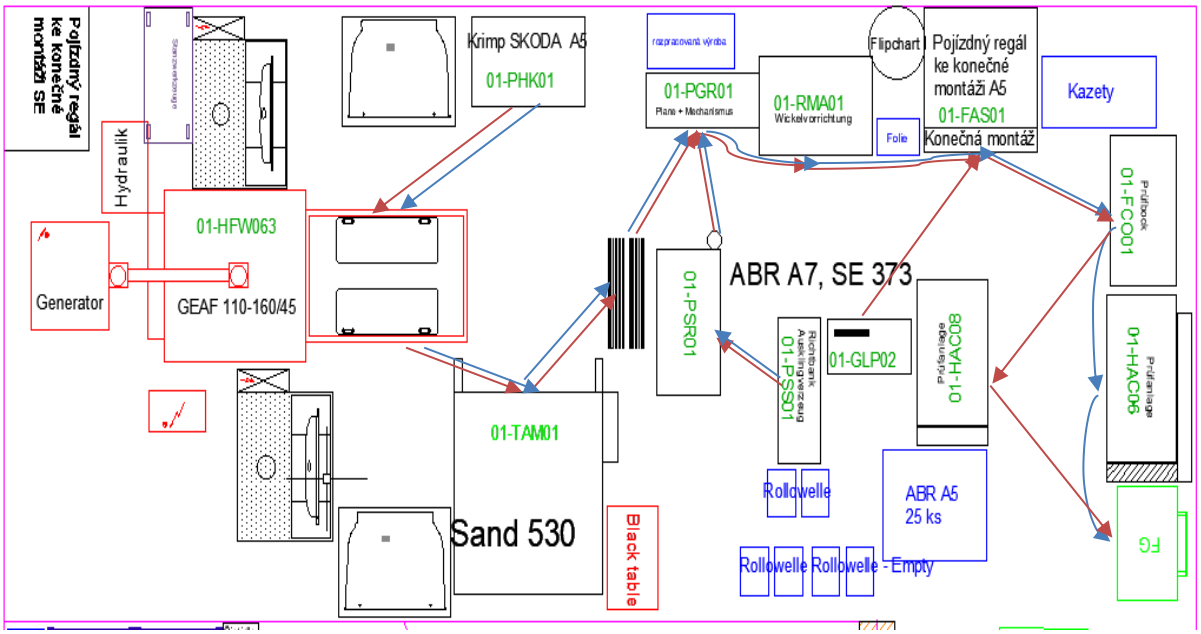


Figure 12: Production Cell 1[13]

The above shown figure is the image of the current product cell 1ayont with the direction of movement of the material in the cell, in which it is used to produce luggage cover for Skoda Octavia and SEAT. The luggage covers for both the cars are manufactured based on the demand in a shift manner. The processes that take place are mentioned below:

- HARDO: from this place the wooden boards are supplied to the production cell.
- Crimping, Slider mounting: in this place the wooden boards are crimped off and then the slider is mounted onto it (PHK01).
- Welding: after mounting the slider the boards are welded with Fabric like material in a welding machine (HFW063).
- Cutting off: then the extra material is cut out using (TAM 01).
- Mounting the spring, Crimped, Straightening, tape: the spring which is used for extraction and retraction of the whole assembly is mounted into a rod by crimping it off and tape it outside (PSR01).
- Final assembly of the spring (PSS01).
- Wounding mechanism: the spring inserted rod is wounded along the fabric like material (PGR01).

- Inserting into charger: the wounded setup is inserted into a charger in this station (RAM01).
- Inserting of spring and side cover: then the charger is fitted with springs and they are covered with side covers in this station (FAS01).
- Gluing the flap: in this station the flap is glued (GLP02).
- Final assembly: here the final assembly of the part is done (FCO01).
- Final check: here the part is finally checked for errors (HAC06).
- Packing: after checking if the part is good they are packed and stored.

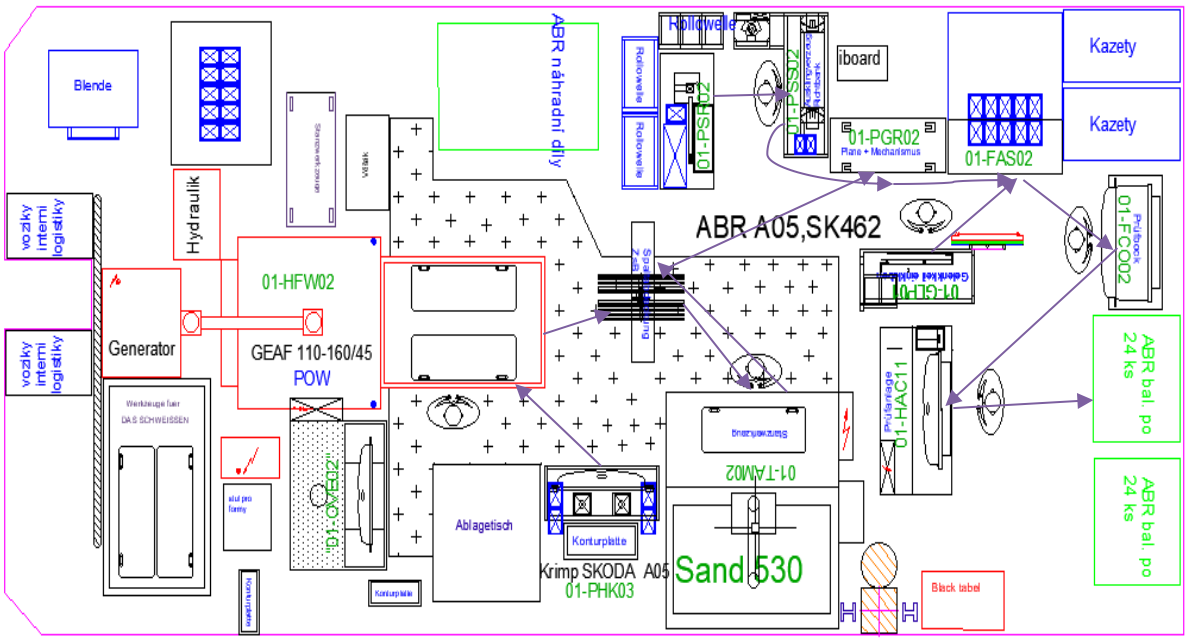


Figure 13: Production Cell 2[13]

The production cell 2 is used for the manufacturing of luggage cover for Skoda Fabia, Fabia combi and Skoda Superb, Superb combi. The manufacturing of the luggage cover in this cell is like production cell 1. The major difference between production cell 1 and production cell 2 is the difference in dimensions of the products being manufactured. The processes take place in this production cell is explained below:

- HARDO: from this place the wooden boards are supplied to the production cell.
- Crimping, Slider mounting: in this place the wooden boards are crimped off and then the slider is mounted onto it (PHK03)

- Welding: after mounting the slider the boards are welded with Fabric like material in a welding machine (HFW02).
- Cutting off: then the extra material is cut out using (TAM 02).
- Mounting the spring, Crimped, Straightening, tape: the spring which is used for extraction and retraction of the whole assembly is mounted into a rod by crimping it off and tape it outside (PSR02).
- Final assembly of the spring (PSS02).
- Wounding mechanism: the spring inserted rod is wounded along the fabric like material and they are inserted in a charger (PGR02).
- Inserting of spring and side cover: then the charger is fitted with springs and they are covered with side covers in this station (FAS02).
- Gluing the flap: in this station the flap is glued (GLP01).
- Final assembly: here the final assembly of the part is done (FCO02).
- Final check: here the part is finally checked for errors (HAC11).
- Packing: after checking if the part is good, they are packed and stored.

