

POLITECNICO DI TORINO

Master's degree in Engineering and Management



**Politecnico
di Torino**

Thesis Title:

Analysis of the design and Production processes of
Volkswagen car doors.

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Academic Year 2023/2024

Acknowledgments

I would like to thank my professor and supervisor Prof. **Giulia Bruno** for supporting me in writing this thesis, for her availability and flexibility. I thank Autorobot Stefa's employees, **Mr Daniel Bodurka, Mr Jakub Wiktorek, Mr Bogdan Besala, Mr Marcin Latacz** for having provided me a lot of information about the company, for having answered to all my doubts concerning this project, because they gave me the opportunity to do this wonderful job. I want to express my humble acknowledgement to my teachers of Polytechnic of Turin for all the knowledge acquired during the bachelor's and master's degree. Thank you also to my classmates.

I am extremely grateful to my parents for their advice, love, caring, sacrifices, their presence and their understanding, especially my mum who inspires me enough to this world. Special thanks to my brother **Ing Tardivel Kenny Takam** for allowing me to find this internship in Poland where I got the opportunity to write this thesis. I would like to express my gratitude toward my sister-in-law **Tatianna Nguoana** for her multiple advice. I would like to say sincere thanks to my sisters, brothers, and friends for their love, understandings, and ideas.

Thank you to all of you!

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Glossary

OEM: Original Equipment Manufacturer

ACEA: European Automobile Manufacturers' Organization

OECD: The Organisation for Economic Co-operation and Development, an international organisation that works to build better policies for better lives.

CEE: Central and Eastern European countries

EPA: Environmental Protection Agency

DDP: Delivery Duty Paid

VAT: Value Added Tax - a tax on the amount by which the value of an article has been increased at each stage of its production or distribution.

OSHA: Occupational Safety and Health Administration. It is a regulatory agency of the United State Department of Labor that originally has federal visitorial powers to inspect and examines workplaces. OSHA's mission is to "assure safe and healthy working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education, and assistance."

Jigs: is a device used to hold a piece of material and guide cutting tools and they are used to ensure the process can be repeated accurately and to a high quality. For example, a carpenter making a hole of a specific alignment and depth may use a jig to aid accuracy.

Fixture: is a device which holds and locates a workpiece during an inspection or for a manufacturing operation. The fixture does not guide the tool. In construction, the fixture comprises a different standard or specially designed work holding the device, which is clamped on the machine able to hold the work in the position. The tools are set at the required positions on the work by using gauges or by manual adjustment.

Machining: is a process in which a material (often metal) is cut to a desired shape and size by a controlled material-removal process. The methods that have this common theme are collectively called subtractive manufacturing, which utilizes machine tools, in contrast to additive manufacturing (3D printing), which uses controlled addition of material.

Turn-key operation: is a type of project that is constructed so that it can be sold to any buyer as a completed product. This is contrasted with build to order, where the constructor builds an item to the buyer's exact specification.

ABSTRACT

Nowadays, the automotive sector is evolving at an exponential rate since the car is our daily companion. It is shown that more vehicles have been produced since the economic recession of 2008–2009, which approached 97 million vehicles in 2017, but it has diminished a little to 85 million in 2022 (Placek, 2023), here I am only talking about motor vehicles. Therefore, the most interesting part is to look how the tendency of the electric vehicles tries to grow beyond what we could expect. The giant Volkswagen, one of the leading companies in this sector has expanded its production plant to US Chattanooga to produce electric vehicles and, the project is in place since 2019. Under a new production series which is planned for 2024, my work here in this thesis is to analyse the production of car doors, the necessary fixtures, explain in detail the issues that can be encountered and then propose a plan of solution. In fact, I did an internship in the company Autorobot Strefa located in Gliwice (Poland) the supplier of those fixtures for this project, where I have conducted my research to write this essay. Lastly, I will also present a set of unforeseen events that are not directly correlated to the production but can also affect the project with small, medium, or huge impact.

Key words: Fixture, production of car doors

1. Introduction

First of all, the automotive manufacturing process involves a long and complex supply chain. It includes the production of raw materials (e.g., steel, aluminium, plastic, and glass), fabricated parts, components, and subsystems (internal/external processes); the assembly of these parts, components, and subsystems; and finally, the distribution and sale of the vehicles. The sector affects and is affected actively by other energy-intensive industrial sectors, such as steel, glass, and petroleum-related industries which supply plastic and rubber (for tires production). The economic and environmental concerns for the automotive sector will therefore largely influence these sectors. A representation of the complex automotive production supply chain is shown in Figure 1. Furthermore, Energy employed in an automotive plant can be classified as primary and secondary, for various applications. Primary energy source use includes electricity and fuel, i.e., 56% and 44% respectively for the automotive OEMs (Original Equipment Manufacturer) industry in the United States in 2011, for instance (Giampieri, 2020). Meanwhile, compressed air, chilled and hot water, and steam are examples of secondary energy carriers, which are produced from the primary sources to carry energy throughout the plant. Due to the extensive consumption of secondary energy carriers, most vehicle manufacturing plants power their production lines by employing an on-site energy conversion and transmission system. By contrast, since the protection of the environment is becoming increasingly a concern for companies, some are driving their production through the electric vehicle production that is also the case of Volkswagen.

Volkswagen Group, also called Volkswagen AG, major German vehicle producer, established by the German government in 1937 to mass-produce a low-priced “people's car.” Central stations are in Wolfsburg, Germany. Its generation extended quickly within the 1950s after the episode of World War II. The company presented the Transporter van in 1950 and the Karmann Ghia roadster in 1955. Deals overseas were for the most part solid in most nations of trade, but, since of the car's little measure, bizarre, adjusted appearance, and historical association to Nazi Germany, deals within the Joined together States were at first drowsy. The car started to pick up acknowledgment there as the 1950s advanced, be that as it may, and Volkswagen of America was built up in 1955.

In mid-2015 Volkswagen briefly held the refinement of being the world's biggest car producer by volume after outperforming Toyota Engine Organization. Be that as it may, in no time from that point Volkswagen confronted an open relations emergency when the U.S. EPA decided that the manufacturer's diesel-powered cars contained computer program that changed the vehicle's execution in arrange to pass outflows tests. Volkswagen conceded to introducing the “defeat device,” and it reviewed more than 10 million automobiles around the world. Within the Joined together States alone, the carmaker confronted fines of more than \$4 billion, and a few Volkswagen authorities afterward were found blameworthy of different wrongdoings. Despite the scandal, Volkswagen deals around the world kept on increment.

After going through several redesigns over the course of around eight decades, Volkswagen stopped manufacture of the Beetle in 2019. Two years later, Volkswagen decided to open a new assembly plant in US for an all-electric ID.4 compact SUV¹ in Chattanooga Tennessee. The vehicle includes materials and components assembled in 11 U.S. states, from steel in Alabama and Ohio, to interior parts in Indiana and South Carolina, and electronics components in Kentucky and North Carolina. The EV battery will be supplied by SK Innovation located in Georgia (Mark Gillies, 2022). For the new upcoming series of production that will start in 2024, this company has outsourced the production of doors to Autorobot Strefa in Poland. Hence, this manufacturing is the object of interest of my thesis.

In the body of my essay, I will address my work on following topics: firstly, say more about Autorobot Strefa, the organization where I spent 3 months of an internship, its history, its different projects with worldwide companies. secondly, I will describe the subcomponents and the main fixtures of car doors. Thirdly, I will give you more information about other suppliers or subcontractors involved in the project. Fourthly, we will discuss about the production itself and the key issues that can be present during the ongoing of the project and last but not least, the most important one, the solution plan.

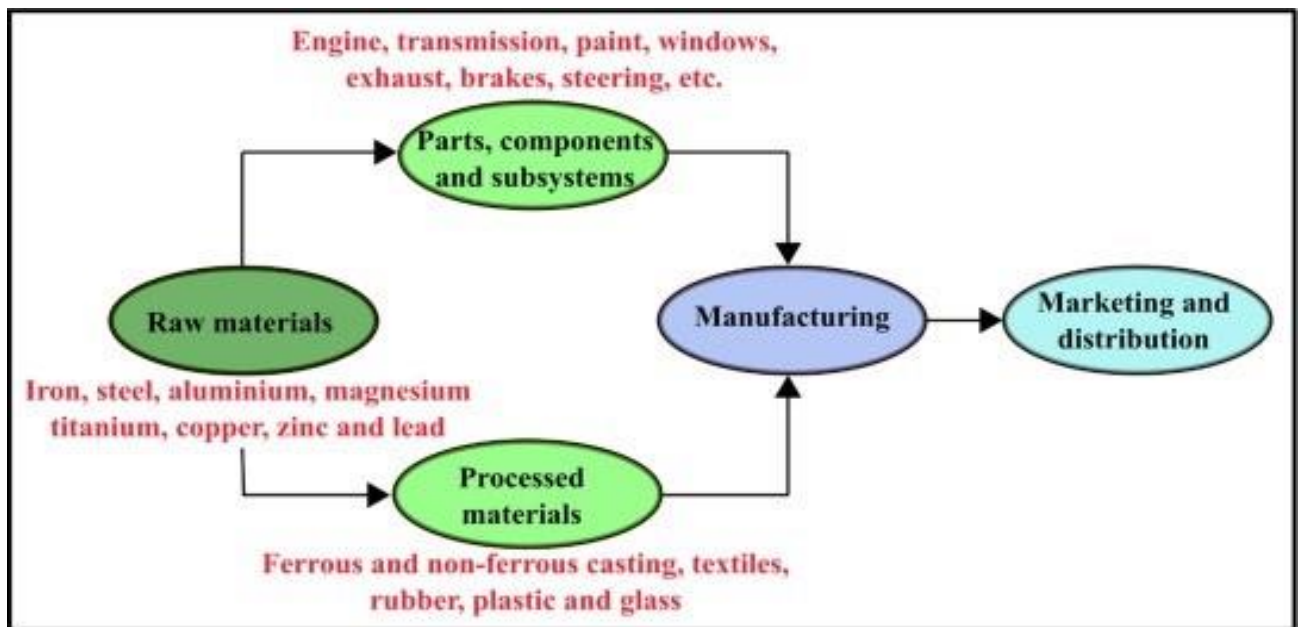


Figure 1: Processes involved in the automotive production supply chain

¹SUV stands for Sport Utility Vehicle, is a car classification that combines elements road-going passenger cars with features from off-road vehicles, such as raised ground clearance and four-wheel drive.

2. General information about Autorobot Strefa

2.1 Autorobot Strefa Description

Autorobot Strefa is a leading European company in the development of turn-key production systems, for the Automotive and the Aircraft industry. The company is created in 1993, with a first location in Skoczów (Poland) and then the plant has been transferred to the special industrial zone in Gliwice



(Poland) which extends over an area of 12000m². Their mission is to develop solutions for manufacturing processes with high productivity and reliability, through the integration of the most advanced available technologies, as a leading Group on the market. Furthermore, as mentioned in the logo, the company is a member of the EFORT GROUP another big company in China that produces robots.

In this small table below, we can see the group capacity in terms of number of hours performed per year:

	Internal Hours	External Hours
ENGINEERING CAPACITY	27,700	9,600
MANUFACTURING AND INSTALLATION CAPACITY	339,000	264,000

Table 1: Autorobot Strefa Capacity in hours/year - Forecast December 2018

The company has been knowing a constant grow in the sector acquiring a know-how and expanding a product and process range and technological expertise to offer a strong reliable partnership to their customers worldwide. Here below we can see the evolution of Business area:



Figure 2: Company evolution from 1993-Now

Their clients: **škoda (Czech Republic), Volkswagen (Germany), Volvo (Poland), CNH industrial (France), Alstom (Italy), Airbus (Hamburg Germany), Iveco Bus (Czech Republic and Italy), Valmet Automotive (Finland), Audi (Poland), Leonardo (Helicopters, Poland), FCA (Fiat Chrysler Automobile, Italy), Tofas (Turkey), Renault (France), PSA group (known as Peugeot based in France)**

Set of Activities of the company:

- ◆ Design
- ◆ Manufacturing and machining of mechanical components for Body-In White production fixtures; purchase of commercial components and integrated systems
- ◆ Fixture assembly
- ◆ 3D measuring and certification of the fixtures, with report issue
- ◆ Robot programming
- ◆ Final assembly at Customer's plant
- ◆ Commissioning, Customer's staff training, assistance to production ramp-up
- ◆ Assistance after sale

AUTOROBOT-STREFA's machinery stock for mechanical manufacturing consists of:

- ◆ CNC (Computer Numerical Control) horizontal boring machines
- ◆ CNC machining centers
- ◆ Universal horizontal and vertical milling machines
- ◆ Wire electric erosion machine
- ◆ Lathes, grinders
- ◆ Flame cutting machines
- ◆ Water jet cutting machines



Figure 3: WRD 150Q Gantry Milling Machine 6 axis



Figure 4: MESSER Multitherm 4000 Plasma Cutting Machine- 3 axis



Figure 5: Rambda MG 220 – 3 axis- for machining operation as well

And the last machine that I am going to show you is in the following image, it is also used for the machining operation.



Figure 6: ZAYER XIOS G 1250 – 6 Axis Machining

These are the images of just 4 machines that we can find in the manufacturing area of Autorobot over more than 20. As we can see, each machine has several axes in which it can work and rotate, some of them can be controlled by a CNC machine while others can be checked manually. The Zayer XIOS is one of the important machines because it is used to do the machining operation, and almost all the part that we produce are machined and this process takes long time. Since each item is different from each other's, so, we always have different processing time.

2.2 Company Background and sample of main projects

Since its creation, Autorobot Strefa has been managed many times different projects to supply to a variety of companies namely fixtures, lines, or robots. Indeed, it is important to highlight that for the production lines they also train customers in the use of the lines, and mostly the security systems and ensure a guarantee of at least two years in some cases. Amongst all, I present here below a sample of projects.

PREMIUM AEROTEC – AIRBUS

Founded on December 18, 1970, with its main headquarter in Netherlands, Airbus is a European aircraft manufacturer that is the world's second largest maker of commercial aircraft (after Boeing Co.). It is co-owned by the German-French-Spanish European Aeronautic Defence and Space Company (EADS), with an 80% interest, and Britain's BAE Systems (British manufacturer of aircraft, missiles, avionics, naval vessels, and other aerospace and defence products), with 20% (Encyclopaedia, 2023).

Premium AEROTEC is one of the world's driving providers (level 1 provider) of commercial and military flying machine structures and could be a key accomplice within the major European and universal aviation programs. Its centre competencies incorporate the advancement and generation of huge and complex formed airplane components from aluminium, titanium and CFRP (Carbon Fiber Reinforced Polymers) (premiun-aerotec, None).

In this project, Autorobot oversaw manufacturing of 5 Part Carriers for Upper, Lower and Side shells of fuselage Section 18 of A320 plane. Part carriers are used during assembly process and on automatic drilling and riveting station in AIRBUS Augsburg plant.

