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BUS MANUFACTURING: LINE BALANCING AND OPTIMIZATION

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BUS MANUFACTURING: LINE BALANCING AND OPTIMIZATION

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ISEP – School of Engineering, Polytechnic of Porto
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KEYWORDS

Bus manufacturing, Production lines, Line balancing, Assembly lines optimization

ABSTRACT

Bus production is a singular industry due to the product variety and customization usually required by clients. Buses are usually conceived based in a chassis where a frame is built, following the safety rules adopted by the sector. The external view can be similar, but some construction aspects and internal view are usually defined by the client, leading to a high customization. Thus, the bus can be manufactured in a common line, but the different configurations usually lead to a complex assembling process that needs to be carefully thought. Moreover, this kind of industry is permanently subjected to huge competitiveness and sustainable evaluation, which implies a rigorous cost planning and production, avoiding budget problems.

This work was carried out in a bus manufacturer located in the Porto surroundings, which produces a large number of bus types for airports, tourism, urban or scholar purposes. The factory has three different production lines, being each one allocated to a different kind of bus manufactured. The lines needed an optimization and balancing improvement, thus, this study intended to make a contribution to this purpose.

PALAVRAS CHAVE

Produção de autocarros, Linhas de produção, Balanceamento de linhas, Otimização de linhas de montagem.

RESUMO

A produção de autocarros é um negócio singular devido à variedade de produtos e personalização requerida pelos clientes. Os autocarros são normalmente concebidos com base num chassis, onde é construída a estrutura, seguindo as normas de segurança usuais no sector. A vista exterior dos autocarros pode ser similar, mas existem alguns aspectos construtivos e o interior, que são normalmente definidos pelo cliente, conduzindo a uma elevada personalização do produto. Assim, os autocarros podem ser fabricados numa mesma linha, mas com configurações diferentes, levando normalmente a um complexo processo de montagem que necessita ser convenientemente pensado. Acresce que este tipo de indústria está permanentemente sujeito a uma elevada competitividade e avaliação da sua sustentabilidade, evitando problemas relacionados com o não cumprimento do orçamento inicial.

Este trabalho foi desenvolvido numa empresa construtora de autocarros sediada nos arredores do Porto, a qual produz um diversificado leque de tipos de autocarros para aeroportos, turismo, urbanos ou para transporte escolar. A fábrica possui três linhas diferentes de produção, estando cada uma alocada a um tipo diferente de autocarro fabricado. As linhas de produção necessitavam de uma otimização e balanceamento e este estudo pretendeu dar uma contribuição nesse sentido.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

CAD	Computer Aided Design
HDV	Heavy Duty Vehicles/Engines
LM	Lean Manufacturing
LB	Line Balancing
LDV	Light Duty Vehicles
MMAL	Mixed Model Assembly Lines
PDCA	Plan - Do - Check - Act
TPS	Toyota Production System
VSM	Value Stream Mapping

FIGURES INDEX

FIGURE 1 BUSES EVOLUTION....29
FIGURE 2 MINIBUS....31
FIGURE 3 TOURISM BUS....32
FIGURE 4 COBUS....33
FIGURE 5 URBAN BUS....33
FIGURE 6 ARTICULATED BUS....34
FIGURE 7 DOUBLE DECKER BUS....35
FIGURE 8 EXAMPLE OF SERIAL LINE....42
FIGURE 9 PDCA CYCLE....43
FIGURE 10 LEAN HOUSE....45
FIGURE 11 LAYOUT OF THE LINE UNDER STUDY....52
FIGURE 12 PRODUCTION FLOW CHART OF A BUS MANUFACTURING....54
FIGURE 13 TOTAL NUMBER OF WORKSTATIONS IN FINISH SECTION....54
FIGURE 14 WORKSTATION G05.01.1....55
FIGURE 15 WORKSTATION G05.02.1....55
FIGURE 16 BALANCING OF LINES WORKED IN DETAIL....56
FIGURE 17 YAMAZUMI CHART....58
FIGURE 18 3D VIEW OF A BUS....64
FIGURE 19 STRUCTURE SECTIONS....64
FIGURE 20 SKELETON OF A BUS AND CHASSIS....65
FIGURE 21 MOUNTING OF FRAME INTO CHASSIS....65
FIGURE 22 CABLES INSTALLATIONS....66
FIGURE 23 FIXING OF MUDGUARDS....67
FIGURE 24 FIXING OF LATERAL PANELS ON BOTH SIDES....67
FIGURE 25 FIXING OF FRONT AND REAR FIBRE PANELS....68
FIGURE 26 CUTTING, ADJUSTING AND ASSEMBLING THE LUGGAGE DOORS IN THE BUSES....69
FIGURE 27 GRACO OLD PUMP....75
FIGURE 28 NEW ELECTRIC PUMP....75