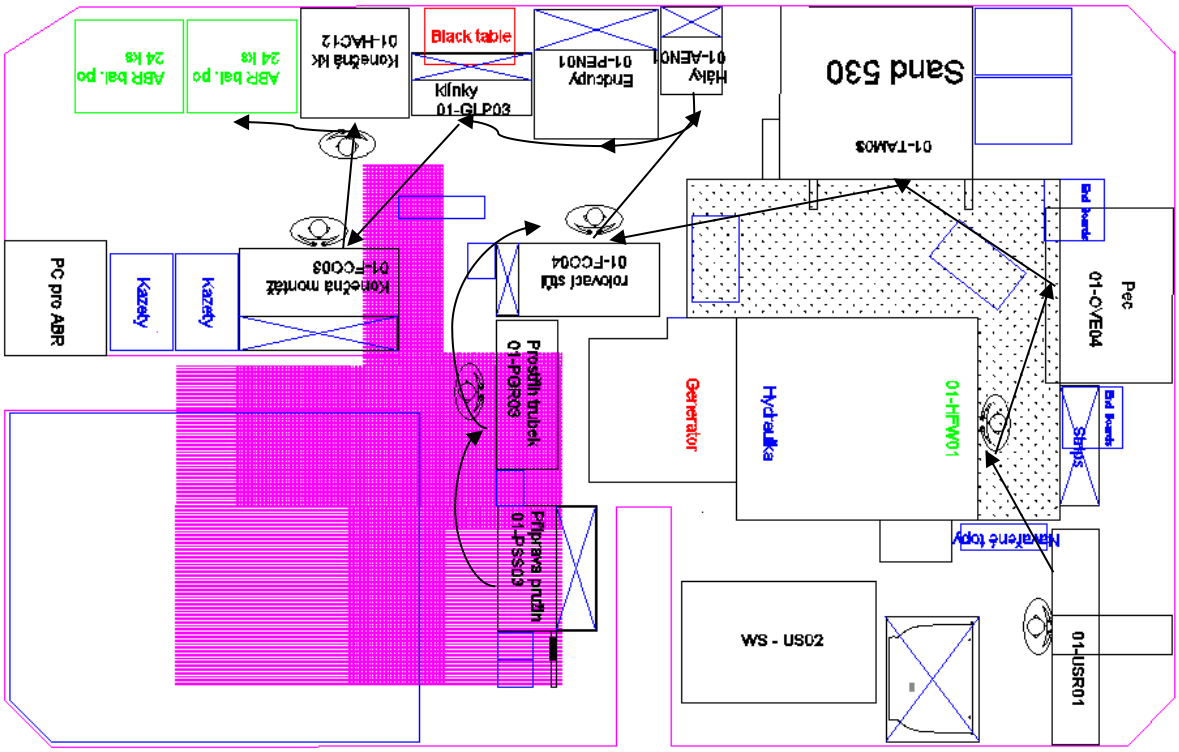


Figure 14: Production Cell 3[13]

The above shown figure is the image of production cell 3 which is used for the manufacturing of luggage cover for Skoda Karoq. This production cell contains one extra operation from other cells. A fabric cutting machine (USR01) is used before welding. Other than this most of the operations are like production cell 1 and 2. The image of the fabric cutter is shown in the below figure.

Figure 15: Fabric Cutter in Production Cell 3[13]

The processes that take place in this production cell is explained below:

- HARDO: from this place the wooden boards are supplied to the production cell.
- Crimping, Slider mounting: in this place the wooden boards are crimped off and then the slider is mounted onto it.
- Welding: after mounting the slider the boards are welded with Fabric like material in a welding machine (HFW01).
- Cutting off: then the extra material is cut out using (TAM 03).

- Mounting the spring, Crimped, Straightening, tape: the spring which is used for extraction and retraction of the whole assembly is mounted into a rod by crimping it off and tape it outside (PSS03).
- Final assembly of the spring (PGR03).
- Wounding mechanism: the spring inserted rod is wounded along the fabric like material and they are inserted in a charger (FCO04).
- Fitting of HOOK (AEN01).
- Inserting of spring and side cover: then the charger is fitted with springs and they are covered with side covers in this station (PEN01).
- Gluing the flap: in this station the flap is glued (GLP03).
- Final assembly: here the final assembly of the part is done (FCO03).
- Final check: here the part is finally checked for errors (HAC12).
- Packing: after checking if the part is good, they are packed and stored.

5.2. Product Family Matrix

Grouping of products into families is called as Product Family Matrix. This matrix can be used by indicating the process steps of each products. Process steps which are common to each other are grouped together to form product families.

The flow of the processes is arranged in an order of downstream processes which are closer to the customer. By these the layout of the manufacturing unit can be configured to which it can accommodate workflows with small differences and planning is done according to the use of the equipment portability.[14]

	Fabia 262	Superb SK 482	Octavia SK 372	SE373	SK326 Karoq
Cutter				x	
Support board - 993100524100	x	no			
Support board - 993100524200	x	no			
Support board - 993100524300	x	no			
Hardo	no	x	x	x	x
US piping	no	no	no	no	x
Crimping, Slide Assembly	x	x	x	x	
Welding	x	x	x	x	x
cutting out	x	x	x	x	x
Bonding of Abstract Profile	no	no	no	x	
spring mounting, crimping, straightening, trap	x	x	x	x	x
final spring mounting	x	x	x	x	x
	x	x	x	x	x
winding mechanism, s.č. 0.3 min	x	x	x	x	
Gluing the flap	x	x	x	no	x
rubbery into the endcup	x	no	no	no	
Final assembly	x	x	x	x	x
Visual check station	x	x	x	x	x
Inspection station		x	x	x	x
Packaging	x	x	x	x	

Figure 16: Product Family Matrix[13]

The above figure shows the Product Family Matrix of the cars for which the luggage cover is made. It shows the similarities of the processes for different cars in different production cells.

5.3. Process analysis

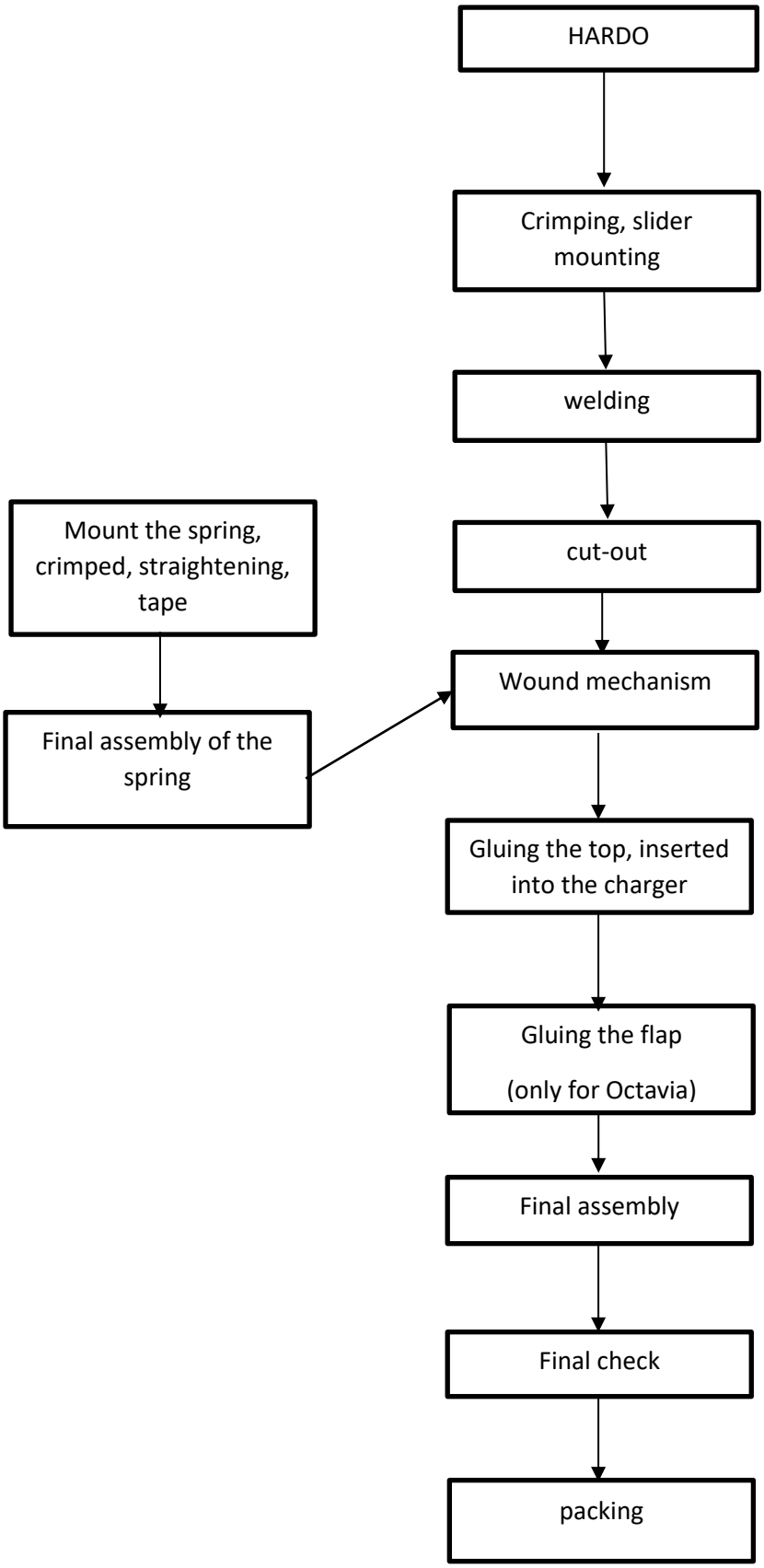
Process analyse

Numb er	Activity description	Operati on	Transp ort	Control	Entry into docum entr	Waiting	Storag e
1	01-GAP01						
2	01-PHK01,01-PHK03						
3	01-HFW063,01-HFW02						
4	01-TAM01, 01TAM02						
5	01-PSR01, 01PSR02						
6	01-PSS01, 01-PSS02						
7	01-GLP02, 01-GLP01						
8	01-PGR01, 01-PGR02						
9	01-RMA01, 01-RMA02						
10	01-FAS01, 01-FAS02						
11	01-FCO01						
12	01-HAC06, 01-HAC11						
13	PACKING						