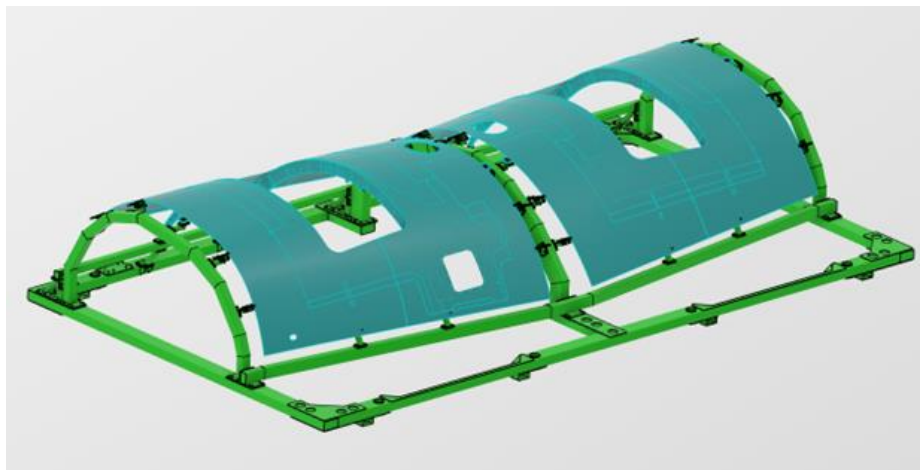


Figure 7: 3D Design of assembling line for Airbus



Figure 8: Figure 7: Ready Fixture-Assembly line for Airbus

HELICOPTER LEONARDO AW169 (Świdnik, Poland)

Scope of supply:

- Purchase of materials and commercial parts, according to Customer's design specification
- Welding of jigs components
- Machining
- Thermochemical treatment, coating, black oxidation
- Pneumatic installation for suction cups
- Complete assembly at Autorobot-Strefa plant
- 3D measurement of the jigs with measuring report
- Certification by Bureau of Technical Inspection
- Reassembly and installation at Customer's plant
- Measuring at customer's Plant after installation, by means of mobile laser trackers

It might be important to highlight that the whole scope of supply was performed in advance to the timing deadline agreed with the Customer.



Figure 9: Set of fixtures supplied to Helicopter Leonardo

VALMET - Battery F34 PB42x line (Automotive)

Valmet is a company that operates in an automotive sector and supplies electric mobility. The most important topic in the automotive industry today is electric mobility. And the same can be said at Valmet Automotive. In all the business lines at their company, electric mobility and electric drivetrains play a leading role. They meet OEMs' (Original Equipment Manufacturer) increasing need for efficient battery systems and for production capacity for battery packs along the entire value-added chain: concept, engineering, prototypes, testing, manufacturing. With their battery plant, which they opened in Salo, Finland in 2019, and an additional plant at their vehicle manufacturing site in Uusikaupunki (Finland), they are underscoring their excellent market position as a first system supplier for battery systems and modules. Then in January 2017 they made a project with Autorobot Strefa for manufacturing front end, body shop and back-end lines.

Front End line

Autorobot manufactured 50 units of different equipment +378 pallets for new Battery production lines in Valmet plant in Finland: Grippers, Deposits stations, racks, stands, Assembly stations, pallets, Templates, Buffers, Magazines, Trolleys, Flip stations, Turntable.

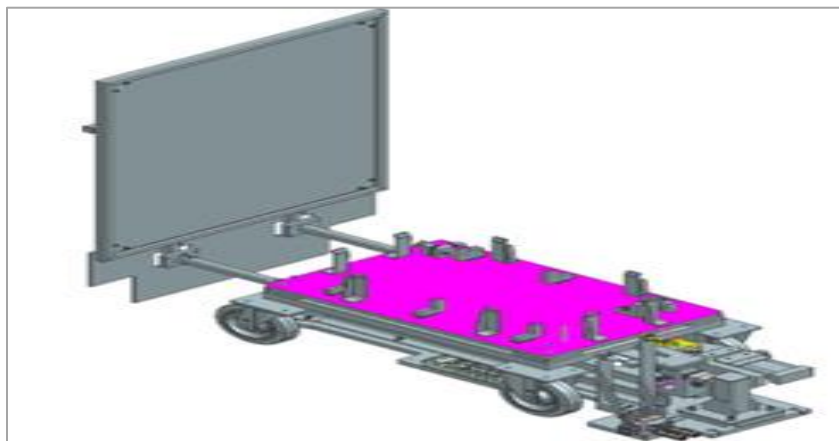


Figure 10: A Trolley used to transport elements from 1 station to another one.

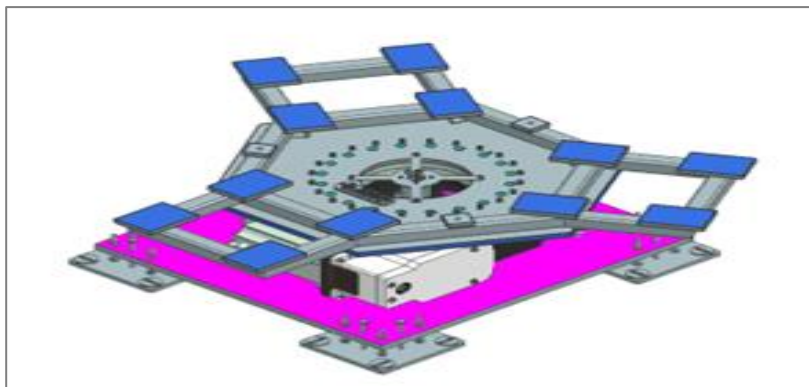


Figure 11: A buffer used as loading station.

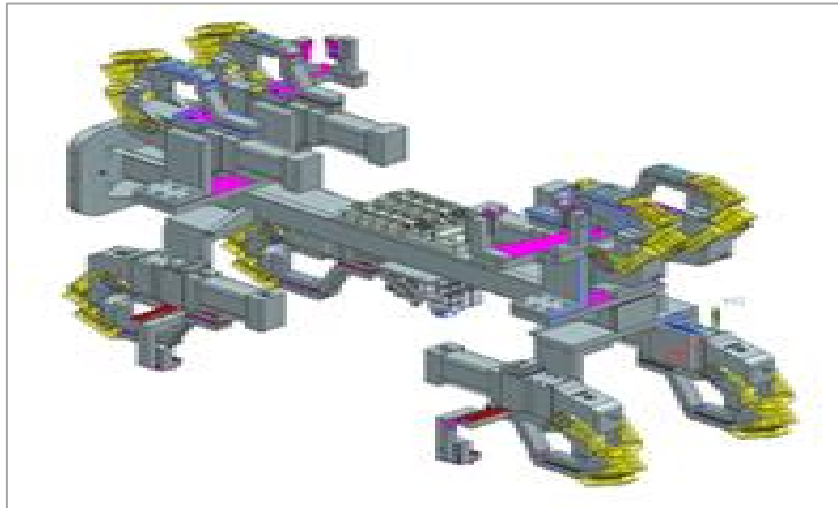


Figure 12: A Gripper used in manufacturing plant to allow the movement of robots

Back End Line

In scope of Autorobot: Material purchase, Machining, Assembly, 3D controls, Wiring and piping, Transport to customer site. The total project value is 1 331 447 €, and bellow, I insert some images of the units produced.

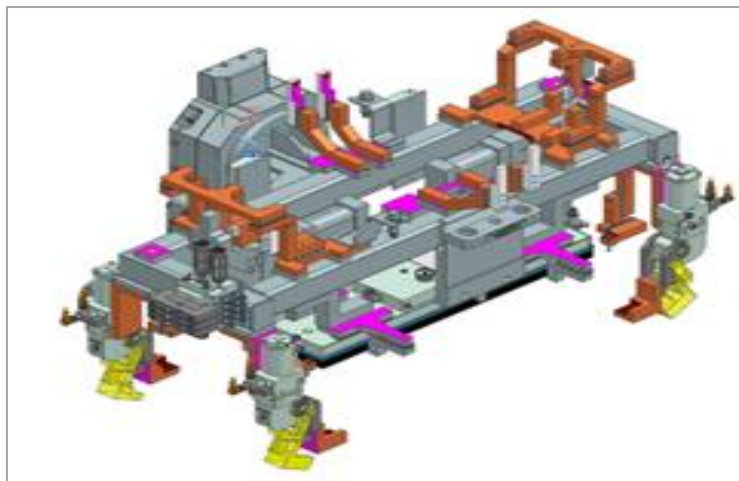


Figure 13: Gripper for back-end line with many movable sub-parts.

The main goal of the Gripper is to consent and ease the movement of the robots during the manufacturing process because today, we use enough robots in many operations. This product will be well described in part 5.3 of this thesis. The following image instead, is used as a loading and unloading station.

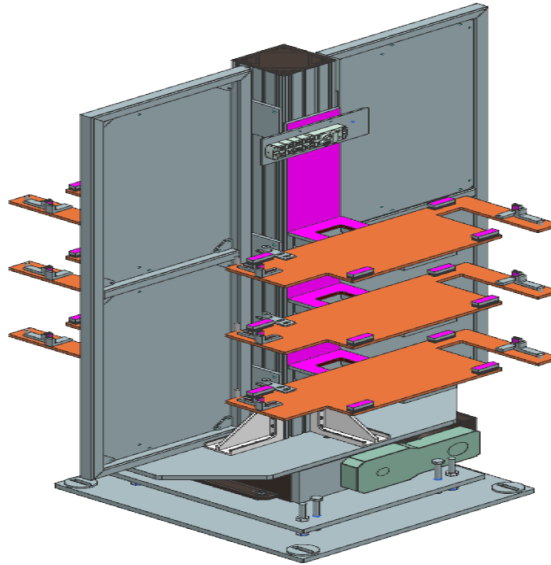


Figure 14: One loading station in shelf.

VALMET – Bodyshop VI2 project

In scope of Autorobot:

- Material purchase,
 - Machining,
 - Assembly,
 - 3D controls,
 - Wiring & piping
- Project value: €56 560

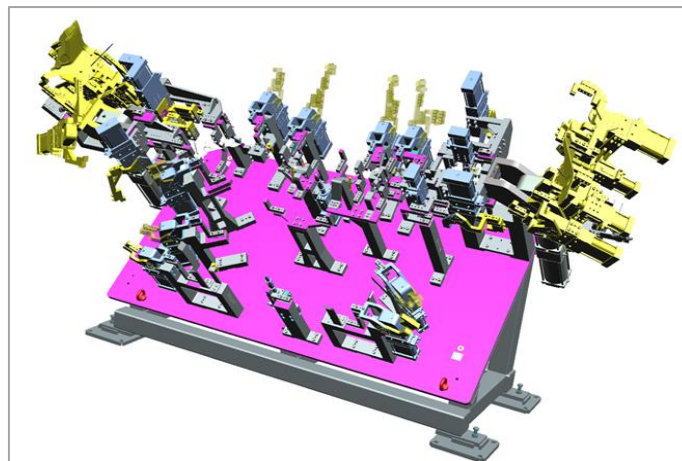


Figure 15: Ready fixture to weld sheet metal for Valmet

BMW – Centering stands for Dingolfing plant

First, who is BMW? “With our brands BMW, MINI, Rolls-Royce and BMW Motorrad, we are the world's leading provider of individual premium mobility and services. Our team consists of around 120,000 creative minds worldwide who all have one thing in common: passion and the drive to shape the individual and sustainable mobility of the future. Passion for future technologies and enthusiasm for innovative ideas. In order to be able to continue to do pioneering work, we are constantly looking for visionaries who want to share their passion with us and tackle the technological challenges of our time.” (bmwgroup, None). Their values: appreciation, openness, responsibility, transparency, trust, corporate culture, diversity, sustainability, benefits.

Regarding, the project with Autorobot, the latter supervised:

- Material purchase
- Machining
- Assembly
- 3D control
- Transport to customer plant

Value of the project – 17 752 €



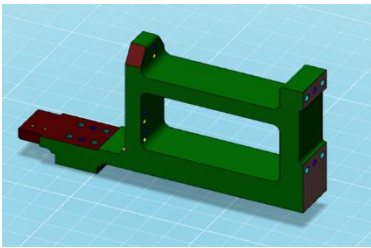
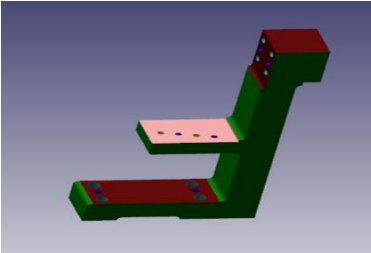
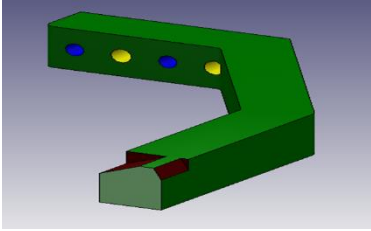
Figure 16: Set of fixtures provided to BMW

3. Main mechanical items description

First, this project is divided in 2 phases: the first one which is already in process now is for making fixtures for 8S cars and the second one that will start in few months is for 5S cars. But both drawings including 2D and 3D are made in the GMS in Brazil. In order to make completely one door, many fixtures are needed. The first one called GEO SCHATELN (the main rear door fixture) is made of by a lot of other small items, and while some are manufactured in the plant e.g., brackets, located bloc plate, best, others are bought from subcontractors for example shims, clamps, sensors, photocells, pins, cylinders. One fixture is called gripper that is made of by almost many commercial units because they are standards, we also have the Stapler, the loading station the one in direct contact with the door. The fixtures are well described in the part 5.

Some of manufactured subcomponents:

Below, I show you few items that are manufactured in the huge plant of this leading company, the list is not exhaustive because they produced hundreds of items for this project. In the following table I illustrate a small number of different items.

Item Numbers	images	Description
1		<p>This item is an example of a Console/Bracket used as a support group in the final fixture. It takes on average 9h50min to be produced.</p>
2		<p>This item is an example of a Console/Bracket used as a support in the final fixture. It takes more or less 6h45min to be manufactured</p>
3		<p>This item is an example of Pressure piece that must be hardened before the assembly process, and we need approximately 50 min to complete its production.</p>

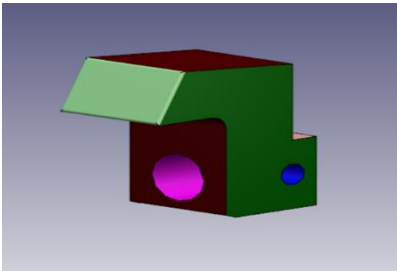
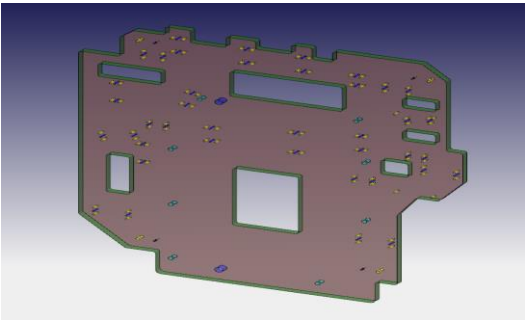
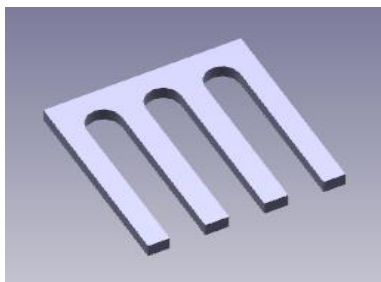
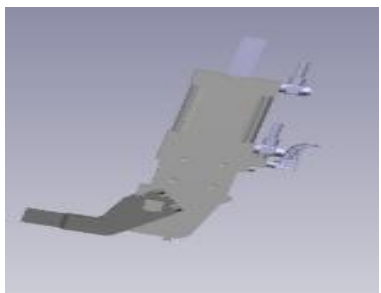
4		<p>This item is an example of a Best which must be hardened before the assembly process, and it takes approximately 35min to be ready.</p>
5		<p>This item is a plate, it is more used in production in general and in this particular project as well. It is required approximately 33 hours and 30min to be done.</p>

Table 2: Variety of manufactured units in Autorobot's manufacturing plant

Some Outsourced items:

Other types of items are bought because they are standards one or because producing all in the company could induce a delay in the project. But I would like to highlight that some pieces can be adapted basis on the final product.