TABLES INDEX

TABLE 1 - SPECIFICATION 31
TABLE 2 - SPECIFICATION 32
TABLE 3 - SPECIFICATION 34
TABLE 4 - SPECIFICATION 34
TABLE 5 - SPECIFICATION 35
TABLE 6 - SPECIFICATION 36
TABLE 7 - INTERNAL DIVISIONS OF MANUFACTURING UNITS 53
TABLE 8 – WORKSTATION G01.03.1 69
TABLE 9 – WORKSTATION G01.04.1 70
TABLE 10 – WORKSTATION G01.05.1 72
TABLE 11 – WORKSTATION G05.01.1 72
TABLE 12 – WORKSTATION G05.03.1 73
TABLE 13 – WORKSTATION G05.05.1 74
TABLE 14 – COMPARISON OF SAP QUANTITY AND ACTUAL QUANTITY 74
TABLE 15 – COMPARISON OF PUMPS 76
TABLE 16 – MONETARY VALUE 76

INDEX

1 INTRODUCTION 23
1.1 OVERVIEW 23
1.1.1 CONTEXTUALIZATION 23
1.2 MAIN GOALS 23
1.3 METHODOLOGY 24
1.4 STRUCTURE OF THE THESIS 25
1.5 WELCOMING COMPANY 26
2 LITERATURE REVIEW 29
2.1 BUSES 29
2.1.1 BUS HISTORY AND EVOLUTION 29
2.1.2 BUS TYPES 30
2.1.3 BUS MARKET 36
2.1.4 BUS MANUFACTURING SYSTEMS 38
2.2 LINE BALANCING 39
2.2.1 HOW TO BALANCE A LINE 39
2.2.2 LINE BALANCING STRATEGIES 42
2.2.3 LINE BALANCING RECENT MODELS 44
2.3 PRODUCTION OPTIMIZATION 44
2.3.1 LEAN PRINCIPLES 44
2.3.2 WASTES 46
2.3.3 YAMAZUMI CHARTS 47
3 DEVELOPMENT 51
3.1 COMPANY PRESENTATION 51
3.2 INITIAL SITUATION 52
3.3 BRAINSTORMING 56
3.4 SELECTING THE BEST IDEAS 56
3.5 IMPLEMENTING IDEAS 57
3.6 MEASURING THE CORRESPONDING IMPACT 58
4 GLUE OPTIMIZATION 63
4.1 INTRODUCTION 63
4.2 SIKAFLEX 263 63
4.3 TYPES OF PACKAGES 63
4.4 SKELETON STRUCTURE OF A BUS 63
4.5 PRE-STRUCTURE 64
4.6 THE STRUCTURE SECTIONS 69
4.7 FINISH SECTION 72
4.8 ACTUAL QUANTITY OF SIKA FLEX -263 600 ML PACKS IN EACH WORKSTATION. 74
4.9 IMPLEMENTATION OF GUNS IN THE STRUCTURE SECTION 74
4.10 COMMON IMPLEMENTATION OF PUMPS 75

4.11 FINAL PROPOSAL 76
5 CONCLUSIONS 81
REFERENCES.. 86

INTRODUCTION

1.1Contextualization

1.2 Main goals

1.3 Methodology

1.4 Structure of the thesis

1.5 Welcoming company

1 Introduction

1.1 Overview

1.1.1 Contextualization

The buses' evolution in modern society brought the necessity of different city buses types: intercity, tour, airport or school coaches. Nowadays, it is possible to observe to the development of modern buses, more suitable for the upcoming needs.