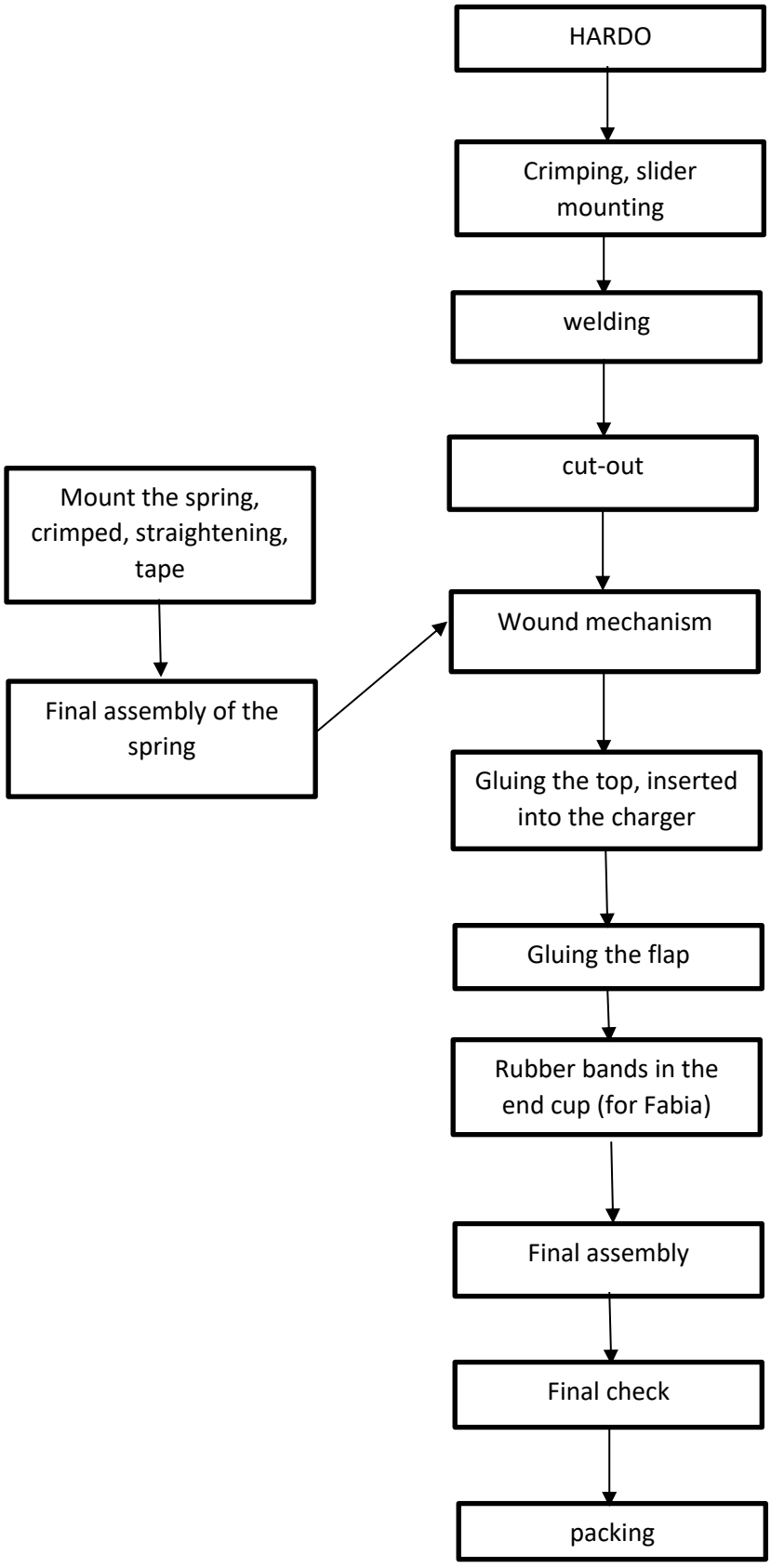
Figure 17: Process Analysis [Source: own]

The above figure shows the process analysis from the company BOS. This analysis is made to show how similar the work is done in all three production cells. It clearly shows that almost 85-90% operations are done similar in all three production cells. This analysis helps in finding the major bottleneck in the production area.

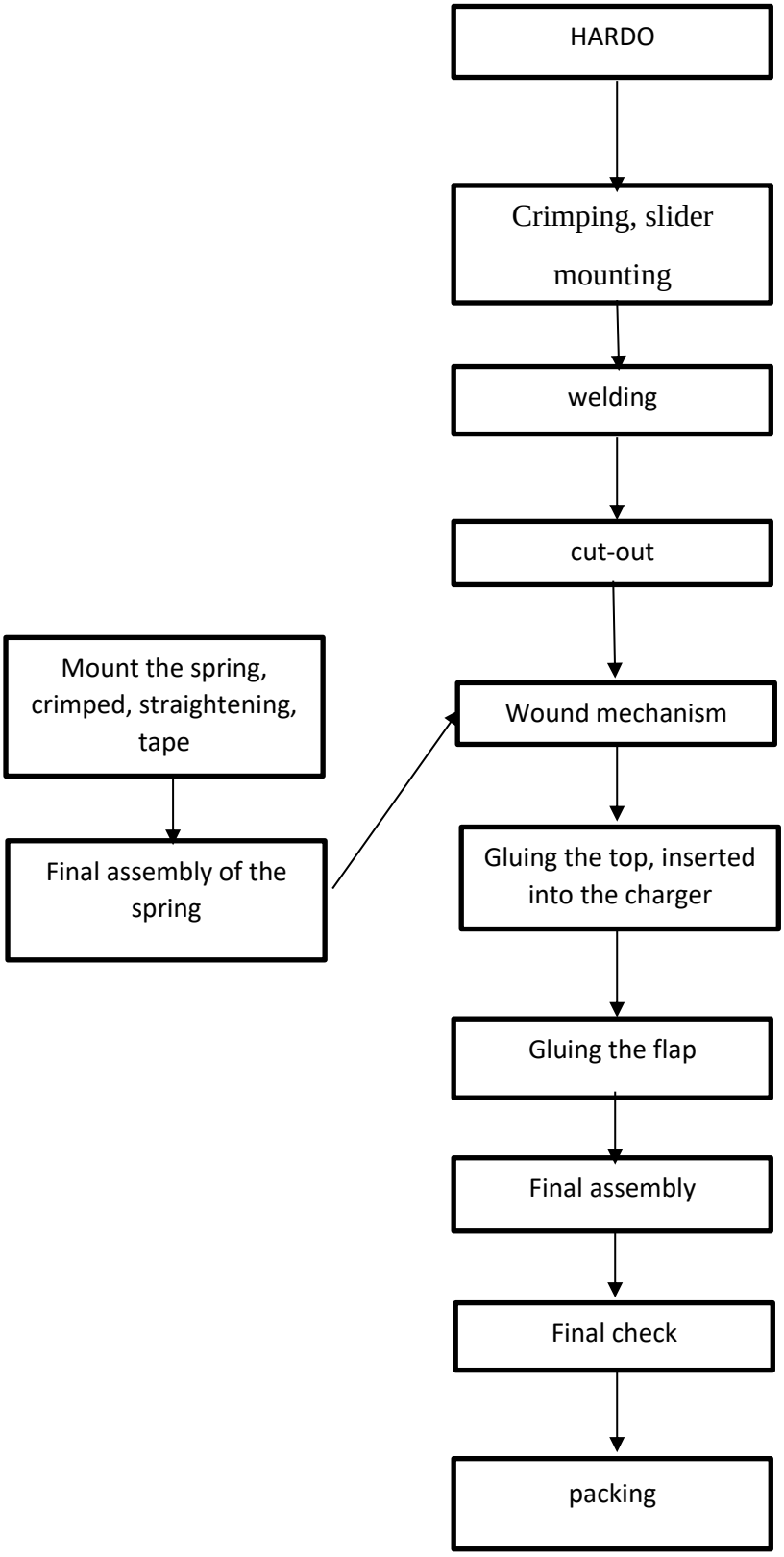
Process flow diagram for production cell 1



Process flow diagram for production layout 2



Process flow diagram for production cell 3



5.4. Moment analysis

Moment analysis is used to find activities which add value and helps in eliminating the activities that do not add value which are considered as waste. This helps in increasing the productivity and efficiency by calculating the capacity of the manufacturing product, which leads to produce products with better quality and at lower price.