Item number	images	Description
1		<p>A shimming plate allows to have a small space of tolerance when the door will be loaded in the fixture.</p>
2		<p>A Clamp, this is one of the most useful items on which it is mounted the located block. This allows for the opening and the closing movement to load and weld the car door.</p>

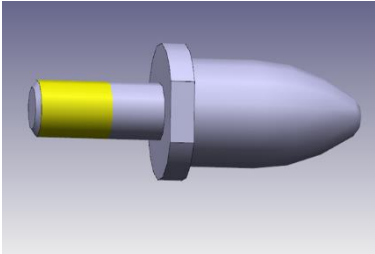
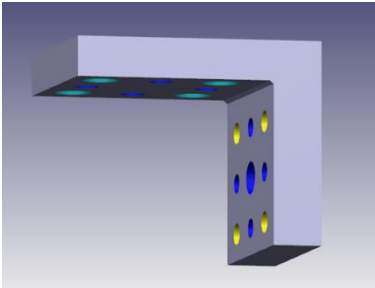
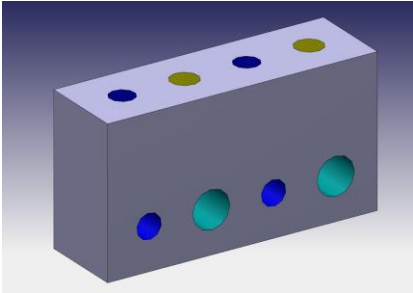
3		<p>A pin used to allow fixing the screws. Indeed, we always use 2 pins to fix 1 screw to avoid the rotation.</p>
4		<p>This is a standard bracket as aforementioned it is used as a support block. Its role is to be as a support item for other elements.</p>
5		<p>This part is called Adjustment block (65X35X20) is also one important element that is used for the fixture, it is bought from the market, and it complies with the standard: 39D 20658/2 39D 20658/2</p>

Table 3: Example of commercial items

4. Subcontractors involved: production outsourced

Nowadays, it is almost unthinkable to operate in each company alone from the beginning till the end of the production line, not only because we need procurement to launch a production, though this means we need suppliers, but also because we need sometimes specific products or services or a specific technology from our partners that we cannot afford them in our manufacturing area. So, this is the case of Autorobot that deals with 40 subcontractors already and they will be associated with this project.

Autorobot Strefa seeks partners and suppliers who share the company's values. Transparency and trust are essential ingredients to work for the Autorobot team. Partners and suppliers will need a proven track record of operational reliability and delivering on shared commitments. In particular, Autorobot looks for partners who are ahead of the game, offering creative, innovative, and digital solutions in a complex environment. This ensures Autorobot Strefa provides first-class qualitative products to all its customers.

Now, in the following lines I am going to present you 3 of the subcontractors of this company, the name will not be disclosed for confidential reasons (Autorobot is TISAX certified – confidentiality must apply).

4.1 Subcontractor 1

- **Supplier of well smoothed items:**

It is a company just established in Gliwice too, they have this particularity of well defining the shape of the items, the material is worked thoroughly, and the surfaces are smooth. Maybe in certain cases this could be more than the one needed by Autorobot, but for this amazing job, they offer a competitive price.

Below we have pictures of 4 different finished items made with aluminium base.



Figure 17: Set of items provided by Supplier 1

4.2 Subcontractor 2

- **Supplier of welding operation:**

This company also makes many separated car items to supply to other assembly companies, they usually do the welding operation for Autorobot. In following lines, I list you some characteristics:

- Headquarters Silesia region
- Distance approx. 60 km from Autorobot
- Welding, detail processing (painting, heat treatment in cooperation)
- The company mainly produces for **Alstom, CAT, Danfoss, Volkswagen**
- They made smaller milled details for Autorobot (special feature - milled part numbers - they have an engraver²)
- They have milling machines, lathes³ (machining center in operation)
- Can process welded details - dimensions shown in the photos - approx. 1200 - 1600 mm length), ECCENTRIC SHAFT PRE-SET

² Engraving is the practice of incising a design onto a hard, usually flat surface by cutting grooves (a long narrow cut) into it with a burin (synonym-graver: a steel cutting tool) - Wikipedia

³ Lathe is a machine for shaping wood, metal, or other material by means of a rotating drive turns the piece being worked on against changeable cutting tool.

- The work so far has been done well, there is potential for expansion of the structure.
- First measurements for VW, parts of the line, equipment - shown in photos
- Interested mainly in manufacturing of entire devices

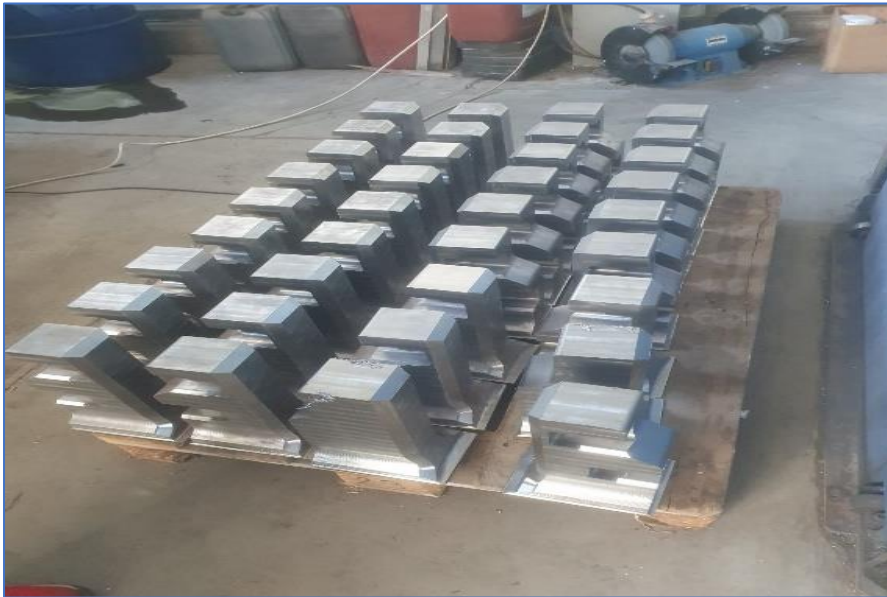


Figure 18: An example of items produced by supplier 2



Figure 19: The turning machine of supplier 2

4.3 Subcontractor 3

- **Supplier of laser cutting:**

Is the company that does laser for Autorobot, they are partners since few years ago already and the quality of work remains appreciable. Just as a brief definition, a Laser is a device that stimulates atoms or molecules to emit light at peculiar wavelengths and amplifies that light, typically producing a very narrow beam of radiation. The emission generally covers an extremely limited range of visible, infrared, or ultraviolet wavelengths. Below, I show you some pictures of this company, some of their machines and pieces:



Figure 21: A cutting machine of supplier 3



Figure 20: A vertical turning machine of supplier 3



Figure 23: Example of ready parts provided by supplier 3



Figure 22: Example of ready items provided by supplier 3

Besides, I can also present you some components that are produced thanks to the process of laser cutting. The particularity of these items is the thickness (max 12 mm)

and the precision with which the process is done, furthermore, some items are bended. We need to be careful because no errors are admitted otherwise, we will rework the part, and this implies another huge cost that we do not desire.

The different figures below are to show you the items coming from laser cutting, the first image on the left and the last on the right contain oxidized one:



Figure 24: Example of bended Components after oxidation in bottom left, we have the shims.

To sum up, this fourth part only shows tree of a long list of sub-contractors involved in this project, but I prefer to stop here. In the following section I will go thoroughly in the production itself.

5. Project description and key issues before and during the manufacturing processes

This chapter of my thesis in few words is the core of my work, because dealing with project means clients negotiation, the production itself from the beginning until the shipment also mean dealing with a peculiar type of issue that we will deep into in this part. Therefore, I will present you the project design and cost estimation, then the time estimation, after that, the production and shipment and finally, the multiple unforeseen events.

5.1 The project design and cost estimation

➤ The project Design

Autorobot Strefa has received the RFQ (Request for Quote) since April 2023, but it took almost 10 weeks to negotiate with the clients about the clauses of the contract in order to know how the final door will look like, to set the milestones, to set what fixtures do they need and how many. They also negotiated about price, and who will oversee the shipment, and who will be responsible of damages during the transportation. There were of course many other suppliers in competition with Autorobot, but this company has been chosen not only because of good price vs quality but, also because the client Volkswagen wanted to try a new supplier. Thus, after that time, the contract has been signed and the supplier (Autorobot) is in charge of drawings, raw materials buying, manufacturing of a total of 30 fixtures, 7 for left door, 7 for right door, 8 for front door and the rest 8 for rear door, the same as to be applied both for 8S and 5S. It is also responsible for producing the 2 "Graffatrice" for each door, and on top of that, oversee the shipment. All this must be done to ensure the start of series of production in Volkswagen Chattanooga plant from week 35 of 2024 estimated to end in September 2026, and this is the most important milestone agreed up on. In the figure 25 you can see the image in 3D of one the rear door fixture, I will provide more detail in the section 5-3.

Furthermore, it is critical that all parties included be counselled during the extend plan stage. Hold normal group meetings and make beyond any doubt to incorporate all significant partners in at slightest the introductory session. "Bring all the partners ... into the discussion," says Elyse Kaye, CEO of item improvement consultancy AHA Item Arrangements. "Aligning on objectives and pulling imaginative thoughts from each will offer assistance to streamline the method. On endless ventures, proposals or questions come from the foremost unsuspecting people, which can offer assistance to rethink the complete project." (Eby, 2006).

One difficulty faced by the supplier here was to have the final version of the product by the client and this generated a delay on contractor side. Being aware of that, the client allowed few weeks of flexibility.

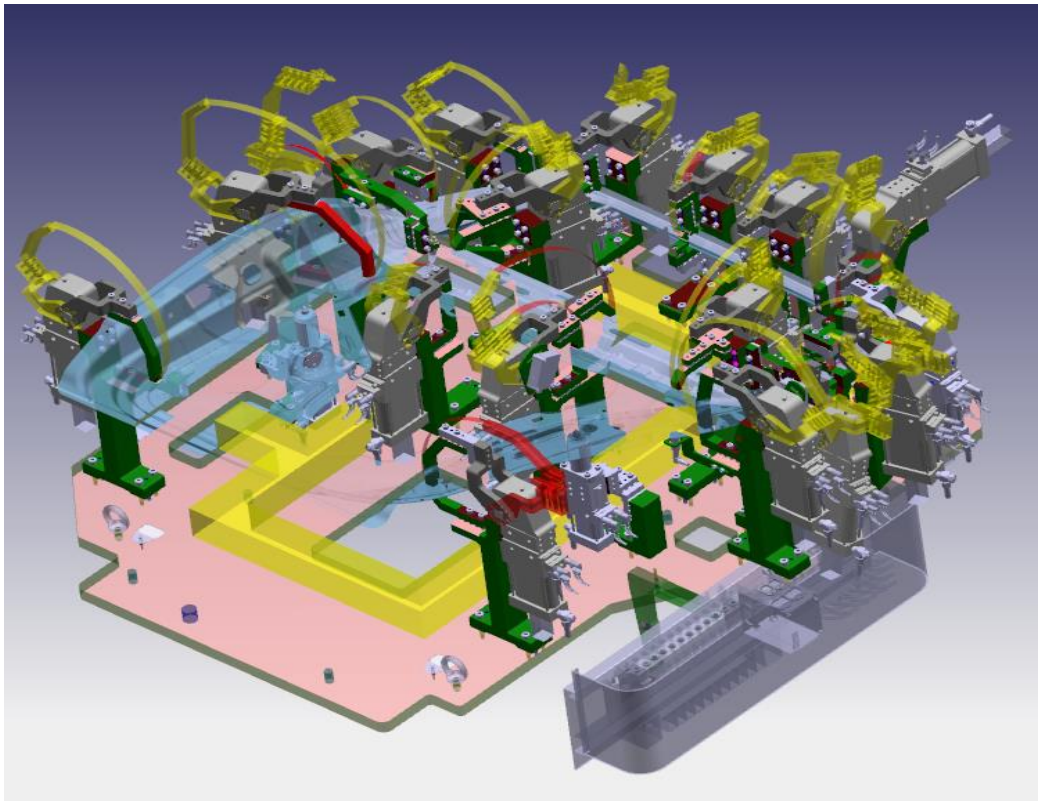


Figure 25: 3D image of a rear door fixture with a door sheet metal.

➤ **The project Cost Estimation**

The process of estimating project costs involves accounting for both direct and indirect costs as well as other project expenses and creating a budget that will enable the project to be completed with the required financial commitment. A cost breakdown structure is used by project managers and project estimators to figure out all project expenses in order to do this.

For each kind of project, from creating a new software to constructing a bridge, project cost assessment is essential. Money is necessary for everything, thus the more certain you and your project team are about the quantity needed, the more probable it is that you will reach your goal.

Project cost estimation is a critical stage during the project planning phase because it helps project managers build a project budget that includes the project expenditures that must be incurred to meet the project's objectives and goals set forth by executives and project stakeholders (Schwartz, 2023).

The definition of the price has not been an easy task because it has been made based on many assumptions and estimation. For this project, it is made up of raw materials

(many parts are produced with steel), labour cost, the design, the engineering, the shipments. Indeed, on one hand, the design cost is divided into HW&SW design and documentation, Mechanical design and documentation, Virtual commissioning, and management cost. In the other hand, we have the other costs divided in Emergency materials, Transport, Rentals on site, Material upon completion of the system Training, Replacement pliers, Ultrasound instrument no. It is important in this section, to show how the cost structure looks like see the table 1 below.

In the file excel in attachment to this this thesis, if we look at the row 353 for the production of ‘Nuovo gripper promiscuo 312/846 traversa tg piccola’, the quantity needed is 1, the column *kg mat carp* shows the total number of kilogrammes which is 70, the column *carp* represents the price to pay for the welding of that unit and following column *ore carp* is the total number of hours needed. For this same product, it is also present the hour of painting and other treatment, the number of working hour small and big machines, the total assembly hour, and many other information without forgetting the total cost for this specific product.