Buses were initially configured with an engine in the front and an ingress door at the rear. Following the development of ground transportation, the buses became more comfortable and spacious, gaining market share. Buses were fitted with technology appropriated to the local climate or passengers' needs such as air conditioning, multimedia and bathrooms. The buses types and features have grown according to local demands. Therefore, the development of buses brings the rivalry in the ground transportation.

Production is a method employed to transform tangible and non-tangible inputs (ideas, information, knowledge) into goods or services. Manufacturing processes are used in this process to create a final product that is suitable for use or has exchange value. It is expected that the growth in the ground transportation remains stable in the next decades. The major components manufacturers, which are essential for the automakers, have improved their production systems in order to keep their profitability and market share.

The term "organization culture" means sharing of information, beliefs and people's behaviour inside the company or organization. The strong family and supportive culture of employees in the organization, can be translated into a standard of practices and values that does not prevent individuality.

1.2 Main goals

The main objectives of this work were to dissect all tasks carried out on a bus assembly line, balancing operations by the different assembly workstations along the line and improve the productivity, minimizing the production stopovers, overtimes, excessive or misplaced manpower and high tier inventory, promoting cost savings, because all these production problems contribute to a poor line balancing process.

The company is determined to increase the production output rate by resolving the troubles along the different workstations. However, it is necessary to eliminate misplacing manpower problems in the first three workstations of the target line, leading to a better output flow in the finishing workstation.

Line balancing is challenging when we are focused in the deterministic calculation, making a considerable attempt to improve and bringing up to the production lines to have a closer overview of the industry with a more reliable response.

Time management is the most significant way in this new environment because cycle time studies work better in manufacturing or in the operating environment. Reduction of the cycle time can translate into better competitiveness and higher customer satisfaction. A prompt response can build new products and can improve the penetration of new ideas and bring new customers.

The problem comes when a variety of buses or trucks with shapes and sizes have to be produced, and the problem occurrence may differ in many ways, which can be technical or non-technical. In order to analyse the problem in the technical field, CaetanoBus suffers from problems in the line balancing of the first two workstations in the assembly line, such as:

- Lacks real cycle-times;
- Unbalanced station workloads;
- Misplacing of workers.

1.3 Methodology

The methodology is the way to approach and find the solution amongst the various ideas, as it can be seen below.

Initial theoretical approach
A deep research about the theoretical issues related to the subject of this work was done.

Shop floor recognition and problems identification
One of the first steps was to know the company shop floor, enabling to identify the different workstations, tasks and problems that were necessary to overcome. Two main problems were identified: (a) optimization of glue consumption in the workstations and (b) line balancing of these workstations.

Brainstorming
In a first stage, an overview of the company was carried out in order to identify the problems and get ideas, which were discussed later with the remaining team in order to establish their suitability and implementation priorities.

Selection of ideas
The concept of picking out ideas can contribute to getting a new pathway to approach and to build up the system in the future. The selection of ideas in the line balancing process may depend on different organisational points of view.

Ideas put into the field
In an organization or company, group discussion is the most successful step to implement the agreed ideas. In this work, regarding the different aspects detected as subject for improvement, such as the production line, some tools like *Heijunka* and *Yamazumi* charts were thought as useful, leading to overcome the line balancing problems and improve the results. The expectations can be profitable or non-profitable to the organization. It is necessary that the company or organization is aware of the advantages and drawbacks that each idea can bring, and to assume or not assume the corresponding risks.

Implementing the ideas
Measurements of the cycle time and takt-time were done, giving rise to data used to think about the right way to improve the production. Thus, *Yamazumi* charts were used in order to put the ideas into the field and test the solutions applied to the problems, getting the right feedback about their suitability to solve the problems.

Measuring the impact of the ideas implementation
Assessing the impact of the ideas is a vital factor in the organization development. The structure of the work intends to put the emphasis on fieldwork were key factors.

Writing the thesis
The thesis writing process will enable to describe in an official document the line balancing work carried out in this thesis.