It is used for developing a better way for the operation of process. By finding out some standard motions and assigning time for each process they can be made better which get some good results in the market.

There are three steps are followed in the data processing for the standard time calculation:

- Sample size calculation.
- Finding of normal time by multiplying observed times with rating factor. The determination of rate factor is done by the observer, where 1. V>100% (Rating above normal), 2. V=100% (Normal rating), 3. V<100% (Rating below normal).
- Further allowance factor of each operations are to be multiplied with normal times.[5]

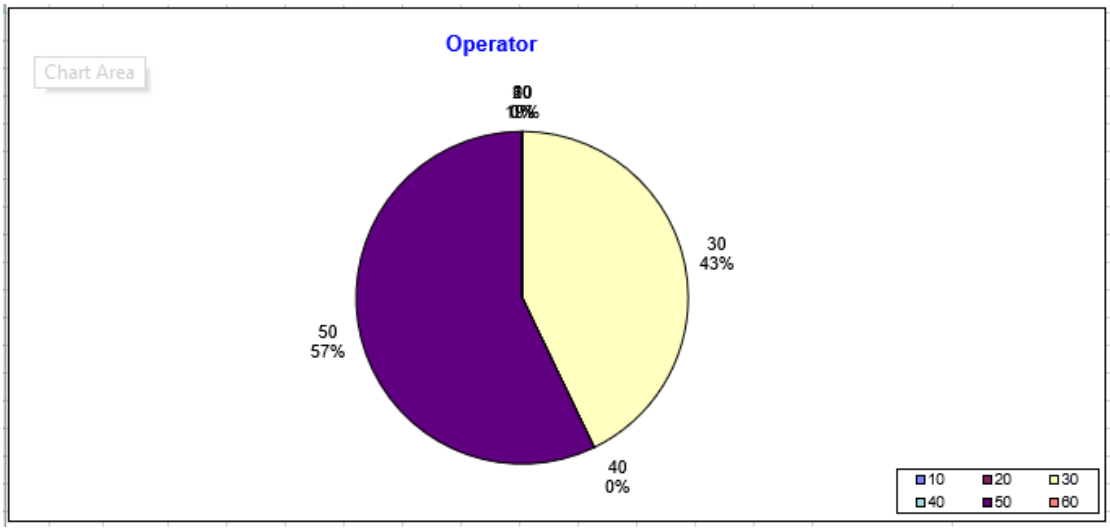


Figure 18: Main Activity [Source: own]

The above pie chart shows the main activities that are carried out by the operators in BOS automotive s.r.o. the light yellow colour represents the activities which is mentioned as 43% in the chart and the one in the purple colour is denoted as waste (Non-Value added time) which

is almost 57%. All we need to do is find an appropriate way to eliminate those wastes from the manufacturing cell. The wastes are maybe because of some unwanted waiting, motion of workers inside and outside the cell or maybe because of some group discussion before the work, etc.

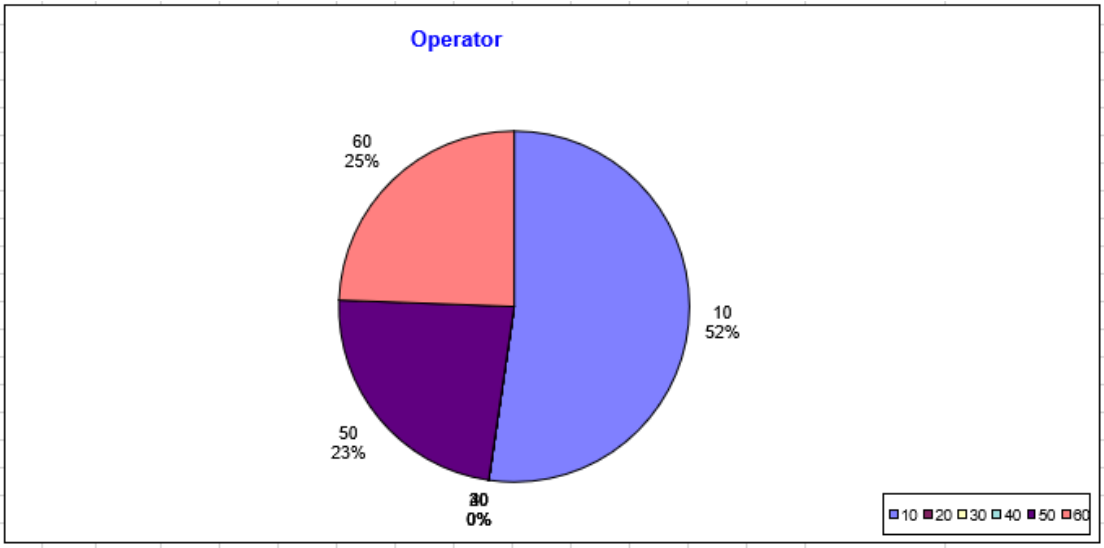


Figure 19: Quality Control [Source: own]

The above pie chart represents the quality control of the operators in BOS automotive s.r.o. the blue coloured one is the main activity which has a quality control of about 52%. The one in the purple colour is the waste (Non-Value added items) which is about 23% in the manufacturing cell, finally the light pink coloured one are the other activity that are done by the operators, such as one operator doing two operations and so on which is recorded as almost 25% from the manufacturing cell.

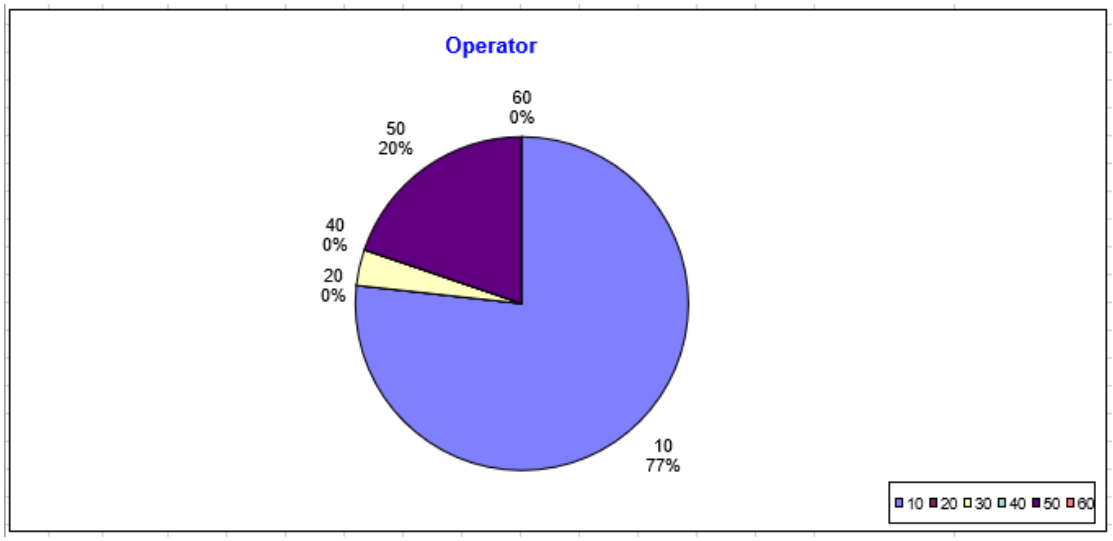


Figure 20: Maintenance [Source: own]

The above pie chart shows the percentage maintenance done by the operator in BOS Automotive s.r.o. the blue coloured one is the main activities of the operators which is recorded as about 77% and the purple coloured one is the waste which is about 20% and finally, the light yellow coloured one is the maintenance activity that are done by the operators in the manufacturing cell.