Description	Mech Design hours	Design HW&S W hours	Cost/ hr/ proje ct	Total Cost in €	BGT	Make	Buy
HW&SW DESIGN AND DOCUMENTATION							
ELECTRICAL HARDWARE DESIGN EPLAN P8 VERS.		400	35	14000	14000	14000	
PNEUMATIC HARDWARE DESIGN EPLAN P8 VERS.		100	35	3500	3500	3500	
SOFTWARE DESIGN PLC + HMI + SCADA		350	40	14,000	14,000	14,000	
VALUTAZIONE ANALISI RISCHI		40	60	2,400	2,400	2,400	
COLLAUDO FUNZIONI DI SICUREZZA IN CANTIERE		20	60	1,200	1,200	1,200	
TRANSLATE SCHEMA HW		40	25	1,000	1,000	1,000	
TRANSLATE SOFTWARE		40	25	1,000	1,000	1,000	
PROGETTAZIONE MECCANICA E DOCUMENTAZIONE							
CATIA MAKE	2918		50	145,900	145,900	145,900	
PROCESS MAKE (rob cad)	1200		60	72,000	72,000	72,000	
OFF-LINE MAKE	700		60	42,000	42,000	42,000	

LAY-OUT MAKE	600		60	36,000	36,000	36,000	
CICLI BUY	200		30	6,000	6,000	6,000	
DOC. MAKE	300		60	18,000	18,000	18,000	
DOC. BUY	300		20	6,000	6,000	6,000	
METODI MAKE	200		60	12,000	12000	1200	
Virtual Commissioning							
LIBRARY							
ROBOT CONFIGURATION - Robot+Fixture+Load station+Pallet conv							
OP SIMULTATION							
TECNICO ROBOTTISTA X SIMULAZIONE V.C - ORE CANTIERE							
TECNICO SOFTWARERISTA X SIMULAZIONE V.C - ORE CANTIERE							
Gestione							
PROJECT MANAGER	1,200		30	36,000	36,000	36,000	
TECHNICAL LEADER MECCANICO	800		60	48,000	48,000	48,000	
TECHNICAL LEADER HW	400		60	24,000	24,000	24,000	
TECHNICAL LEADER SW	200		60	12,000	12,000	12,000	
COORDINAMENTO HW-SW-VIRTUAL COMMISSIONING			60				
COORDINAMENTO E DOCUMENTAZIONE E SICUREZZA			60				
VARIE							
Materiali di pronto intervento (ricambi prima dotazione)				8,000	8,000		8,000
Trasporti				5,000	5,000		5,000
Noleggi in cantiere				10,000	10,000		10,000
Materiale a completazione impianto				10,000	10,000		10,000
Formazione							
Pinze di ricambio							
Strumento ultrasuoni							

Table 4: Cost overview

The table above represents some data collected from that excel file showing the budget of certain activities and either there made by the company, or they are bought. Some rows are empty because the project was still in progress and not all costs are already defined so, for now the estimated total cost is €1,700,011 including others costs that I did not mention in this table. Indeed, the file is huge, I preferred to insert it in the attachment.

But we can't say that we will stay at 100% in budget, thus let me list some relevant issues agreed by the project manager:

- ⊗ Sudden raise in raw material costs in the market
- ⊗ High cost of external hours, sometimes because of less time they must produce what is required

5.2 Time estimation

We cannot talk about cost, that is to say money, without talking about time because they are closely related. Accurate time estimation is a key deliverable in project management. Understanding how long a specific task will take will allow you to plan more efficiently, significantly affecting the project's success and your reputation. Every company has a budget and wants to determine if a project is worth the investment before devoting resources to it. It is impossible to plan a project if you don't have the correct time estimations. You can't plan to go ahead if you don't know how long the project will take or which team members you need. (Bonassi, 2022)

Precise time estimation benefits everybody on the group:

- Extend supervisors provide ventures on time and inside budget
- Group individuals hit extend milestones without working extra minutes and feeling focused.
- Partners and clients are happy.

To assess, the project length, numerous steps have been embraced:

i. The analysis of historical data

begin with what you already know till now. Make a deep analysis of projects that look alike to get an idea of what activities and team members you will need to complete the project. In this case, since the supplier has already dealt with this kind of fixture, the company's database has been used to estimate the production time of the components and subcomponents needed. Going ahead with this method, we were able to obtain the estimated assembly time of the products. For the rear door fixture, it is approximately 125 hours and 30 minutes.

In the table below, we can see the historical data coming from a fixture divided in group of units produced by Autorobot during a previous project.

THEORETICAL ASSEMBLY TIME FOR 1 STATION		
Units	Description	Time (Min)
Very simple units	Groups of type: Guides, Bracket with sensors	20
Simple unit's	Groups of type: MYLAR supports without the clamp cylinder, Supports with sensors, laser scanners	50
Medium unit's	Groups of type: Supports with 1 cylinder and / or 3-5 MYLAR	110
Difficult unit's	GROUPS OF: - Bottom brackets with 2-3 cylinders or 6-10 MYLAR - Groups with Cylinders size 80 - C P N groups (OL-CI STD.) - O P N groups (OL-CI STD.)	200
Expanded unit's	Groups of type: Groups with cylinders > 80 but not very extensive, Extended groups with welded supports, catenaries, levers etc ... - OSCILANTE groups (STD O.L.C.I.) - SLITA groups (STD O.L.C.I.) - Groups with small abatants	420
Very expanded unit's	Groups of type: - Large SLITA groups (nonstandard) - Very extensive groups with the largest cylinders - Groups with large levers and abatants	840
gaps (gap setting)		10
plates (aluminium)		10

Table 5: Production time estimation

i. The creation of an overall project scope document

Here are the most crucial components to include in your overall project scope:

- Begin with the business case, explaining why the project is needed and identifying goals.
- Make a list of all the deliverables you expect from the project team.

- Provide a list of needs and conditions to ensure acceptable deliveries.
- Make a note of any challenges or bottlenecks that may arise during the project.
- When a project is in its early stages, there are often many unknowns. Consider "expecting the unexpected" while planning.
- It is also critical to omit anything that is not within the project's scope.

ii. Build out a list of tasks for the entire project.

The next step is to make a list of all the tasks that need to be accomplished. You should also prioritize them and organize them for fulfilment. Create tasks, assign team members, construct checklists, and set deadlines using a project management application such as Project Tasks. Determine who is required and should contribute to each position on your project team. At this stage of the planning process, don't make any estimates about how long the tasks will take. Just make a note of any crucial deadlines.

iii. Forecast the project timeline, together with dependencies.

When you have a thorough image of all the tasks required, you will have a better idea of the project timetable. If your project team is engaged, they will accept more accountability for the time estimates they provide and work harder to fulfil them.

Many project managers use project management tools such as Hub staff Tasks or Microsoft Project to speed up future initiatives, with that software, you can:

- It allows you to create a project management schedule and set time estimates to each activity.
- Make use of task dependencies to determine the sequence in which tasks must be completed to build your project timetable.
- Encourage team members to log time spent on tasks to improve project estimation accuracy.

With project management software, project managers and team leaders may rapidly understand how everything in the project works together.

The Excel software has been used to draw a timeline of this project as we can see in the image below, figure 26. Moreover, in the table 6 underneath I list and describe the main activities identified by team members. Autorobot has more control over the drawings (111 days for 8s, 129 days for 5s), production (109 days for 8s and 200 days for 5s) and shipment which lasts from October 17th, 2023 till December 22nd, 2023 for 8s cars, whereas the one of 5s cars begins the 26th of February, 2024 until the 19th of July of the same year. As we can observe many activities are done in parallel to avoid loss of productivity and time wastage.

Task ID	Task name	Start date	End Date	Duration (working days)
1	Project start- ROQ	5-4-2023	6-4-2023	1
2	Project negotiation	09/04/2023	30/06/2023	82
3	Drawings 8S	03/07/2023	22/10/2023	111
4	Procurements	01/08/2023	15/09/2023	45
5	production 8S	04/09/2023	22/12/2023	109
6	outsourcing	04/09/2023	26/04/2024	235
7	Shipments 8S	17/10/2023	22/12/2023	66
8	Drawings 5S	17/10/2023	23/02/2024	129
9	production 5S	04/12/2023	21/06/2024	200
10	Shipments 5S	26/02/2024	19/07/2024	144
11	Training period	19/08/2024	23/08/2024	4
12	start production series	25/08/2024	25/09/2026	761

Table 6: Description of main activities of the project

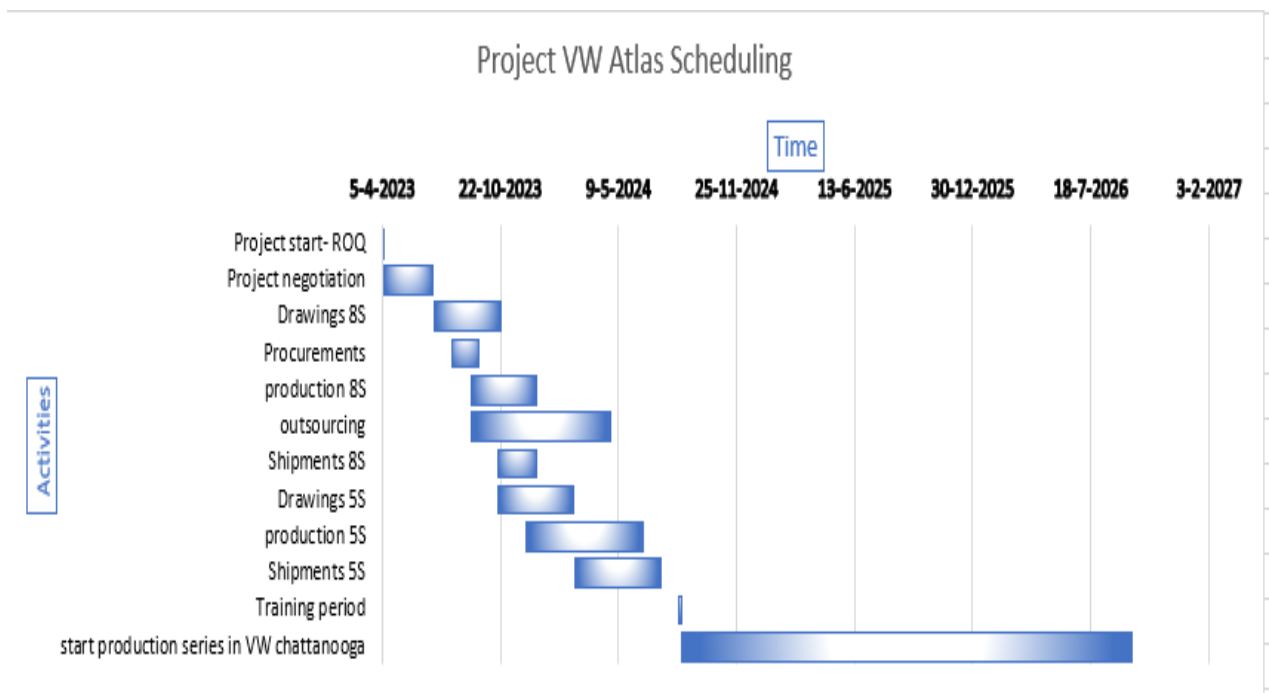


Figure 26: Project timeline.

iv. Study project estimation techniques and trends

There will always be new agile estimate methods. To keep up to date, project supervisors must regularly study industry trends and emerging estimate approaches. In order to meet the needs and preferences of clients. Autorobot is available and engages some meetings with the client for making some adjustments in the project either in some drawings or in the time schedule.

There are many ways to estimate time. You might find it helpful to use a mix of these project management estimation techniques:

- Three-point evaluating: Assess a project utilizing best-case, worst-case, and most likely scenarios. Include up all three gauges and partition by 3 to urge an normal.
- Top-down estimation – Utilized when there's constrained venture data. You see at the extend as a entire and part the assignments into noteworthy stages of work.
- Bottom-up estimation – Break down enormous assignments into littler ones, at that point assess the time needed to wrap up each littler chunk. Because you're assessing each assignment independently, you may be more exact.

Practically equivalent to evaluating – Quickly compare the extend to comparable authentic ventures to get a last appraise. Parametric assessing – Comparative to practically equivalent to estimating, you use past ventures to assess modern ones. With parametric evaluating, you make strides time gauges by comparing earlier information with current extend determinations.

v. Account for risk, worst-case scenario.

There's continuously a worst-case situation that might cause delays in venture arranging. These extra hours will assist you get ready for unexpected or spontaneous occasions all through the extend. Within the best-case situation, you do not require extra time, and your group completes the project ahead of plan.

In any case, on the off chance that things don't go as scheduled, this additional time will provide to bargain with any complications. Inquire your group for their conclusion. They can assist you figure out how much buffer time you ought to include for chance administration in extend administration. But the ultimate conveyance time is non inactive, the client has permitted Autorobot Strefa two months adaptability.

vi. Review the entire project and create a realistic estimate.

Once you have got all your data, you'll include up all the hours to induce a time estimate for your project.

Be beyond any doubt to incorporate inside and outside tasks, project tasks, corrections, and possibility hours. Once you have a add up to appraise, double-check it to guarantee you have got recorded everything. Share the appraise together with your group for criticism.

Talk about the gauge together with your group individuals and compare it to comparative ventures together. In the event that it appears much higher or lower than comparative ventures within the past, you might need to see at each assignment to figure out why.

For this project, we know the project start, April 2023 and the project end, September 2026. The first assembly has been done from September 06th, 2023, to October 13th, of the same year accounting for 116h25min below the estimated time. And it is the supplier responsibility to ensure that they will meet all deadlines.

Underlined issues by the project manager that may lengthen the project duration:

- ⊗ Change in customers' requirements: this could lead to new documentation of some components.
- ⊗ The workers' health
- ⊗ Less productivity of people because of harsh weather
- ⊗ Accident in the manufacturing plant
- ⊗ Underestimated of manufacturing and assembling time

5.3 The production and shipment

➤ **The Production**

As far as the production concerns, it has been started since the end of August 2023 with the manufacturing of rear door fixture for 8S and the Gripper. All the drawing part has been done in the headquarter GME Brazil. Each people are engaged and share the same objectives of the company. At the end of October 2023 many ready fixtures started to be shipped in the US Chattanooga.

The figure below shows one ready fixture for rear door, how does it work? Before everything else, I need to emphasize that each colour has a specific meaning on the request of client, the grey colour reminds the commercial units, the black is for moveable components they are also called located block, the yellow is for support units or brackets and then we have the plate the object on which all other items lie on. The wires consent the electric connection among the electronic components.

When the fixture is in use, the located blocks open first, to allow the loading of the first car door sheet metal, then thanks to the different robot and machines, other elements are loaded and fixed accordingly to the design, after that, the second plate is put above and finally all the blocks are welded and bended.



Figure 27: Rear door fixture.

The second main fixture that I am going to show you is the GRIPPER, its key role is to ease the movement of the robots or car skeletons. In Autorobot They produce Gripper of different shapes, some can allow the movement of only one door at time as in figure 28 and others can allow the movement of 2 robots at time as in figure 29.

With the continuous advancement of technology, robots are playing an increasingly significant role in the automobile manufacturing industry. As part of the robot, the robot gripper also plays a key role in automobile manufacturing.

Firstly, the robot gripper has strongly improved the production efficiency of automobile manufacturing through its efficient operation capabilities. In the traditional automobile manufacturing process, the assembly of parts usually requires manual participation, which is not only time-consuming and labour-intensive, but also prone to errors. The robot gripper can accurately grab and position parts and complete the assembly task in a brief time, greatly reducing the production cycle and improving product quality.