1.4 Structure of the thesis

The document is divided into four main chapters: Introduction, Literature review, Development and Conclusions.

The Introduction intends to make the reader familiar with the main issue, providing an overview about the work, its main goals, the methodology used and the structure of this thesis.

The theoretical overview of this paper (Literature review) aims to explain the bus types and corresponding manufacturing process, as well as some theories about line balancing. A summary of the literature was carried out, allowing a better approach of the reader to the practical work done. Some ideas about Lean Manufacturing and optimization of the assembly lines were also considered, based on the literature. Thus, it is intended provide to the reader the theoretical fundaments about the issues related to the next chapter, the Development.

In the Development, a brief description is made regarding the production line, the main concerns are identified, some improvement suggestions are pointed out and the way to implement them is also referred based on data previously collected.

The Conclusions intend to underline the main goals achieved by this work.

1.5 Welcoming company

This thesis was held in CaetanoBus, located in Vila Nova de Gaia, Porto, Portugal. CaetanoBus is the leader company in the production of heavy vehicles in Portugal, being well infrastructured with two noteworthy plants and a large number of workers.

This company usually grants for internships in order to collaborate with the Universities and bring new ideas to the company, developing focused works in restricted fields, leading to improvements difficult to carry out by internal collaborators due to the limited time available and their focus in the current matters.

LITERATURE REVIEW

2.1 Buses

2.1.1 Main goals

2.1.2 Methodology

2.1.3 Structure of the thesis

2.1.4 Welcoming company

2 Literature review

2.1 Buses

2.1.1 Bus history and evolution

Humans’ first means of ground transportation was walking. Early, humans felt the need to go from place to place, as well as carry goods produced in a location, but needed in other one. In order to facilitate the movement of people between different locations and properly carry animals and goods, more and more sophisticated networks based on ground transportation have been constructed in order to allow the utilization of different types of vehicles (wagons, cars, trains, and so on). The first concepts of public transportation were established based on humans or animal traction, as illustrated in Figure 1 (left hand). Nowadays, ground transportation comprises many kinds of vehicles, from the individual to the collective ones. This dissertation will be focused in modern heavy-duty vehicles devoted to the transportation of people, as also depicted in Figure 1 (right hand). Thus, there was a huge evolution, as described below.

Figure 1 - Buses evolution

Ground transportation evolution

In the previous era, the first mode of land transport invented in Japan in 1869 was called “Rickshaws“, which is basically a wooden vehicle powered by humans. Later on, this popular mode of transport migrated over the Asian countries like India, China and Nepal. As the time went by, and with the consequent technological development, the improvements in urban transportation increased day by day to fulfil the citizens’ needs. For example, regular steam ferry service began in New York City in the early 1810s and horse-drawn omnibuses stepping through city streets started in the late 1820s. The expansion of horse railways networks emerged by the mid-19th century and the electric streetcar became the dominant mass transit vehicle a half-century later [1]. In the 1920s, the public transportation started to decline due to the automobile ownership. In the 1960s, new policies were established by the U.S.A. The government, in order to reinvigorate the public transportation, implemented heavy and light train systems.

As the need of travel increased, the evolution took a step beyond in movement pattern to make the humanity run faster. Thus, the adaptation of human civilization to the new transportation systems was quickly accomplished, and the evolutions took over and transformed it into a modern society.

The transit expansion in the modern society led to innovation in the infrastructures design, facilitating the interconnection between different modes of transportation (public transportation centres). The evolution took place and the mobility became easier, giving a new impetus to public transport and offering new opportunities for the travellers to make new choices, using public transportation instead of its own vehicle. The challenges in mobility remain valid again, now due to sustainability reasons.

The evolution around public transportation did not stop to be challenged and the competitiveness amongst market players remains very strong. Each manufacturer tries to fulfil all costumers' expectations and anticipate the market trends. Electric heavy-duty vehicles and customization are the current key factors to keep a player in this competitive global market.

2.1.2 Bus types

Buses are large wheeled vehicles that are designed to carry passengers, generally on a fixed route. In the present time and in the future, world's automobile industries want to be more competitive and they are divided into various classes and diverse patterns. Bus types can be separated according to their capacity and standard size. In this regard, the bus lines are a key factor to contribute the required targets [2].