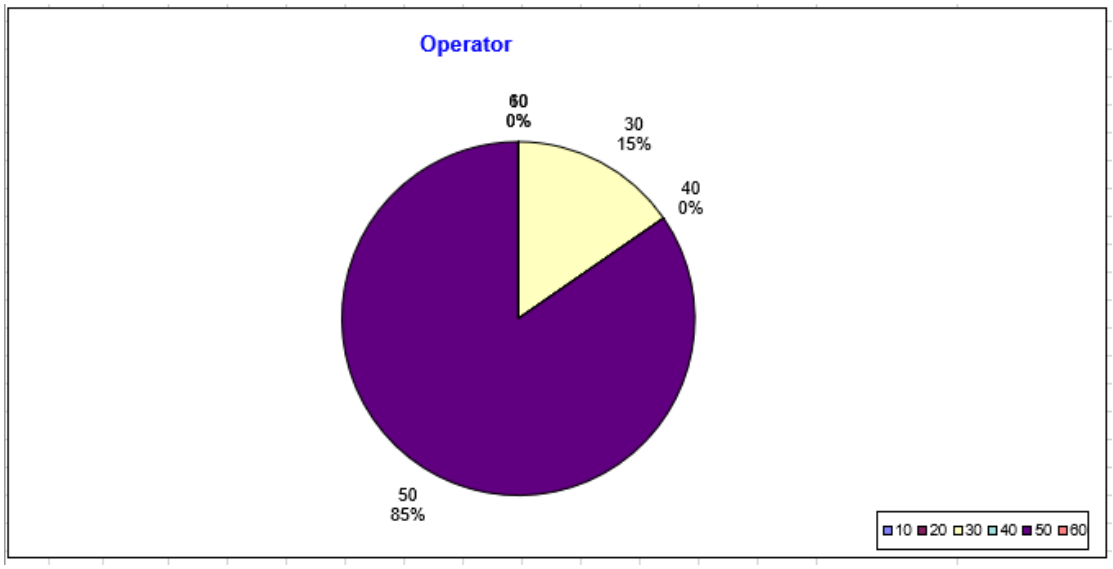


Figure 21: Manipulation [Source: own]

The above pie chart shows the manipulation of operators in the manufacturing cell. Manipulation is by means of some transportation of materials from one place to another, movement of the operator in the manufacturing cell, waiting time, etc which are waste, and it is recorded as about 85%. These wastes are to be eliminated for better productivity. The remaining 15% is the maintenance activity done by the operators apart from the work.

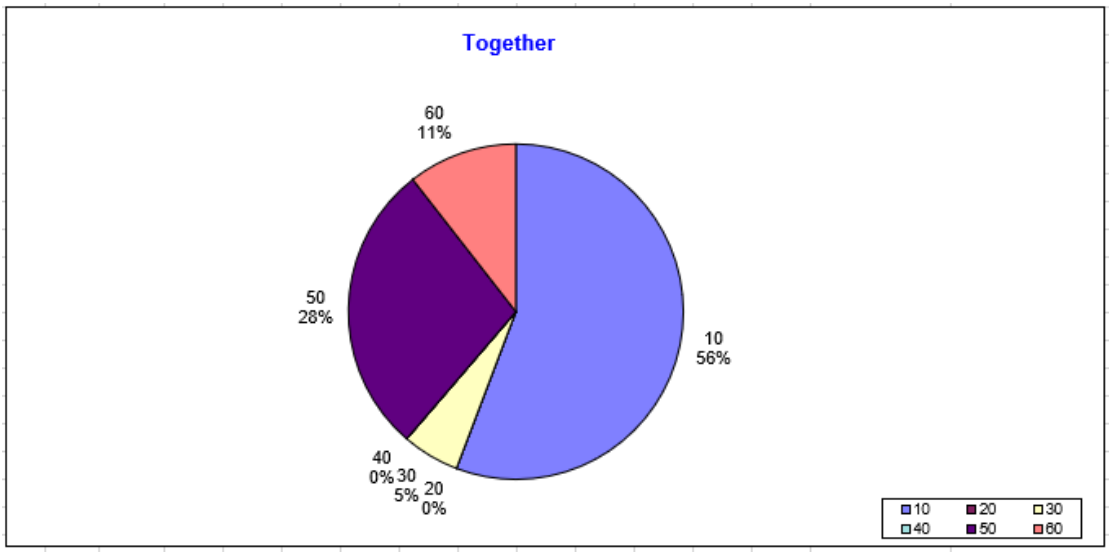


Figure 22: Together [Source: own]

The above pie chart shows the overall activities and the Non-Value-added times of the operators. This shows a clear picture of what is needed to be removed and what else are needed to be added in the manufacturing cell.

6. DESIGN OF NEW MANUFACTURING CELL

Before designing of a manufacturing cell, one must follow the prerequisites. Shortening of changeover time, reliable machine and work force are included in the prerequisites. Both the design of the cell as well as the production systems are to be considered during the design of the layout. While designing a manufacturing cell apart from the prerequisites all the other aspects like customer demand, production length, performance level of the operator, design of the ergonomics, design of inventory and everything must be considered for achieving full benefits of the manufacturing cell.[15]

6.1. Bottlenecks in the current layout

Bottlenecks are such things in a production system which reduces the performance of the work and overall efficiency of the process. When there is a stoppage or defect in one machine it will affect the whole production process, which is considered as the bottleneck of the system and it leads to lower level of output in the organization. Bottleneck varies with time and change in production system.

FILTER					[MIN]			
			workplace	Time tg	Sum	P 1	P 2	P 3
		balancing time			0,27		0,03	0,03
	M				1			
Pos	Nr	OPERATIONS	volume per workplace in %	per process (items/cycle)	time tg/item 7,71	1,33	1,30	1,30
1	P 2	Krimpovani, Montáž Gleitsteinů	01-PHK03 (100%)	0,35 (1)	0,35		0,35	
2	P 1	GEAF HF- TOP + FLAP	01-HFW02 (100%)	1,33 (1)	1,33	1,33		
3	P 2	Vykrajování TOP + FLAP spolecne	01-TAM02 (100%)	0,15 (1)	0,15		0,15	
4	P 3	montaz pruziny, krimpovani, rovnani, paska	01-PSR02 (100%)	0,8 (1)	0,80			0,80
5	P 3	konecna montaz pruziny	01-PSS02 (100%)	0,3 (1)	0,30			0,30
6	P 4	lepeni topu, vložení do navíječky	01-PGR02 (100%)	0,65 (1)	0,65			

Figure 23: Bottleneck with Takt Time[13]

The above figure shows the takt time of all the operations done, in which the welding operation is taking a long time than other operations. Because of this reason this machine is considered as the bottleneck. The goal of the thesis is also reducing the takt time of this machine or utilising this machine efficiently with the current takt time without affecting the customer demand and any other aspects of the product being manufactured. In the below layout suggestions, it has been mentioned how to utilize this machine effectively. The image of the welding machine is shown in the below figure.

Figure 24: Welding Machine[13]

6.2. Layout suggestion 1

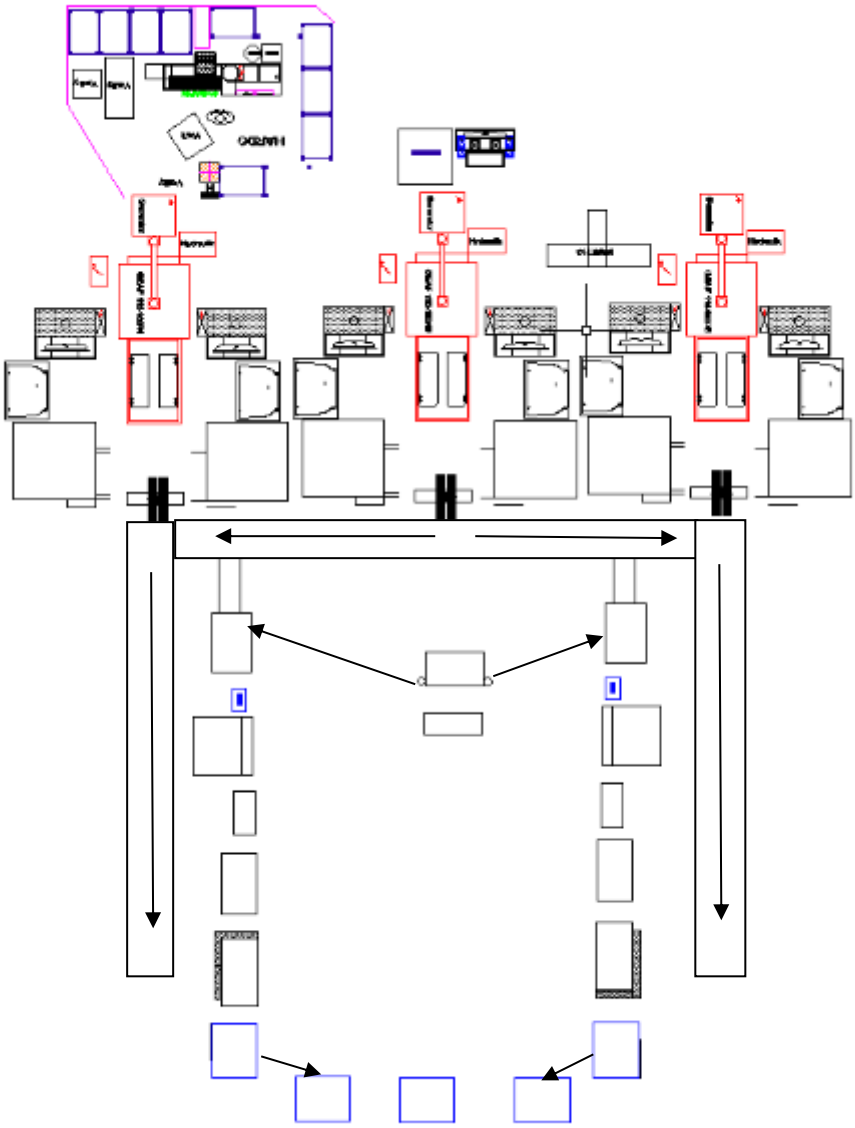


Figure 25: Layout Suggestion 1 [Source: own]

The above-mentioned figure shows the design of the new layout suggestion 1. In the above layout the welding machines are grouped together, so that it is possible to weld six products at a same time using possible fixtures as shown in the figure 25.