Secondly, the flexibility of the robot gripper makes the automobile manufacturing process more adaptable to diverse needs. With the rapid changes in the market, automobile manufacturers need to continuously launch new models to meet the needs of different consumers. The design of the robot's gripper can be adjusted to different product needs to accommodate the grasping and assembly of parts of assorted sizes, shapes, and materials. This flexibility not only improves the efficiency of the manufacturing process, but also brings greater business opportunities to enterprises.

Thirdly, the precision and stability of robotic grippers help improve the safety of automobile manufacturing. In automobile manufacturing, many links require high-precision operations, such as welding, spraying, painting etc. The robot gripper can perform precise motion control according to preset parameters, making the operation process more accurate and stable. This not only avoids errors caused by human factors, but also ensures the consistency and quality of automobile manufacturing.



Figure 28: 23216 8S ST5540 GRIPPER

As a result, the use of robot grippers also effectively reduces labour costs. Compared with manual operation, robotic grippers can continue to work efficiently without breaks and wages. This not only reduces the company's labour costs, but also reduces workers' labour intensity and occupational risks. For automobile manufacturing companies, this is a long-term investment and relatively stable return option.

To sum up, robotic grippers play a key role in the automotive manufacturing industry. It improves production efficiency, adapts to diversified needs, improves manufacturing safety, and reduces labour costs. With the further development of technology, it is believed that robot grippers will play a more important and diversified role in automobile manufacturing (mini.new, 2023).



Figure 29: 23216 8S ST5570 GRIPPER

Furthermore, the third fixture that I am going to present you in the following image is used as a loading station. It must be used in a perfectly accurate manner because since it is in direct contact with the car door, we need to avoid the lines on the surfaces otherwise they will be unremovable even with the painting and treatment. The blue parts that we see are made up with plastic.



Figure 30: 23214 8S ST5690 Fixture

Underlined issues:

- ⊗ Missing drawings
- ⊗ Missing dimensions in some drawings
- ⊗ Incompatibility of documentation amongst production, mechanical, electronic and automation departments
- ⊗ Collision between the clamp and the Bracket
- ⊗ Wrong movement of the gripper

➤ **The Shipment**

The shipping is also by all means, another important activity in this project because the supplier here is responsible to transport all fixtures after their production till the manufacturing plant of the client VW in Chattanooga. Indeed, they have signed a contract under a DDP that is a delivery agreement whereby the seller assumes all the responsibility, risk, and costs associated with transporting goods until the buyer receives or transfers them at the destination port. This agreement includes paying for shipping costs, export and import duties, insurance, and any other expenses incurred during shipping to an agreed-upon location in the buyer's country.

- Under DDP, Autorobot must arrange for all transportation and associated costs including export clearance and customs documentation required to reach the destination port. In fact, for this reason, the firm decided to entrust an international company which operates in the domain of transport, and they also have a headquarters in the US.
- The risks to Autorobot are broad and include VAT charges, and storage costs if unexpected delays occur. In effect, the supplier has four hours at its disposition to unload the boat after the arrival at the port, the time after which they will pay extra costs.
- A DDP benefits a buyer as the seller assumes most of the liability and costs for shipping.

To better understand the level of responsibility I insert a picture of the different type of contracts under INCOTERMS (International Commercial Terms).



Figure 31: Type of INCOTERMS Contracts

In the file Cost.xlsx in the attachment, sheet DATI X PROJECT row 60, the budget inserted there includes both cost of transporting raw materials from sub-contractors to Autorobot and cost of shipping ready fixture to our customers, it is valued at 5000 euro. But after the real costs have been considered it amounted to 6,300\$ and an insurance of 257\$.

All products will be shipped by boat and the estimated time is one month for each series of transport. The first shipment has been done at the end of October(2023) , the second one by the middle of November(2023) and the rest in 2024. A total of 5 containers for 50 boxes are necessary for all fixtures. The supplier expects to have the first arrival by December 8, 2023, because from December 28, the first mountings must be made as well as the tests of the machines.

Special packaging than usual made by wood must be used for reasons of security, resistance, oxidation, long duration, moisture, and rust. To be clearer, I show you in the picture below how one box of fixture looks like with inside a kit of utilization. For identification, on each box, it is written the box number, the order number, the container number as well.



Figure 32: Structure of packaging box

5.4 Unforeseen events

Many external incidents can absolutely happen independently of manufacturer's voluntary and have some influence on the ongoing business. Unfortunately, we cannot prevent those incidents to occur because they could be either natural or by specific organizations that take decisions in the global marketplace. Thus, here in this part of my thesis, I have listed 4 accidental situations that could eventually affect the manufacturing process of the project between Volkswagen and Autorobot Strefa.

5.4.1 Raise in interest rate in the market

The interest rate is the amount a lender taxes a borrower as a proportion of the principle, or loan amount. An interest rate also pertains to the amount earned from a bank or credit union's deposit account.

“If the Federal Reserve decides to raise interest rates, as it hinted earlier this week, automobile experts believe the sector would lose \$22 billion in sales. According to analysts, consumers may buy 150,000 fewer new automobiles and 500,000 fewer older models” (Hampton, 2022).

Those anticipated rate climbs are likely to happen at the conclusion of the central bank's another policymaking assembly – and nearly precisely two a long time after it

sliced rates to zero in reaction to the rise of a fast-spreading coronavirus that debilitated to destabilize the complete budgetary framework (Hampton, 2022).

Climbing rates would likely affect several U.S. segments at the side the car industry, with a few examiners fighting the increase will trigger more instability within the auto world. And of course, Volkswagen Chattanooga headquarter is not spared.

Tyson Jominy, the data and analytics vice president at buyer intelligence firm J.D. Power, stated that while there is often an automotive roadmap for when interest rates fluctuate, there is little precedence for a worldwide pandemic and a car supply-chain shortfall. "We don't have a lot of experience with climbing rates with nothing to sell," Jominy went on to say. According to J.D. Power, rising borrowing rates would result in a \$15 billion loss in used car sales and another \$7 billion in misfortunes on modern automobiles.

The worldwide chip deficiency appears to be coming beneath control, but there are still broad stresses almost other supply chain disturbances influencing elastic, plastics, and steel, which has made it troublesome to make vehicles, NBC News detailed. Wall Street has underscored concerns approximately rising interest rates and inflation.

"Interest rates have been the one area of relief for consumers that want to buy a vehicle because prices right now are at all-time records," said Jessica Caldwell, official executive of insights of Edmunds, a car shopping inquiring about website. She included that customers have managed an account on getting high esteem for their exchanges and low intrigued rates for car buys.

In December, the average price of a new vehicle was \$45,000, up from \$35,034 two years before. Traditionally, if manufacturers had more production and inventory, they could raise incentives and competitive rates, but there are now not enough vehicles being created to fulfil demand, according to Jominy.

So, all this is only to say that the more the Federal Reserve will want to increase the interest rate in the US, the worst will be the investment and Volkswagen might decide to reduce the production capacity required or spend more for the same capacity and increase the purchase price of the car.

Here below, we have a graph of a change of interest rate in the United States from July 1954 to October 2023. In 2023, we have a slight increase in interest rates so this will negatively affect the investments in the region as well as VW project. The data come from the reliable website Statista.

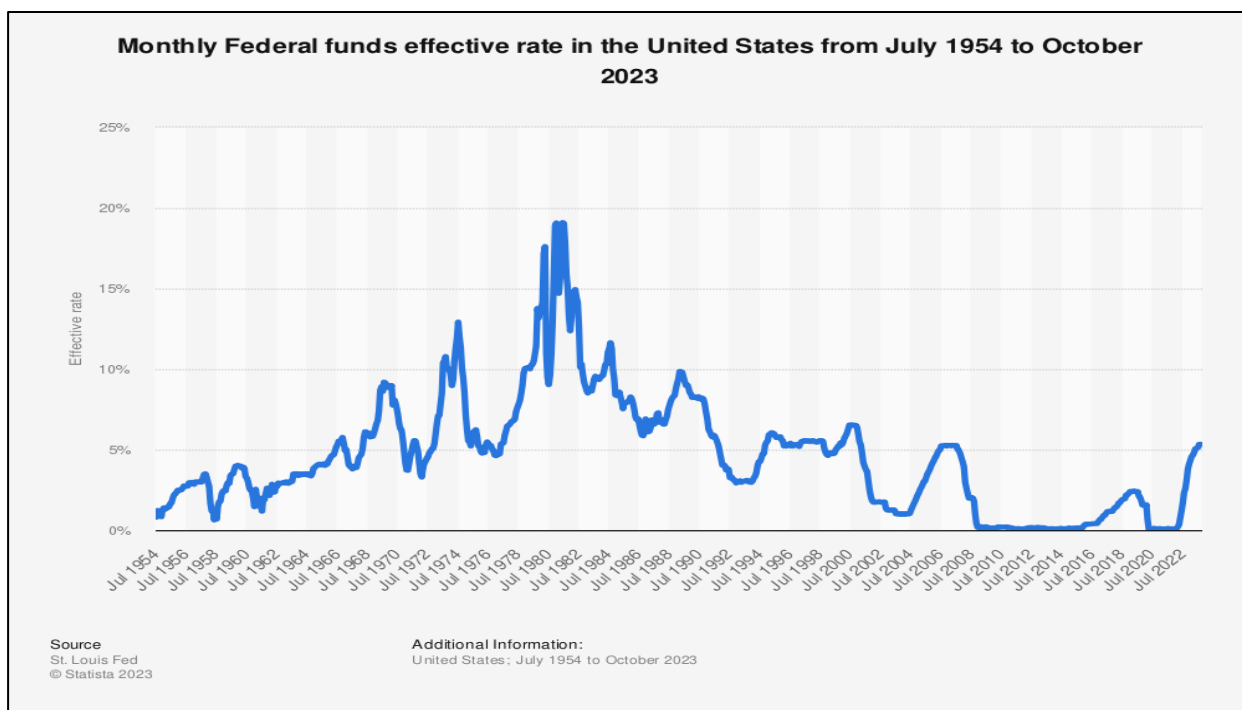


Figure 33: Waves of interest rate.

5.4.2 The change in Exchange rate

Being an international corporation, Volkswagen faces in one way or another the issue of variation in exchange rates between euro, us dollar and Polish Zloty.

A prediction of the theory is that a firm's exchange rate exposure depends on its foreign as well as its domestic demand elasticities. Therefore, because of the different characteristics of the firms in the world automotive industry, the components of this exposure should vary across markets. Consistent with this prediction, the findings show that exposure varies across firms from different countries.

Let make an example with 2 different rates using the chart below. On April 7, 2023, at 00:00, 1 US dollar was worth 4.29066 PLN. Therefore, for a project value of \$100,000, the equivalent in Polish currency should be 429,066 PLN which is merely different from 402,653 PLN if the exchange was 4,02653 as of November 17,2023 at 12:51 UTC for a decrease of 6.16%. So, depending on when the payment will occur, one of the 2 companies will suffer from these fluctuations. Here below I show you the graph of big changes in exchanges, the screenshot is taken on November 17, 2023 at 12:51 UTC from the web site xe (xe, 2023).



Figure 34: The changes in exchanges rate

5.4.3 A possible new pandemic

A pandemic is the situation in which an infection disease affects many people in variety of regions in the country or in the world at the same time. Just to name a few diseases that have significantly affected the world: in 1350, The Black Death, in 1665, The Great Plague of London, in 1957 Asian flu, in 2003 SARS, and in 2019, the COVID-19. We will use this last case to present the impact of this unforeseen event in the car manufacturing industry.

The spread of Covid-19 over the world has negatively affected the production in automotive industry. Even if it is true that many departments like IT, Accounting, purchasing could perfectly adopt the home working but others department mainly the manufacturing itself need the presence of people, but, due to the lockdown, it was not possible to work. Consequently, many companies shutdown the plant for a while or have reduced the capacity production.

While it recovered considerably after the initial lockdowns and when the economies reopened, the car industry has been severely impacted (Figure 35, Panel A). Many CEE nations, notably the Czech Republic, Hungary, Poland, Slovenia, Slovakia, and Romania, rely heavily on the automobile sector for economic growth and job creation. Faced with the risk of a prolonged crisis as well as underlying obstacles caused by technical advances, the industry's prognosis in each nation will be dependent on overseas demand (with potentially varying outcomes for various market groups). The capacity to capitalize on new possibilities as the industry adapts and develops. (Caroline Klein, 2021):

- The auto sector faces significant instability. Car demand is projected to stay weak in the near to medium term. Demand for automobiles made in Europe is anticipated to remain 8% under its pre-crisis level in 2021, according to OECD Economic Outlook forecasts and an estimated link between car sales and GDP⁴ growth.
- The CEE automotive business relies heavily on international demand, with Europe and Germany accounting for 67% and 30% of motor vehicle exports, respectively. Car sales follow the business cycle (Figure 35, Panel B), and the epidemic is projected to have long-term negative consequences on economic development in the CEE nations' primary trading partners (OECD, 2020).

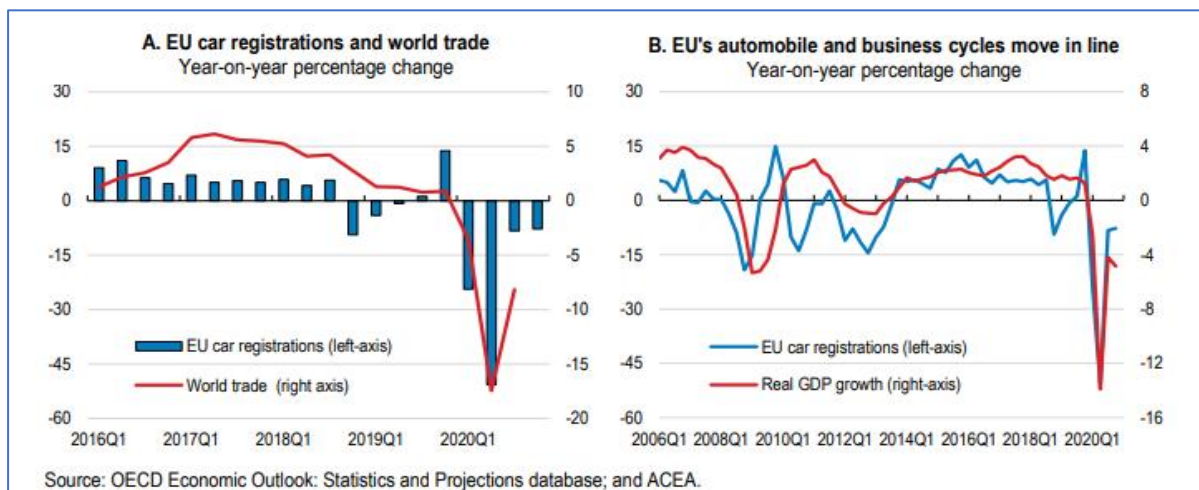


Figure 35: International trade fallen, and car sales plunged during the first lockdowns

Looking at these 2 graphs we can clearly see a sudden fall both in the total cars produced and in the real GDP during the first quarter of 2020. If we only stop here and think for few seconds, we may conclude that this is a big issue to address while operating in this sector.