According to the transport authority guidelines, buses are to be designed, and manufactured to their respective belonging sizes and have their ability to carry passengers in their specific manner. The passenger limits for buses are around 80 passengers for a regular bus and 120 passengers for an articulated bus [2].

The general Classification of the bus sizes varies in their models: 41, 39 or 40 feet are used for the public buses, and the vehicles have a capacity of 42 passengers. On the other hand, wise 30-foot public coaches bear the capacity of 30 passengers, and 35-foot urban coaches can carry 35 passengers [3].

Buses are designed and modified to the present and the future environmental surroundings. Companies, in order to reach the desired level of competitiveness, have their own means of manufacturing the buses to the customer requirements, and work under some variety of bus models in the present and in the future, such as [3]:

- Minibus;
- Tourism;
- Airport (shuttle bus);
- Urban;
- Articulated;
- Double-decker.

Mini bus

Mini buses are smaller transport vehicles that can be fabricated with various wheel bases and equipped with different body structures, and they significantly differ from regular buses in all the ways. They can hardly bear the limited capacity of 33 passengers in maximum. Hence, the use of these buses can be seen in regular public roads, mostly used in short range trips and in remote areas to carry of passengers [3].

Figure 2 - Minibus

Table 1 - Specification

Bus body	CAETEANO
Length	8430mm
Width	2475mm
Height	3072mm
Wheelbase	4750mm
Seated	Up to 33

Tourism

This type of bus is bigger in size and it is highly configurable, more than any another bus, and it is especially used for long trips. The coaches are developed for tourism, InterCity, and as regular school buses (yellow bus) [3]. The standard specification can be seen in Table 2.

Figure 3 - Tourism bus

Table 2 - Specification

Bus body	CAETEANO
Length	13100 mm
Width	2550 mm
Height	3700 mm
Wheelbase	6570 mm
Seated without WC	55 seats +driver + tour guide
Seated with WC	53 seats + driver + tour guide
Motorisation	Euro 6

Airport (shuttle bus)

Shuttle buses are generally well known, and they are most often called as “Cobus“, which is a German manufacturer bus company. These types of buses are fancier looking coaches with a limited number of seats. The regularity of these buses is seen in airports in order to pick up the passengers and drop them in the airport exit terminals. The Cobus buses are highly demanded and available in numerous models in VIP and Executive versions in the airport bus markets [3].

Figure 4 Cobus

Urban bus

Coaches are simply called as regular buses or urban buses. They are most suitable for the narrow roads inside the cities and even sometimes in rural areas. Therefore, these buses have their standard size and design remodelled, and they are eco-friendlier with less fuel consumption, which makes them more successful in a daily basis [3]. The specification can be seen in Table 3.

Figure 5 Urban bus

Table 3 - Specification

Bus body	CAETEANO
Length	12730 mm
Width	2500 mm
Height	3145 mm
Wheelbase	6565 mm
Seated	41
Standing	47
Motorisation	Euro 4

Articulated bus

Extra-long (59 feet) buses, which are typically urban buses, are more unusual, In these buses, the rear body is connected to main body of a bus by a joint mechanism, enabling a higher capacity of carrying passengers [3]. The specification of these buses can be seen in Table 4.

Figure 6 Articulated bus

Table 4 - Specification

Bus body	CAETEANO
Length	18000 mm
Width	2500 mm
Height	3115 mm(AC),3262 mm (Engine Bonnet)
Wheelbase	5190 mm 6755 mm
Seated	44+1 CR (wheel Chair)
Standing	100

Double decker bus

This modern bus makes a huge difference in the entire bus market and this innovative vehicle is usually associated with luxury tourism. However, these buses are heavier and bigger in their size, with different models and capacity. The word "double decker" are associated to the combination of two chassis together, which are connected by stairways. These unique coaches are manufactured and equipped to provide more comfort to the passengers [3]. The specifications of this modern bus are drawn in Table 5 and Table 6.