Figure 26: Fixtures used for welding[13]

By placing same type of fixture in all welding machines it is easy to produce same products in larger number. Which helps in eliminating one whole cell from the workspace. It also reduces the number of operators in the line by eliminating a cell. The flow of work or process is shown in the below figure.

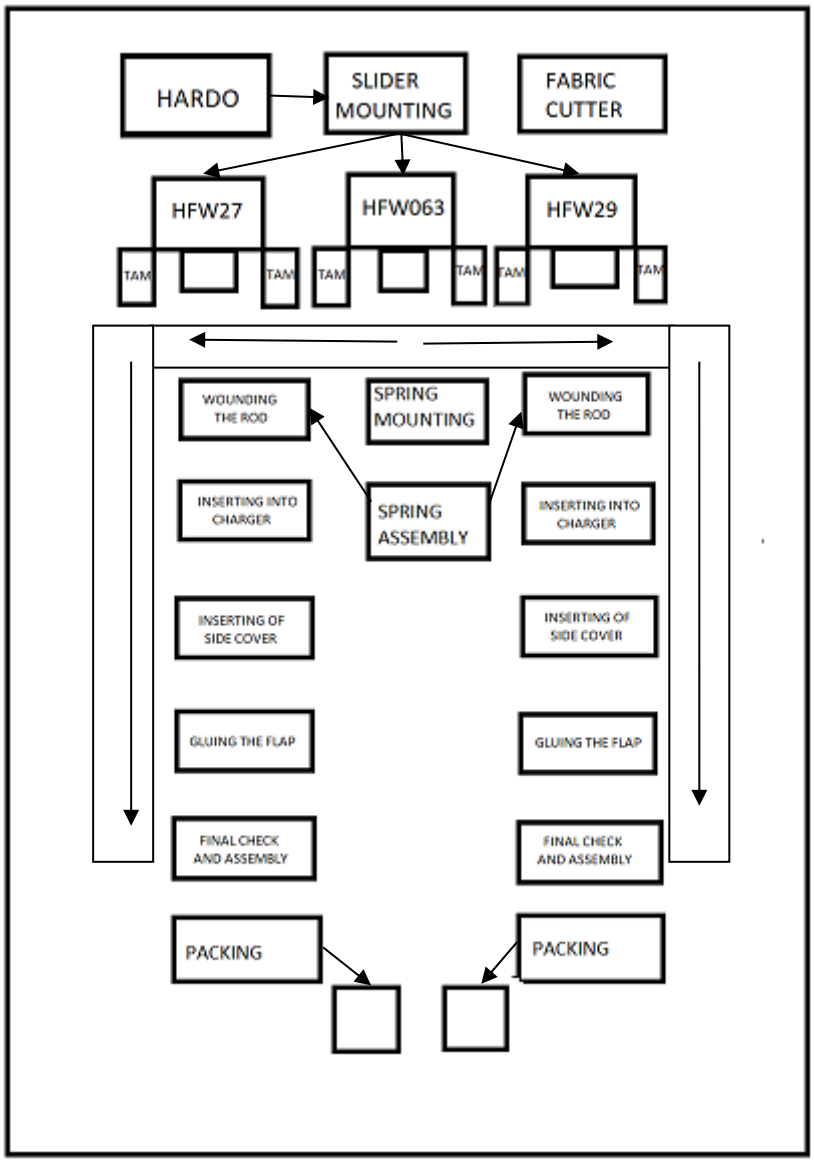


Figure 27: Process flow in Layout Suggestion 1[Source: own]

This diagram clearly explains how the process goes on in the new universal layout. At first the wooden pieces are sent from HARDO to slider mounting machine where the sliders are mounted onto the wooden pieces. Then those parts are transferred to the welding machines. From there each line will get three parts to be finished at one time. Then the process goes on till the finished product is packed. A separate place is made for the mounting and assembling the spring in a rod from where it is easy to pick the rods by the operators quickly without any movement inside the work area.

Total number of operators needed = 19

6.2.1. Ergonomics

The ergonomics that are possible to make the line efficient and effective to produce luggage cover are mentioned below:

- Using of conveyors between station will eliminate the movement of workers inside the workspace. It also helps the works to stay in a fixed position which results in production of more parts with some reduction of takt time. These conveyors help in connecting in all the stations in a cell. The image of the possible conveyor is shown in the below figure.

Figure 28: Conveyor System for transportation of products in Layout 1[16]

- Pick and place robots can be used for packing of finished products. These robots help in elimination of couple of operators from packing and they can work for very long time without any ease. Now a days a lot of robots like KUKA, FANUC, ABB, etc are available in low cost for doing some small operations. The image of pick and place robot is shown in the below figure.

Figure 29: Pick and Place Robot[17]

6.2.2. Merits of layout suggestion 1

- It eliminates on complete cell from the production area.
- Reduces the number of operators.
- Continuous workflow is obtained.
- Movement is reduced when compared with current layout.
- Work is made easy with some new ergonomics.

6.2.3. Demerits of layout suggestion 1

- Consumes a little bit of space because of straight line production.
- Initial instalment of robots and conveyors will cost a lot.

6.3. Layout suggestion 2

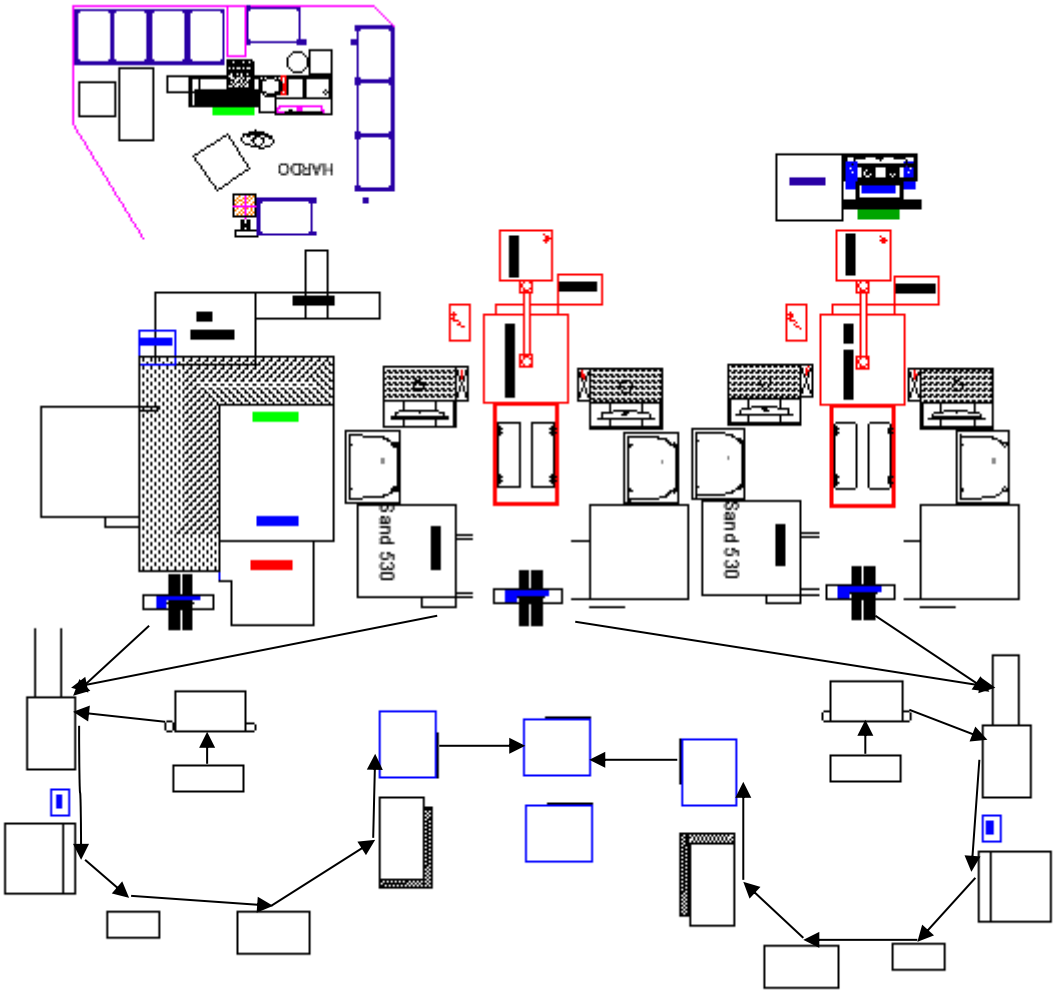


Figure 30: Layout Suggestion 2[Source: own]

The above shown image is the design of new layout suggestion 2. This layout is somewhat like design of new layout suggestion 1, but the main difference between these two layouts is the manufacturing cells are placed in U shape which help a lot in reduction of space in the job floor. The image of process flow in this layout is shown in the below figure.