Moreover, The Covid-19 outbreak dealt the global automobile sector an unexpected shock. In Europe, the introduction of containment measures has created production and demand interruptions for automakers and their subcontractors. The unexpected production halt in early 2020 sent shockwaves through the industry, virtually shutting down the whole supply chain. The lifting of limitations at varying speeds across sectors and nations has resulted in input shortages in the sector's complex value chains. At the same time and more persistently, a demand shock significantly lowered output across all assemblers. Recently, the continuous negative demand shock has been the most significant issue hurting the automobile business. Recent lockdowns in reaction to the virus's reappearance have not created supply issues thus far (Caroline Klein, 2021).

⁴ GDP short for Gross Domestic Product is the total amount of final products and services provided in a country during one year.

The crisis's impacts became apparent early on and were particularly evident in the CEE area. In instance, automobile sales fell by over 32% in the first two quarters of 2020 (ACEA, 2020). Car manufacture effectively ceased for an average of 28 days. In September, the predicted drop in automobile production owing to factory shutdowns and chronically decreased manufacturing capacity was between 17% in Slovakia and 25% in Poland compared to 2019 levels. While the shock is considerable, it has been smaller in most CEE nations than the average in the European Union (EU) (Caroline Klein, 2021).

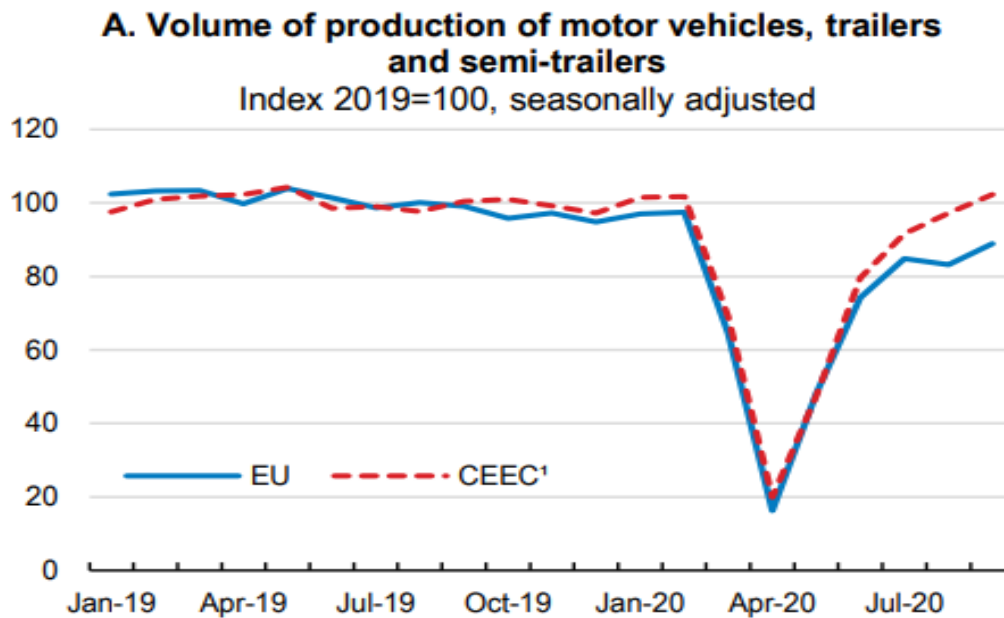


Figure 36: Significant reduction of the volume of production of motor vehicles

5.4.4 The Global warming

Finally, let address some lines of my essay, to this last accidental event. By definition, the Global warming is a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, chlorofluorocarbons, and other pollutants. Global warming jeopardizes our health, national security, and other fundamental human necessities. Some implications include record high temperatures, rising seas, and severe flooding⁵ and droughts⁶—are already increasingly common.

⁵ The covering or submerging of normally dry land with a large amount of water.

⁶ A prolonged period of abnormally low rainfall, leading or a shortage of water.

Our private cars are a major cause of global warming. Together, cars and trucks account for nearly one-fifth of all U.S. emissions, emitting about 24 pounds of carbon dioxide and other greenhouse gases for every gallon of gasoline. Approximately 5 pounds of heat is generated during fuel extraction, production, and distribution, but the majority of heat-trapping emissions (more than 19 pounds per gallon) come directly from vehicle exhaust gases.

In add up to, the US transportation sector—which incorporates cars, trucks, planes, trains, ships, and freight—produces about 30% of all US worldwide warming emanations, more than nearly any other division. Shockingly, oil-related emanations may rise within the coming a long time as the oil industry extricates and refines “unconventional” oils, such as tar sands and tight oil. Utilizing less oil—and maintaining a strategic distance from superfluous emanation from the oil we do use—is the genuine solution (Union of Concerned scientists, 2014).

In Europe (Paddison, 2023)

A joint report by the World Meteorological Organization and the European Union's Copernicus Climate Alter Benefit found that final summer (2022) was the sultriest on record for Europe and caused more than 16,000 overabundance passings, concurring to the report. A few nations, counting the UK, Spain, Switzerland, and Italy, saw their most sultry a long time on record in 2022. Europe is the fastest-warming landmass within the world, agreeing to the report, and has been warming twice as quick as the worldwide normal for the final four decades.

The continent was not just hot, but also exceedingly dry, which had significant consequences for agriculture and water supplies. Many sections of the continent received relatively little precipitation last year, with France recording the driest January-September period on record. According to the research, Spain's water reserves have fallen to little more than 40% of capacity.



Figure 37: Europe's state of Global warming.

Scientists are afraid that the onset of El Niño, a natural climatic phenomenon that contributes to global warming, may lead to catastrophic climate extremes in 2023. However, there are some signals of optimism. According to the research, renewable energy generated more electricity than fossil gas for the first time ever last year, with wind and solar accounting for 22.3% of the EU's electricity, fossil gas for 20%, and coal power for 16%. “Increasing use of renewables and low-carbon energy sources is crucial to reduce dependence on fossil fuels,” WMO Secretary-General Petteri Taalas said in a statement.

Thus, with all these data on hand, the institution will take or in many sectors are already taking stringent actions to overcome this issue, such as the promotion of manufacturing and using of electric vehicles. In Italy, the use of Diesel 5 cars is forbidden, this implies that many firms will change their raw material in their productions.

As a sort of conclusion to this sub-part, I draw a table to have a complete understanding of the impact of these accidental events. The increase in interest rate has a high impact because the amount of interest for a specific amount might be too high to deflate the investor (borrower) or to reduce the potentiality of investment. Regarding the exchange rate, I think, it has a low impact because for many partners the amount could be negligible, or they can decide to wait catch the best opportunity to effectuate the transaction. Besides, the pandemic has a significant high impact because with the lockdown, the manufacturing companies must close the plant. Then, the global warming has a medium impact because the firm will not totally stop the investment but to move from one niche to another one remaining in the same sector, but of course some it will suffer some costs.

Unforeseen event	Impact	Description
Rise in interest rate		High
The change in Exchange rate		low
The pandemic		Definitely high
Th global warming		Medium

Table 7: Degree of Impact of accidental events on the project

6. The Proposed Solutions

This last part is mainly dedicated to bringing or to proposing solutions to all the issues listed in the previous part. Because I absolutely think that it would be useless if I just list the issues without trying to find a way to overcome each difficulty. Hence, it is wise for me in this chapter to summarize and bring solution to key issues mentioned above and then establish another general type of routine that the company might adopt for its daily activities.

6.1 Solutions of the listed issues

First, for the cost estimation part we have:

1. **Sudden raise in raw material costs in the market:**

This is a prevalent issue that many businesses deal with nowadays, and it is nearly hard to avoid because inflation may occasionally produce problems for any individual or group of individuals. Many raw resources are become more difficult to obtain as a result of events like the COVID-19 outbreak and the continuing Russia-Ukraine conflict that are upsetting global supply systems. Because of this, commodity price volatility could not be a passing fad. Manufacturers must decide whether to accept higher prices, come up with creative methods to reduce costs, or pass price hikes along to consumers who are already reluctant to part with their money. I would only suggest ACCEPTING or MITIGATE this risk and pay extra cost. Moreover, if the company use to deal with the same suppliers, the extra amount can be reduced due to the long-term contract.

Through employing these seven useful tactics, businesses may successfully manage and lessen the impact of alterations to the cost of raw materials :

- **Conduct money related demonstrating of all crude fabric inputs:** through the budgetary displaying of all crude fabric inputs your obtainment divisions will be able to make more extensive supporting openings and relieve the dangers related with crude fabric cost changes. The monetary displaying handle will incorporate examining and anticipating the costs related with obtaining and utilizing different crude materials in a business under different scenarios. It is additionally vital to join hazard analytics by assessing the potential dangers and instabilities related with crude fabric costs, such as supply disturbances, geopolitical components, or administrative changes.
- **Lock in the vital sourcing.** Locks in the vital sourcing hones can offer assistance companies recognize and secure the foremost cost-effective and solid sources of crude materials. This includes assessing providers based on variables such as quality, unwavering quality, estimating, and steadiness of supply. Numerous producers are moreover moving toward nearshoring to relieve supply chain disturbances. Nearshoring – or joining forces with providers inside your quick locale – permits a company to have more control

over its supply chain, and as materials will be less affected by conveyance delays, costs will stay steadier. Companies can moreover decrease their powerlessness to supply disturbances and cost variances by broadening their provider base. To guarantee supply chain supportability and versatility, you ought to survey your provider base, not fair in terms of cost and quality, but too with a see to construct redundancies and fallback alternatives into you organize.

- **Create an agile supply chain:** making an agile supply chain has numerous benefits, counting moved forward stock administration coming about in diminished stock holding costs, minimized stockouts, and improved in general stock administration proficiency and lower costs due to decreased waste and moved forward prepare effectiveness. These components, combined with upgraded supply chain perceivability, empowering superior decision-making and speedier problem-solving and more grounded partner connections, empowers producers to moderate dangers more effectively.
- **Explore manufacturing process changes:** In expansion to in general supply chain optimization, companies seem to investigate ways to optimize or adjust their fabricating forms to decrease their dependence on particular crude materials or discover options that are more fetched successful or promptly accessible.
- **Conduct situation planning:** companies ought to closely screen showcase patterns, worldwide occasions and components affecting crude fabric costs. By remaining educated and conducting situation arranging works out, companies can expect potential cost vacillations and proactively create techniques to moderate dangers and adjust to changing showcase conditions.
- **Focus on continuous improvement:** One of the most benefits of a nonstop change approach to fabricating is that it progresses an organization's strength and capacity to moderate dangers and disturbances. It does this through streamlining forms for progressed adaptability and versatility, reducing costs and squander to extend income and pushing an organization toward generally operational fabulousness(excellence) which gives it a competitive advantage.
- **Adopt sustainable practices:** Embracing maintainable practices is one of the leading ways an organization can relieve the effect of tall crude fabric costs. Economical hones such as squander diminishment, reusing and asset productivity can minimize the utilization of crude materials. Moreover, consolidating renewable or reused materials into the sourcing prepare can make the company less dependent on traditional crude materials, with the included advantage of essentially diminishing its natural impression. Companies can investigate choices such as utilizing reused plastics, recovered metals or bio-based materials determined from renewable sources as options to routine crude materials. Companies are moreover energized to explore closed-loop frameworks recover and reuse materials from their possess operations or outside sources. By closing the circle and reusing materials, companies can decrease their crude fabric acquirement costs.

Another ecologically maintainable way to combat high crude fabric costs is to prioritize optimizing your organization to grasp energy – and water-efficient processing strategies. Not as it were does this offer assistance decrease nursery gas outflows, but it'll too make your trade less defenceless to vitality and water cost climbs.

To summarise, to deal with raw material cost fluctuations and remain competitive, organizations have to embrace new ways of working. From rethinking and optimizing their supplier relationships and supply chains, to embracing environmentally friendly manufacturing practices; the opportunities are endless for those companies brave enough to commit to change.

2. High cost of external hours, sometimes because of less time they must produce what is required.

For having spent 2 months and the half in this company, I have been aware of how it can be stressful to even find the right subcontractor at the right time especially when the firm barely won a big market. Also in this case, long, strong, and good relationship with suppliers matter enough and you also need to have smart and high qualified employees for managing different negotiations for a competitive price. Another possible solution is the better warehouse management: if the company knows that sometimes, components are always necessary for the manufacturing process of different fixtures such as the clamps, the eye bowls, the sensors, it is important to avoid stock out of those elements. The former solution is linked to the awareness of period of high, medium, and low demand because just before the period of high demand the firm can start preparing the inventory. So, the main idea here to AVOID the risk.

There exists a general way to overcome the situation:

Supplier relationship management (SRM) is the discipline of strategically planning for, and managing, all interactions with third party organisations that supply goods and/or services to an organisation in order to maximise the value of those interactions. In practice, SRM entails creating closer, more collaborative relationships with key suppliers to uncover and realise new value and reduce the risk of failure. Getting back to the initial goal of cost savings, the question becomes ‘when cost savings is a critical driver in supplier selection, how do you balance the collaborative relationship with low cost?’ The key is internal alignment between procurement and the business units. Supply Chain leaders must be able to explain why vendors who may not be the low-cost option for reasons like customer service, on-time deliveries, payment terms, reporting, etc. are actually the best overall value option for the business (Procurious, 2022).

In simple terms, it creates a competitive advantage. Whether you are the procurement or the supply chain leader for your organisation, having a strong supplier management system will maximise cost-reduction opportunities, value driven services, and overall systematic efficiencies, which otherwise would not be achieved.

9 ideas to reduce costs using Supplier Relationship Management (SRM) (Procurious, 2022):

- Length of the contract
- Decreased future fetched increments
- Superior rebates or motivating force levels
- Rebates(discount)
- Volume limits
- Conveyance Costs
- Payment Terms
- Ancillary Charges(auxiliary)
- Everything Else (Way better detailing, more straightforwardness, communication arrange)

In case your fundamental objective is to fair pound down the unit cost, at that point there's a great chance your provider will not be excessively open to that approach. Tune in, collaborate, compromise, and create an organization that will eventually be a win-win for all those included.

Second, let analyse here the set of solutions to get rid of the time estimation issues affecting the project:

3. Change in customers' requirements: this could lead to new documentation of some components.

This is a common situation that we encounter in almost all companies. Even after having signed the contract the client might always revise the requirements by adding or removing some of them. But in any cases, it is supplier's responsibility to request additive time if necessary. Volkswagen granted 2 months of flexibility which Autorobot deemed sufficient to complete all operations on time.

Even if you can't see so far into the future, it's critical to establish the criteria as soon as possible in order to get back on track when they keep changing. Focus on what you can control and establish a procedure for adjusting to upcoming changes. Decide on your current situation and your plan of action for handling changes when they arise, because they will inevitably do!

- **Clear set of requirements.** Go back to your scope record, terms of reference, commerce case or venture constitution. What is this venture attempting to accomplish? This shapes the supporting structure of your prerequisites. List all the prerequisites you as of now have on the venture and make beyond any doubt they all tie back to the project's targets.
Inquire all your partners to review the list and affirm that it presents the current see of what they need the extend to convey.
On the off chance that there are clashing prerequisites – Showcasing need the gadget in blue and Client Administrations need it to be orange – inquire your Support to arbitrate. It could be less demanding to induce everybody within the same room to concur the ultimate list, in spite of the fact that in the event that

you anticipate there will be a few clashes you'll organize person sessions with each of your partners within the to begin with occurrence.

- **Set expectations.** Set and oversee desires. As portion of talking to all the project's partners around their prerequisites and the conclusive list, take the time to clarify to them that there's continuously a fetched related with making a alter. On the off chance that they change their minds within the future and need to include or alter a necessity, there will be a cost to pay. It's not continuously a budgetary cost.