Figure 7 Double decker bus

Table 5 - Specification

Bus body	CAETEANO
Length	13250 mm
Width	2530 mm
Height	4050 mm
Wheelbase	6015 mm
Seated	74 seats (wheel Chair)
Seated	76 seats (without wheel chair)
Motorisation	Euro 6

Table 6 - Specification

Bus body	CAETEANO
Length	13250 mm
Width	2530 mm
Height	4200 mm
Wheelbase	7058 mm
Seated	77 seats (wheel Chair)
Seated	79 seats (without wheel chair)
Motorisation	Euro 6

2.1.3 Bus market

According to Cromer [4], buses are self-propelled vehicles that are planned to transport passengers. In the year 1662 the first public line bus was set up.

Globally, automotive industries have gone through a long way in the human civilization.

The growth of bus-manufacturing industry has been enormous in the last decades and, currently, buses are fabricated in a number of sizes and in forms, with a large amount of research being made regarding the emission standards and environmental considerations, such that these vehicles comply with the current regulations.

According to the automotive emission standards, vehicles which are manufactured under the guidelines of the emission standards should be eco-friendly. This also applies to the fabrication of engines in automotive industries, in which the manufacturers are also more concerned about the environmental surroundings [5].

Another sustainable approach by the manufacturers and organizations is to make increase fuel efficiency in the present situation, to make sure that market value of their buses can grow one step higher [5].

There is a limitation in various countries, especially in India, about the release of new vehicles and engines, which should be tested individually as per the law of environment protection Act announced in 1986 [6].

It should be noted that in each country the emission standard policy is strictly followed by their laws. For example, India has their own way to approach their emission standard policy for light-duty vehicles (LDV), heavy-duty vehicles/engines (HDV), two wheelers, three wheelers and even for agricultural land vehicles (tractors) [6].

The European Union (EU) make sure its own set of emissions standards that all new vehicles must meet. Nowadays, standards are set for all road vehicles, trains, barges and 'nonroad mobile machinery', such as tractors used in agricultural activities. EU Regulation No 443/2009 establishes an average CO_2 emissions target for new passenger cars of 130 g/km. The target was gradually phased in between 2012 and 2015. A target of 95 g/km will apply from 2021. For light commercial vehicle, an emissions target of 175 g/km applies from 2017, and 147 g/km from 2020, a reduction of 16%. The EU announced Euro 4 effective January 1, 2008, Euro 5 effective January 1, 2010 and Euro 6 effective January 1, 2014. These dates had been deferred for two years to give oil refineries the opportunity to modernize their plants and give the opportunity to the engine makers develop new technologies able to correspond to the standards requirements [6].

Developing countries like India, which has taken advantage of several technological improvements, use Bharat stage IV, which is equivalent to Euro 4, as well as China, Brazil, South Africa and Thailand [6].

Today’s economy is dramatically changing, triggered by ongoing developments in emerging markets and by other aspects, as a response from the companies resulting from the fear of losing competitiveness in the market and also because of the strong competitive rivalry in the global market. Thus, strong synergies have been created between developers, sharing some know-how, but also preserving other knowledges, promoting together the compliance with the rules established by the governments in order to reduce the harm to the environment [7].

Thus, the discussion about the “organization culture” in the beginning of this work shows the important role of this issue in the market, by keeping a friendly environment inside the organisation and to the outside circles (potential clients). To become competitive a bus manufacturer should be strong in the contact with the buyers, suppliers and take into account and update its strategy as a function of the expected upcoming demands [7].

The threats and competitors can be various, and the bus companies should pay much attention to environmental issues, and implement new strategies accordingly, to make their buses an attractive option [7]. Most likely, the improvement of the demand rate should continue, and all these mentioned issues are important to assure the survival of the organization, by providing products that have values and quality for the client.

Companies must monitorize the market permanently, trying to predict the new trends and anticipate the customers future requirements, sometimes inducing in the market the desire of the customer through bold marketing techniques. Only with this bold form to be on the market the companies survive the global competitiveness that is installed [7].

It is expected that in the next decades, India and China present the most accentuated growths in terms of bus market and related business sectors. Moreover, bus markets are highly demanding and competitive in various countries in different aspects, such as in the emission standards, specificities for airport shuttles, among others.