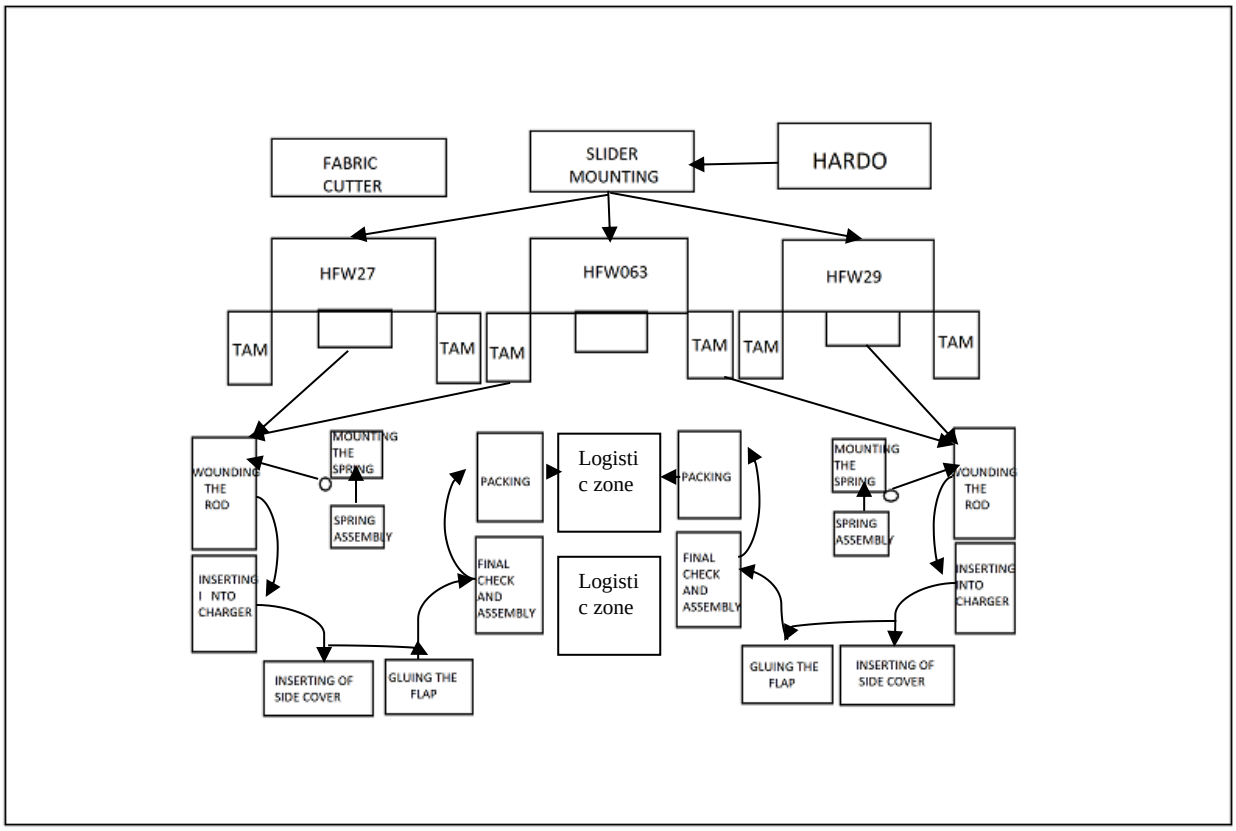


Figure 31: Process flow in Layout Suggestion 2[Source: own]

The process flow of this layout is like the layout suggestion 1, but the stations are arranged in a U shape, which makes the entire layout to look small. It occupies only ½ the space of the layout suggestion 1 with same type of operations. This layout will completely elimination movement inside the work floor.

Total number of operators needed = 19

6.3.1. Ergonomics

- The ergonomics that are possible to use in this layout suggestions are like the layout suggestion 1. Conveyor and pick and place robot can be used in the manufacturing. But the conveyor to be used in the layout is quite small that the one used in the layout suggestion 1, which allows a better space and cost less than layout suggestion 1. The image of the conveyor used in this layout is shown in the below figure.

Figure 32: Conveyor used for transportation of products in Layout 2[16]

- The pick and place robot for packing is same as from the layout suggestion 1. Refer figure 28.

6.3.2. Benefits

- Movement can be eliminated completely.
- Requires less space than layout suggestion 1.
- Continuous flow of process is obtained.
- Less human is required.
- Do not affect the current takt time.
- Easy transportation of material around the layout.

6.4. Layout suggestion 3

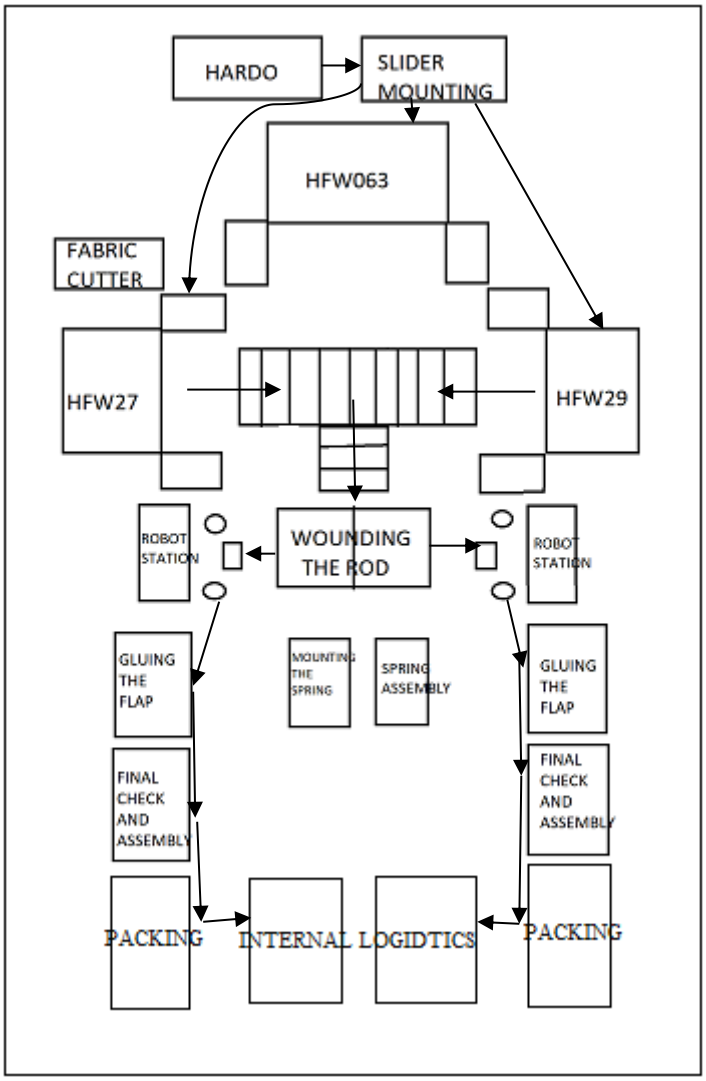


Figure 33: Layout Suggestion 3[Source: own]

In this layout a robotic station is introduced for inserting of charger and side cover of the chargers. For one station it requires 3 robots, in which the robot in the middle holds a charger in which the part after wounding the rod goes in and two robots in the side will fix the spring and side cover for the charger. This will reduce the takt time a lot and pay way to produce more products. By introducing robots in the manufacturing, it will reduce the space and work of

human. This layout utilizes only a smaller number of operators when compared to the current layout and from the above layout suggestions.

Total Number of operators needed = 16

6.4.1. Ergonomics

This layout requires a special robot which rotate its arm in 270 degree for holding the charger and other two robots are for inserting spring and fixing of side cover on the charger. The image of the robot which holds the charger is shown in the below figure.