As a result of the alter: the extend seem take longer or wrap up prior, more resources may be required, the result can be a distinctive quality result to what was already concurred, the venture seem taken a toll more.

Changes are often desirable, so they aren't something to be stressed around. Grasp the changes: partners ought to know that they do have the choice to create changes in case required.

Be that as it may, they ought to do so within the full information of what the affect ought to be, and with direction from you approximately how possible it is to create the alter. For example, it is distant simpler to oblige changes early within the venture.

“If you are building a hotel, it is not going to be easy to change the layout of all the bedrooms when the decorators are just finishing up. Any smaller changes that cannot be accommodated now could be packaged up into a Phase 2 or another project in the future”(Harrin, 2021).

- **Create (or review) the change control process.** Presently you have got a baseline of extend necessities, you would like to know what to do ought to you be inquired to form another alter. A change control handle educates how demands are taken care of for modern prerequisites, or modifications to existing necessities. You'll have a formal alter administration prepare that maybe isn't working, otherwise you may select something less formal.

Either way, the steps to go through are the same:

- An ask to form an alter to the baselined prerequisites is obtained.
- The alter is surveyed against set criteria, ordinarily they impact on: the plan, assets, other prerequisites, the budget, venture dangers, the goals and extend as a whole in case the change isn't done. You will have a characterized list of things against which to evaluate the alter, otherwise you may depend on proficient judgment from the subject matter specialists included. Either is fine but make beyond any doubt the survey handle is reasonable and repeatable.
- A choice is taken whether to actualize the change or not. On the off chance that yes, record the alter, upgrade the plans and plan, and let everybody know. If no, tell the individual who asked the alter that the work will not be done, and the reasons why. Either choice is fine. Give criticism as essential to the requestor and the group so everybody has the same desire of what happens another.

Make beyond any doubt that venture partners and in specific, your Sponsor, get it and concur to the alter control handle that you just will be utilizing from presently on. The encounter of working through this one alter will assist you conversation around why it's fundamental to create changes in an organized way.

4. The workers' health

“Your company may pride itself on being a good employer. But even with the best of intentions, your company could be hurting employees’ health and well-being because of the way the work is organized. Working conditions and the demands of the work environment are a significant source of stress for many Americans, and research has found that the design of work can have substantial effects on employee well-being and health as well as health care expenses” (Erin L. Kelly, 2021).

Therefore, it exists a way to counteract this situation, the great news for directors is that there are attainable ways to update work to foster well-being and surrender long-term benefits to the organization. For occasion, later investigate proposes that deliberately changing work environment conditions to cultivate labourer well-being not as it were progresses employees’ wellbeing but can too bring almost useful commerce results such as made strides work execution (counting expanded efficiency) and lower levels of representative burnout so that each representative feels light and zero anxious working.

Here below, I am going to list 7 strategies to improve Employees’ Health and Well-Being:

- **Give workers more control over how they do their work.**

According to research, having little control over how work is completed is linked to greater incidences of heart disease as well as worse mental health. Nevertheless, a company could adopt mutual adjustment coordination where different members of a team collaborate to share their knowledge without referring always to the boss. Furthermore, there is a considerable increase in the risk of diabetes and cardiovascular mortality when high work demands, and inadequate job management are combined. Employee well-being can be affected by even little adjustments to worker autonomy. According to research conducted at a customer service contact centre, for instance, providing staff with more training enabled them to take on new responsibilities and handle more client complaints independently, which enhanced their performance and well-being at work.

- **Allow employees more flexibility about when and where they work.**

Many studies have shown that giving workers choice and control over their work schedules improves their mental health and ability to adapt to different situations. This may mean simply allowing different start and end times to facilitate shift changes for work that needs to be completed on site. Extensive work redesigns at Fortune 500 companies are giving IT staff control over when and where they work, empowering them to collaborate with teammates to ensure necessary adjustments, and ensuring

that employees are physically fit. It has also led to improved physical and mental health. As a decrease in business turnover.

- **Increase the stability of workers' schedules.**

Several retail and service companies today use on time scheduling to try to match labour to oscillating demand. But erratic, unpredictable schedules make it hard for frontline workers to manage their personal lives and family responsibilities. Research finds a set of negative outcomes occur for employees who have this kind of inconsistent work schedule — including poorer sleep quality and greater emotional distress. Vice versa, a study at Gap found that greater schedule stability can benefit both companies and employees. “Increasing scheduling stability for workers led to a 7% rise in the participating stores’ median sales and a 5% increase in labour productivity. The added stability also improved sleep quality and reduced stress among employees with children.” (Erin L. Kelly, 2021)

- **Provide employees with opportunities to identify and solve workplace problems.**

Giving employees the opportunity to participate in improving their workplace can be an effective approach to promoting employee well-being. A study of physicians, physician assistants, and nurses found that those who were invited to participate in a structured process to identify and resolve workplace issues had lower rates of burnout and improved job performance. I found that the level of satisfaction was high. Employees who had the opportunity to solve problems together were also less likely to say they wanted to quit their jobs. This is a huge advantage for companies looking to retain valuable employees.

- **Keep your organization adequately staffed, so workloads are reasonable.**

High job expectations, such as long hours or the need to work quickly or hard, have been shown to have a negative impact on employees' health and wellbeing. Actually, a number of studies show that a combination of high expectations and poor control leads to health hazards, such as increased prevalence of depressive symptoms, hypertension, and cardiovascular disease. While adding more workers in order to spread out the responsibilities may appear expensive, firms really pay when sick or tired workers quit, burn out, or miss work. One potential answer might be to implement targeted personnel changes. For instance, some researches found that assigning a medical scribe to assist doctors with some of their charting responsibilities increased their productivity and work satisfaction.

- **Encourage managers in your organization to support employees' personal needs.**

Many workers also look for their aging parents or children, and they gain from having bosses who are more understanding of the difficulties they encounter in juggling work and family obligations. According to research conducted in nursing homes, staff

members who had supervisors who were more understanding of their families' needs slept better and had less cardiovascular disease risk factors. Training programs for managers to enhance family-supportive behaviours have been studied in health care and grocery store settings; the results show promise for improving work-life balance and overall health. Employers gained as well, as employees with supervisors who received this training reported improved job performance, increased job satisfaction, and decreased desire to quit.

- **Take steps to foster a sense of social belonging among employees.**

Developing a work environment where employees may form helpful relationships with their coworkers can be a key tactic in improving worker well-being. Such interactions at work have been linked to decreased psychological discomfort, which is a sign of poor mental health, according to research. Creating a sense of social belonging doesn't have to be difficult or costly. In one research, managers of 911 dispatchers—who have extremely demanding jobs, high rates of burnout and turnover—sent out one email each week encouraging dispatchers to encourage one another by telling encouraging tales about their work. In one email, for example, the dispatcher's claim about saving a 911 caller's life by connecting them to the right resources. Dispatchers who received the emails encouraging them to share such stories with one another reported a significant decrease in burnout and were 50% less likely to quit.

Employers gain from various management strategies that enhance employee well-being, as these examples show. That should come as no surprise. Companies that prioritize the health and well-being of their workers will eventually attract workers who share that concern for the company's health and well-being. And all effective leaders aim toward that result.

5. Less productivity of people because of harsh weather

This kind of situation is more likely to happen in some coldest countries such as Poland where I did my internship, also, the journey is difficult when it snows. In this situation we cannot provide clear and strong solution because we are not able to go against nature. But I would suggest to offshoring the production in countries where the weather is stable and easily adjustable with various situations. Another way is also to allow for hybrid working if possible (extremely limited for who must work in the production plant).

6. Accident in the manufacturing plant

In order to do everything possible to prevent on-the-job factory accidents, consider implementing the following manufacturing safety management strategies (VensureHR, s.d.):

- **Provide thorough training, instructional videos, and safety manuals to employees.**

The initial and most efficient method to teach your staff basic facilities and operating practices is through comprehensive training. Make sure you're having an impact and that every worker is ready to carry out their specific responsibilities. Using live training, practical films, and safety manuals as resources, this entails giving students a thorough awareness of personal protection equipment, materials, possible dangers, and how to handle them. In order to prevent workplace accidents, training is essential.

- **Regularly evaluate your operations for safety and health occupational hazards.**

It may seem obvious, but you'd be surprised how many employees turn a blind eye to workplace hazards. Don't fall behind on housekeeping and keeping work areas clean and maintained. If conducting regular safety rounds and evaluations isn't part of your daily (or even weekly) routines, it should be. Additionally, use every tool available – signs, posters, wall and floor markings, colour codes, alarms, lights, etc. to warn employees about potential hazards.

- **Monitor facilities effectively.**

Regular observation may be beneficial in many ways. Initially, it guarantees prompt response times to mishaps as soon as they happen. It also assists you in making sure that Standard Operating Procedures (SOPs) are followed safely. Thirdly, and maybe most significantly, you may refute workers' compensation claims and legal conflicts with the aid of continuous status reports.

- **Utilize machine guards.**

Employees can be shielded from potential risks by machine guards against electrical sparks, spinning parts, etc. At the start of each shift, make sure to test any equipment that makes use of emergency stop capabilities.

- **Instruct staff members on hazardous energy control techniques (e.g., LOTO).**

Manufacturing mishaps brought on by inconsistent Lock Out/Tag Out (LOTO) protocols during maintenance tasks may involve burns, electrocutions, fractures, amputations, or crushing of body parts. In order to comply with LOTO regulations, producers need to create and implement a rigorous energy management program specific to their machinery.

- **Systematically maintain a written Hazard Communication (HazCom) program.**

Manufacturing workers must abide by OSHA's HAZCOM requirement, which includes supplying safety data sheets (SDSs) addressing hazardous chemicals at your place of business, if they work in areas where chemicals are handled, distributed, or manufactured.

- **Uphold the standards for respiratory protection.**

Equip your employees with the appropriate personal protective equipment, such as safety goggles, hard helmets, and face shields. As the figure 38 shows how an operator working in a welding area should be dressed.

- **Conduct proper investigations in the event of an accident.**

Make sure Every one of your supervisors is capable of handling accidents at work. For instance, unlike less serious events, fatal accidents must be reported to the OSHA office that is closest to you within eight hours after the incident.

- **Make sure your company culture promotes a safety-conscious space.**

Think about organizing planning sessions for workplace safety and health, reiterating the need of necessary training, and regularly distributing training materials to individuals. It's also critical to communicate about and eliminate risks as soon as they are found. This emphasizes the importance of preventing injuries and encourages staff members to report hazards with confidence that management will address them promptly.

- **Track your employees' training.**

As you are aware, maintaining documentation of employee hazard communication training is crucial to preventing OSHA violations.

- **Take into consideration state-specific legislation in addition to federal OSHA obligations.**

For instance, 28 states presently have local focus programs in place thanks to OSHA.

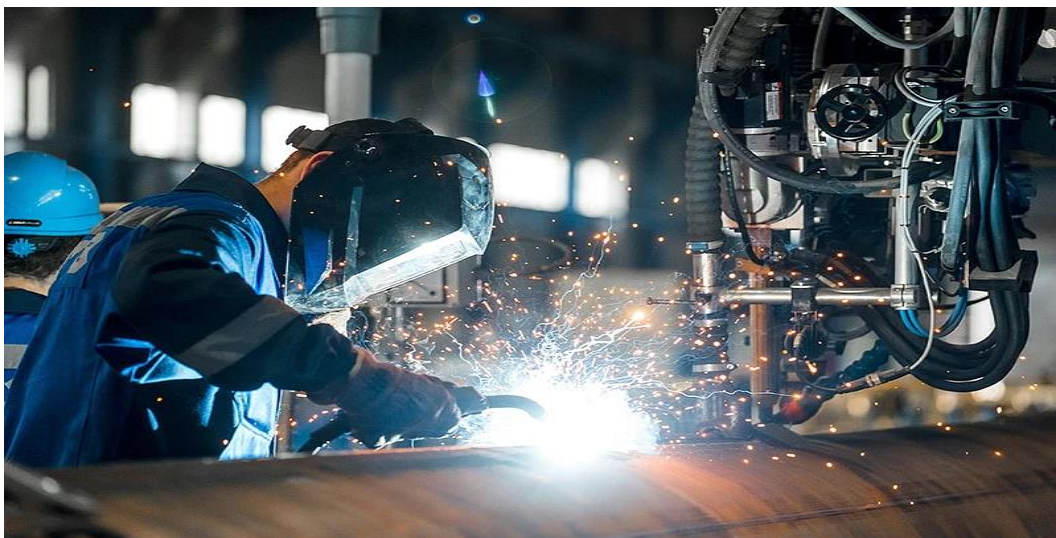


Figure 38: Manufacturing safety block of welding.

7. Underestimated of manufacturing and assembling time

It may happen that we made the scheduling of activities but when it comes down to execution, the current time differ from the planned time. It almost always happens in production because we cannot control anything or because something is over our capacity. To solve this problem, I will first suggest hiring more experienced labours who will take care of such kind of activities (the scheduling) so that we will be able to minimize the slack time. Second, insert some buffer time, both feeding buffer (excess time for some critical activities) and project buffer time (a buffer placed at the end of the timeline). So, the idea is always to be more preventive than reactive.

Third and last part of this sixth chapter, let jump into the solution analysis of the production part.

8. Missing drawings

A frequent and quick check of each step of the different drawings might be necessary to prevent the absence of some of them. Indeed, we have to be sure that the number of required items for the assembly or final items should match the number of drawings. As a corrective action, the company should have some drawers available during the ongoing manufacturing process so that we may quickly solve the issues that will emerge. This means since the production is done in Poland and the drawing and engineering in Brazil, the project manager in Poland must be sure that one or more employees in the drawing team to be available in case of some misunderstanding or missing drawing. At the same time, the same principle can be applied to the missing dimensions issues.

9. Missing dimensions in some drawings

The normal procedure when dimensions are missing is to leave a small note on shop drawings and, if needed, scale dimensions accordingly (noting the precise dimensions scaled and to what degree). "This way, the architect can follow up with the proper dimensions or confirm that your scaled dimensions are correct" (Guru, 2019). This rule is applicable to any kind of dimension required for glazing systems, including reference and coordination dimensions.

10. Incompatibility of documentation amongst production, mechanical, electronic and automation departments

This is the result of lack of communication between the departments, which also use 2 different software for working. So, I can propose 2 solutions here either they make frequent meeting weekly or even daily to update and share their data or they could use a shared platform where to save data such as Google drive or Microsoft share point.

11. Wrong movement of the gripper

Internet of Things (IoT), data science, machine learning, and artificial intelligence are important technologies that have significantly impacted the development of robotic grippers to improve their functionality and performance in several ways: IoT enables the robotic gripper to be connected to a network, which allows it to collect and share data with other devices and systems. This data can be used to optimize the gripper's performance and improve its ability to handle different types of objects.

Data science and machine learning can be used to analyse the data collected by the gripper, identify patterns, and make predictions about the behaviour of the objects it is handling. This can be used to improve the gripper's grasping and manipulation capabilities. Machine learning algorithms can also be used to train the gripper to recognize objects, classify them and make decisions based on that.

Artificial intelligence (AI) can be used to control the gripper, allowing it to adapt to different environments and situations. AI-based control systems can also be used to implement advanced grasping strategies, such as the ability to grasp objects of different shapes and sizes. Furthermore, with the help of AI, robotic grippers can also learn from their experience and adjust to new scenarios, and even troubleshoot problems on their own.

The combination of these technologies can help to make robotic grippers more versatile, efficient, and capable of handling a wide range of objects and situations (Gupta, 2022).

6.2 General solutions in Manufacturing

5s lean manufacturing (FIRST, 2020)

Reducing faults, raising production, improving quality, cutting costs, and pursuing continuous improvement are all beneficial to any generic sector. A variety of ideas and approaches are available to support the implementation of Lean Manufacturing Procedures and Good Manufacturing Practices (GMP).

Lean Manufacturing is a process that aims to maximize productivity and minimize waste in manufacturing operations. Anything that consumers do not think adds value and are unwilling to pay for is considered waste.



Figure 39: 5s Lean Manufacturing structure

5S stands for "Seiri, Seiton, Seiso, Seiketsu, and Shitsuke," which are Japanese terminology for lean manufacturing techniques used in the workplace. It is a visual management tool that may decrease waste, raising an organization's production and profitability. 5S lays forth the essential procedures that, when followed, can result in the creation of a high-quality workplace.

Japan was where the 5S system first emerged. Toyota Motor Corporation was the company that initially used it to arrange its departments. This approach facilitates the simple identification and removal of non-conformances. Step-by-step use of the 5S approach is required to get the intended result. To get the most out of this cycle, which is ongoing, it should be maintained. The English translations of the Japanese terms and their definitions are as follows:

i. Seiri / Sort / Organize

This is the initial phase in which materials, tools, instructions, equipment, components, and so on are sorted and the items that are not necessary (for example, those that are faulty, obsolete, duplicate, or unrelated to the operation) are separated from the important goods. A red tag can be used to identify unknown things. This can assist to free up space in the office and improve the process's orderliness following the sorting stage. The individuals who work there are the best judges of the item's usefulness. After sorting, the item might be discarded, recycled, stored, or moved to another location. Sorting can help limit inventory waste.

This is analogous to GMP⁷ requirement of removing faulty, out of order and broken equipment from the premises. Also, sorting in a GMP setting might also include separating permitted material from under test material, cleaning equipment from dirty equipment, and separating acceptable tablets from defective tablets with flaws, among other things.

ii. Seiton / Set in order/ Orderliness

The stage of "set in order" involves arranging goods in convenient locations so that they may be easily accessed when needed. Labelling is done, materials are arranged by grouping like items together, and unnecessary ones are thrown away. Items are arranged in the most apparent spot based on how frequently they are used. It is best to adopt the most logical layout possible to make it simple for others to determine. This minimizes motion waste, inventory, and time.

According to GMP guidelines, every item must have an appropriate label and be positioned in the correct locations.

iii. Seiso / Shine / Cleanliness

By removing stains and dust, the materials are restored to almost their original state. It's important to identify who is in charge of cleaning and to designate specific locations for any cleaning supplies so that they are simple to find. Routine cleaning should involve dusting, sweeping, wiping, mopping, rearranging equipment, and other tasks. The Shine stage also includes routine equipment maintenance. All of these may contribute to the early identification of flaws and the avoidance of unexpected equipment failure, which may reduce flaws and save time. Additionally, a clean environment gives customers a good image, which is beneficial from a commercial standpoint.

As per GMP, cleaning holds prime importance. Cleaning is not done only for aesthetic appearance but most importantly to avoid contamination, cross-contamination, and mix-up on shop floor. As per GMP, Cleaning validation is must.

iv. Seiketsu / Standardize / Systematize

Standards are written procedures for arranging the workspace in a uniform manner so that it may be performed time and time again and eventually become second nature to the staff. Defect, motion, and waiting time may all be decreased when everything is provided on time and in the proper location. In order to ensure that the items are always returned to the same location after being removed, documented references must be retained. Standards should be ingrained in the routine and might take the form of lists, labels, checklists, charts, directions, timetables, etc.

⁷ Good Manufacturing Practices or GMP is a system that consists of processes, procedures and documentation that ensures manufacturing products, such as food, cosmetics, and pharmaceutical goods, are consistently produced and controlled according to set quality standards. (Tarlengco, 2023)

As part of GMP, labels, checklists, SOP's⁸ are desired so that they can perfectly specify the status and exact place of anything and everything.

v. Shitsuke / Sustain / Maintain

The most significant and challenging aspect of the 5S is this. Upholding and reviewing the established standards are essential to prevent the company from reverting to its previous working practices, as doing so would render the entire 5S process useless. The only way sustain can benefit the organization is if it becomes ingrained in the work culture. Keeping the workplace tidy should be a responsibility that everyone takes on via training. Conducting routine audits is essential for maintaining system integrity. To keep 5S going, commitment needs to be kept up.

As a part of GMP also, it is highly expected that all the procedures, checklists, guidelines established in a plant are regularly respected with utmost precision and dedication.

In addition to the previously mentioned 5S program, several companies have included "Safety" as a "Sixth S." The purpose of this step is to provide a risk-free and secure working environment. To ensure the safety of the staff and the merchandise, a secure atmosphere is established. At workstations, ergonomics play a significant role. It guarantees the workers' comfort while they carry out their duties. Additional safety measures include labelling combustible chemicals, designating assembly zones, labelling pedestrian and forklift paths in the warehouse, and using specialized protection gear for certain regions.

5S methodology has several benefits when implemented properly. Few of them are as follows:

- Defects rate decreases
- Workplace is safe.
- Production rise
- Improved resource utilization
- Decreased equipment downtime
- Reduced rubbish
- higher quality
- increased availability of equipment
- lower cost
- Improved workplace morale
- Enhancement in work environment
- improved representation of the company to stakeholders, suppliers, and customers
- potential for continuous improvement
- Increased profit

⁸ SOP (Standard Operating Procedure) is a set of step-by-step instructions compiled by an organization to help workers carry out routine operations. SOP aims to achieve efficiency, quality output, and uniformity of performance, while reducing miscommunication and failure to comply with industry regulations.

Poka-yoke translates as “prevention of carelessness”.

Poka-yoke is one of several Lean manufacturing technologies made to assist businesses in cutting waste, streamlining workflows, and boosting productivity. Poka-yoke specifically aims to avoid and eliminate mistakes in order to achieve zero faults.

Often referred to as “error-proofing” or “mistake-proofing,” the idea of poka-yoke was developed in the 1960s by Shigeo Shingo, a Japanese industrial engineer whose production innovations are still important in Lean and Six Sigma methodologies today (Lucidchart).

There are several advantages to adopting poka-yoke when this approach is applied. Your company will gain from implementing poka-yoke in several ways:

- By preventing errors (control) and avoiding them (warning), you may train staff members for less money and time.
- Less mistakes translate into increased worker and customer safety.
- Because the system is error-proof, less time and money are lost on quality assurance and inspection.
- Workers embrace a culture of ongoing development as a way of life.
- Defects that are zero, or as near to zero as feasible, cut expenses and waste.
- Stakeholder confidence and consumer satisfaction rise with higher-quality products.

By preventing or significantly reducing mistakes, poka-yoke increases stakeholder, management, and employee confidence. Gaining confidence from doing tasks correctly the first time may lead to better goods, happier customers, stronger brand loyalty, and more profitability.

How to implement poka-yoke

Actualizing poka-yoke ought to be simple, cheap, and adjusted with current forms. You ought to see prompt benefits and quantifiable changes in quality and generation. You'll be able execute poka-yoke by utilizing the steps portrayed underneath.

Step 1: Distinguish the issue.

Keep in mind that people make botches. One or two botches are to be anticipated. An arrangement or pattern of botches shows that there's an issue that should be tended to. That problem may be with the employee or with a blemish (imperfection) in a machine.

You may get to watch the method to identify where the issue is happening. Enrol the assistance of others to decide whether the blunder is human or mechanical. Consider employing a flowchart to imagine your current prepare and plan long-standing time state you need to see because it is outlined within the picture underneath taken from Lucidchart website.

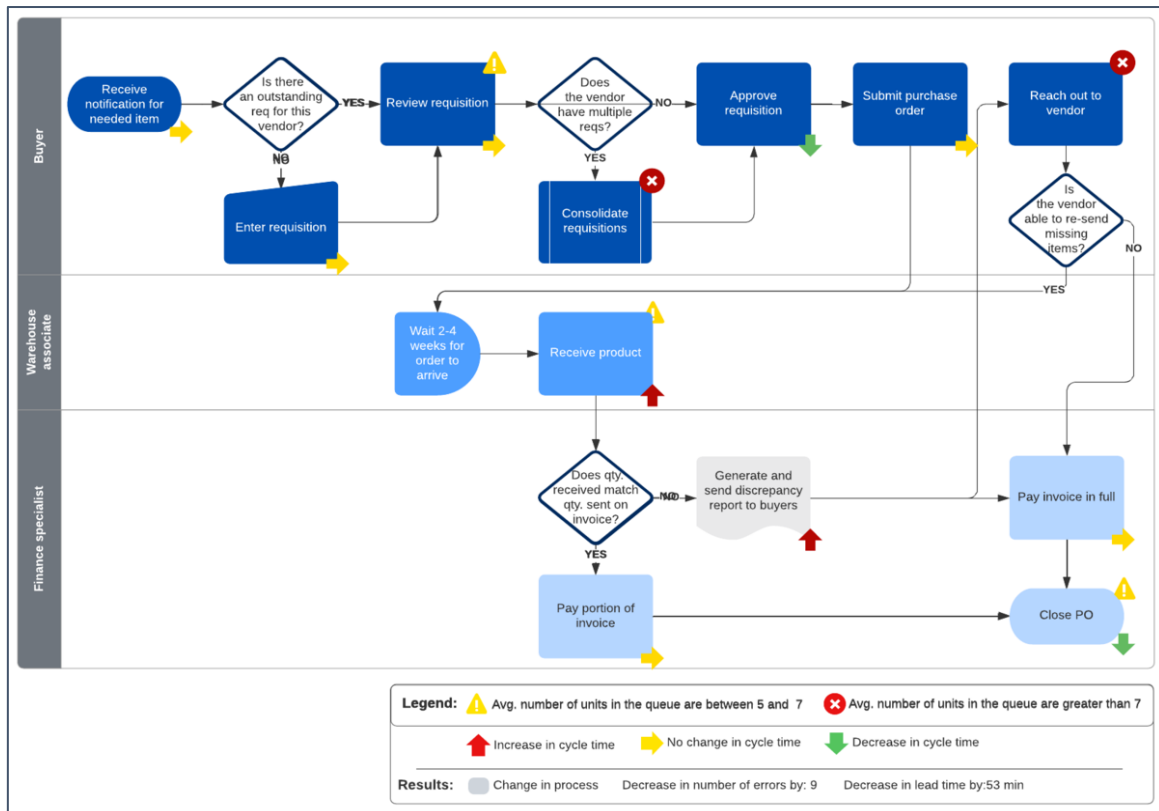


Figure 40: Current vs. future state flowchart example.

Step 2: Find the root cause.

After you distinguish the issue, decide what is the foremost likely cause of that issue. You'll need to consider utilizing the 5 Whys, another quality control procedure created in Japan, to assist you find the root cause. By inquiring and replying five “why” questions, you may burrow down to discover the root cause of the issue.

Step 3: Determine which type of poka-yoke to use.

On the off chance that you'll effortlessly anticipate botches from happening, install a control poka-yoke that avoids the method from proceeding until a crucial step is completed. For illustration, the shape of a component guarantees that it can as it were be embedded within the legitimate way. In case you can't anticipate a mistake, install a caution poka-yoke that alarms the administrator that consideration is required some time recently the method can proceed. These warnings can incorporate colours, flashing lights, buzzers, or any sort of cautions that tell the worker that something should happen sometime recently the method proceeds.

Step 4: Determine the most appropriate poka-yoke method to use.

There are three different methods of poka-yoke one can choose from.

Contact: This strategy employments shape, estimate, or other physical qualities to distinguish mistakes. For instance, you can't embed a square peg into a circular gap.

Constant number: With this strategy, blunders are activated on the off chance that a particular number of activities are not made. The administrator is cautioned on the off chance that the off-base number of moves are made.

Sequence: This method guarantees that the right arrangement of occasions is taken after some time recently a handle can proceed. For illustration, a checklist that must be completed sometime recently generation can move to another step.

Step 5: Test your poka-yoke system to see if it works.

Sometime recently you'll be able to fully actualize a poka-yoke, you would like to be beyond any doubt that it will work. Test it to see on the off chance that the error is anticipated and to create beyond any doubt that the settle does not moderate down the method.

Step 6: Prepare employees.

Indeed, the best poka-yoke can't be effectively executed until representatives are prepared how to do it. Preparing makes a difference with representative selection of the modern prepare, particularly in the event that they can see that the settle makes their work simpler to do. Include your modern poka-yoke to your standard operating procedures (SOP) guide to assist workers get it what is expected of them.

Step 7: Review performance and measure success

Watch the operation once more and degree victory. Start trying to find other mistakes which will be blocking your generation and search for ways to ceaselessly make strides.

Having analysed these 2 tools of lean methodology, I think it shall drastically change positively the productivity of Autorobot in production. But, at the same time, it will be also difficult to implement a new methodology due to the path dependencies of the organization. I didn't show all because lean management contains on average 20 tools: Just-In-Time, Gemba, continuous flow, Autonomation or jidoka, Andon, 5 whys, Hoshin Kanri, kanban, Kaizen(chantier) – Kaikaku, etc.

7. Conclusions

Reached the end of this thesis, we end up with many conclusions. Autorobot Strefa is a leading company in Europe by producing variety of sub-components and sub-systems which are useful in the automotive and aircraft sectors, carries also other activities such as Robot programming, Final assembly at Customer's plant, Commissioning, Customer's staff training, assistance to production ramp-up, Assistance after sale. With a strong root in Poland, this firm also faces several internal organizational concerns like coordination between operators and lack of continuous communications among departments which lead to some delays of production. Working with the Giant Volkswagen will bring back more expertise, will increase project portfolio, more experience in boat freight and the use of new technologies. Furthermore, "producing in total 60 fixtures (30 for 8s cars and other 30 for 5s) is not easy, and with the short time in our possession. But the company possess higher skilled labours in different departments, so we are ready for that and mainly to finish on time" the project manager said.

Having spent 2 months and the half of internship there, I brought some of my knowledge of production helping to underline some issues divided in 4 main categories: cost issues, time issues, production issues and finally the analysis of some unforeseen events. I also provided a large set of solutions for the first 3 categories because I think it is the part where the company can react and internally solve the problems for example to hire more skilled labour for some specific tasks, to sign long-term contract with sub-contractors, avoid accidents in the manufacturing plant, to use Internet of things, data science and machine learning, Artificial intelligence to well manage the movement of the grippers. Instead, for the last category, it is considered as an external environment which is totally beyond the Autorobot's capabilities that is why I didn't provide some idea of solutions.

Above all, more sophisticated solutions can be undertaken within the company production area, the 5s lean management or poka-yoke being both tools of lean production management. But my question is due to the lock-in effect and path dependency, will it be possible for Autorobot to implement these tools? Does the company have the mindset and capability to modify anything?

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