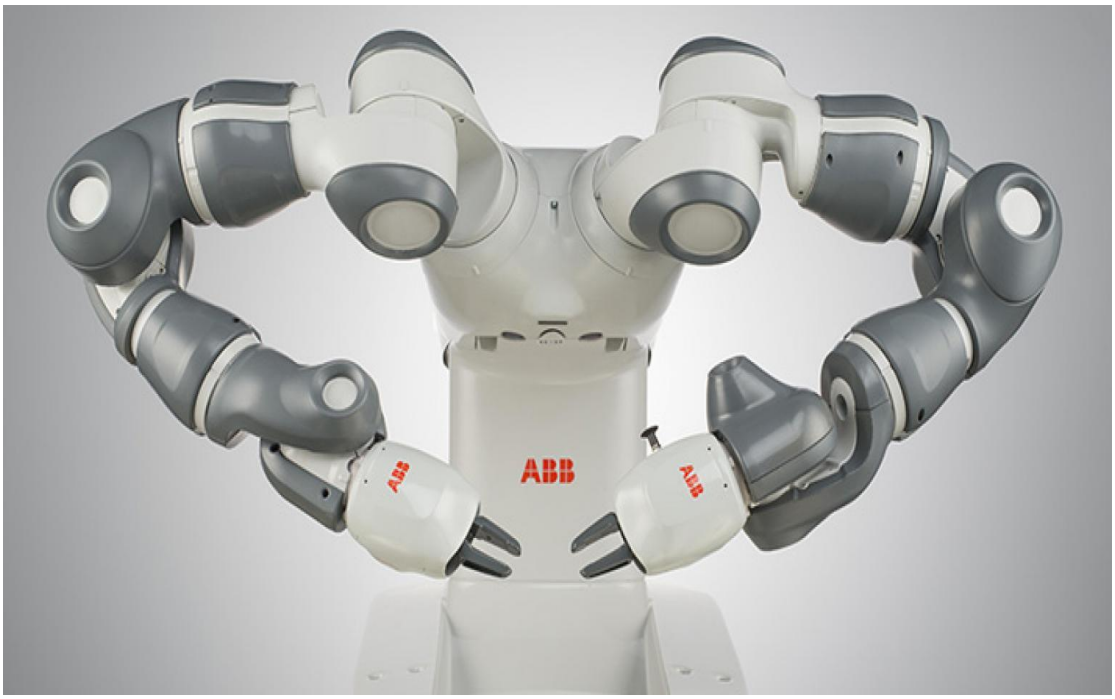


Figure 34: Robot for holding charger[18]

This robot can able to move its arm and its entire body from a fixed position which helps in picking the charger and holding it until the other robots fix the other parts of the charger.

Figure 35: Robot for fixing the side covers[18]

These types of robots can be used for fixing of the side covers of the charger. These robots do not occupy a lot of space in the work floor. It is easy to handle these robots with computers. The accuracy of the work will get increased by using robots. The margin for errors is pretty much less when compared to the errors done by the humans.

6.4.2. Benefits

- Requires less space.
- Human work is reduced.
- Increased accuracy of work.
- Increases the productivity.
- Can be well utilized.

6.4.3. Limitations

- Establishment of this layout will cost a lot when compared to other 2 layouts.
- Still there will be little movement around the cell.

6.5. Comparison of layouts

It is not possible to have all the layouts in one manufacturing plant because of the space constrain. So, it is important to select the best suitable layout for manufacturing. For selecting the best layout, a "Multi-Criteria analysis" must be done. This analysis can be done by comparing the layouts with some criteria.

6.5.1. Multi-Criteria Analysis

In Multi-Criteria analysis a different set of criteria are compared and measured for obtaining an objective. All the positive and negative aspects are measured before making a right decision. The weighting and the ranking process and the performance matrix are the key elements of Multi-Criteria analysis. An overview of score for all the criteria is given by the performance matrix. All the criteria are to be weighed according their importance and scores are given respectively. The results are made from the scores obtained by the objectives.[19]

Table 1: Multi-Criteria analysis

Criteria's	weight	Layout Suggestion 1	Layout Suggestion 2	Layout Suggestion 3
One-piece flow	4	4	4	3
space	3	2	4	3
Ergonomics	4	3	4	4
Movement	4	4	5	3
Productivity	5	4	4	5

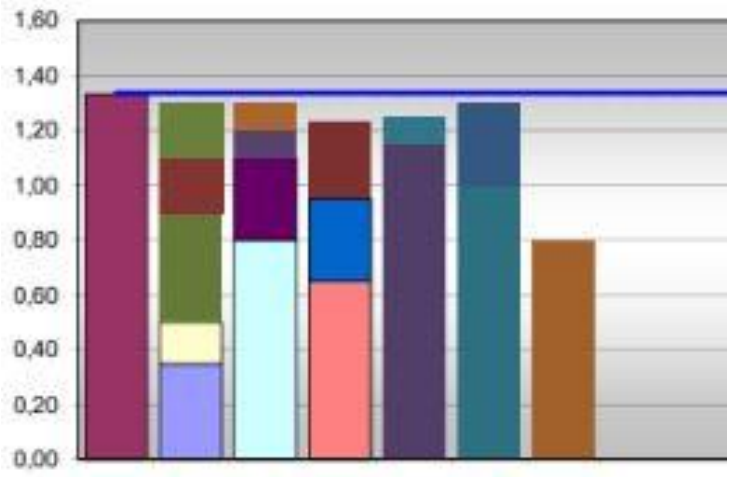


Figure 36: Productivity Unbalance

In the above table a set of criteria is considered, and they are weighed accordingly. The weightage is given from 5-1 (Most important to Least important). The scores are also given with respect to the importance of criteria in the following layouts (i.e., 5-very good to 1-very poor).

Table 2: Overall Scores

Criteria's	Layout Suggestion 1	Layout Suggestion 2	Layout Suggestion 3
One-piece flow	16	16	12
space	6	12	9
Ergonomics	12	16	16
Movement	16	20	12
productivity	20	20	25
Total	70	84	74

In the above table the individual scores are multiplied with their respective weightages then the scores are added to get a total which help us to make a better decision in choosing a right manufacturing line.

It is clear from the table 2, that the layout 2 scores more than other two layouts because it has some better ergonomics in little space and the layout 3 scores second with some automation which help in increasing the productivity finally layout 1 gets the least score because of some bigger space and high costing ergonomics.

7. RETURN OF INVESTMENT

As per the Labour law of Czech Republic, a labour should be paid an average of 120 CZK per hour[20]. Based on this information the Return of Investment is made for the best selected layout from the above analysis.

In the above Multi-criteria analysis layout 2 has been chosen as the best layout and the Return of Investment is made for this layout, in which the current layout has 24 operators in total and the new layout requires 19 operators which reduces the cost of 5 operators.

The Return of Investment can be found using a formula:

$$ROI = \left(\frac{Profit}{Investment}\right) X\ 100$$

$$\text{ROI} = \left(\frac{40{,}00{,}000}{27{,}00{,}000}\right)\ X\ 100$$

ROI = 15%

8. CONCLUSION

The aim of this thesis is analysing the current state layout of the manufacturing cell which produces luggage covers for Skoda and SEAT in the BOS Automotive Products CZ s.r.o. and to design a new manufacturing cell for it. This work has been divided into two parts such as theoretical part (chapters 2 and 3) and the design part (chapters 5 and 6) respectively.

In the theoretical part the methods of manufacturing systems and their processes has been defined and described. With those methods an organization will work more effectively and efficiently which results in higher productivity.

In the design part of the thesis the current layout has been analysed by using some analysis methods such as Process analysis, Moment analysis and by using Product family matrix of the products that is being produced in different cells. After analysing the layout along with spaghetti diagrams for each of them the design of new layout is made.

The design of the new layout is from identifying the bottleneck of the current layout. The bottleneck has been identified with the help of Takt time that were provided by BOS Automotive Products CZ s.r.o. which clearly shows that the welding machine in each cell has larger Takt time when compared to other process in the cell, with the help of this information the suggestions for the new layout is made.

The new layout suggests some possible solutions to overcome the problems faced by the current layout. In the new layout the total number of operators required is 19, where in the current layout altogether it requires 24 operators. The new layout will provide a Return of Investment of 15% by eliminating the cost of 5 operators and by eliminating some space in the work floor without affecting the Takt time of the customer. The new layouts are made by introducing some new ergonomics and reducing some space from the current layout.

Then finally the new layout suggestions are evaluated by doing a Multi-criteria analysis from which the best suitable layout is selected. The evaluation is made by certain factors such as space, productivity, ergonomics, one-piece flow and movement inside the cell. This layout can be implemented to produce luggage cover in BOS Automotive Products CZ s.r.o in future, which makes the work simpler and effective.

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