Nowadays, the companies are compelled to present new products, facing the customer requirements as a challenge and trying to induce new performances in the bus market, persuading the transporting companies to acquire new vehicles' fleets based on adeed confort, lower engine consumption, greater maneuverability, and so on. The constant market monitoring allows for a better knowledge of the further needs and trends, corresponding more quickly to the customers' requirements. It is important to the companies keep an 'open-mind' state in order to react easily to the market trends and changes. However, this depends greatly on the management flexibility and agility.

2.1.4 Bus manufacturing systems

Massive production

The competitiveness in the massive production that is inherent to the automotive industry has shown a dynamic behaviour. Performing the production or a flow of productions of various products in different assembly lines leads to huge profits. In the past, over the last decades, various production strategies, such as small-scale production, the mass production of Henry ford, or lean production, have been used [8]. Mass production can rely on two types of process, based either on machine power or man power.

In a general assembly line based on mass production or large scale manufacturing, the production of products is repeated over and over in order to produce the product continuously [9]. With this type of production, the clients' demands cannot be met since mass production does not accommodate these modifications.

On the other hand, the modification of the production plan and of the assembly line after the input from the customer demands can take place in unitary productions. Mass productions are generally defined batch productions of the same product. It can also be referred as lot production [9].

Before the mass productions starts, detailed information about the products should be given for the production line to proceed in conformity, and this also helps in tracing the products during the production process [9].

Customized production

Customized products and services are innovative through their uniqueness. They often carry greater value than the mass productions, and are an important means to reach the costumers' expectations.

The customized production of a bus model brings additional fabrication difficulties, and modifications may be necessary design, materials, or construction aspects. These products have an added value to their owners.

The customized production can be defined as flexible production, in order to meet specific needs of costumers, enabling to increase the demand flow and the customer satisfaction [9]. Though, customized products are generally more expensive and take more time to produce, compared to mass production products.

As there is a high competitiveness and demand in the bus market, the main three pillars of customized production should be accounted for in the production lines [10]:

- Productivity;
- Quality;
- Flexibility.

Customized products are integrated with different components, materials and related with different outsourcing suppliers. This allows achieving improved products and helps in bringing new knowledge to the organization [9].

Belief, capability and truth worthy is more important in customized production. Thus, it can take more time to show results [9]. However, the market is yet permissible to keep some products as standards, remaing with minor alterations over time. The taxis in London are one of these examples. Each organization should look at the future following its own form and searching the best way to be positioned in the global competitive market. However, the internal organization should be designed under the main principles adopted by the company to face the market.

2.2 Line balancing

2.2.1 How to balance a line

Line balancing is a technique to level the workloads across all process in a cell and to minimize the imbalance between workers and workloads, in order to achieve the best results by removing the bottlenecks.

In the all industrial fields, the assembly line balancing structure depends on the type of assembly line:

- manual assembly;
- flexible assembly;
- semi-automated assembly;
- fixed assembly;
- mixed assembly lines.

Sometimes, the assembly line is interchanged according to the product size and batch size [11].

The implementation of assembly lines for new products into the job floor can be challenging. A manual assembly line can lead to many distractions in the production unit, and this type of manual line can succeed only by many years of practice. In some cases, the products can be fabricated in mixed model assembly lines (MMAL), although the word mixed can be referring to ability to assemble different products at a same time [11].

It is necessary to improve the MMAL methodology in all organizations, to bring a changeover in profits and to enable companies to be more competitive [12]. In fact, mixed assembly lines are similar to the customized production plants in which the lot differs in number of units to produce and time required for each unit produced,depending on the model to be manufactured [12].

When performing the line balancing, many times the major root cause problem can be workloads (bottleneck) by causing a pressure in the assembly line that leads to work delays, extra time and internal or external accidents [13]. In order to rectify and these situations, a solution is to use Yamazumi charts.

Basically, the demand is controlling the manufacture process, which depends on what is being done in each cell, requiring a permanent adjustment of each cell load as a function of the product, having proper procedures to establish the tasks to be done in each cell for each model to be assembled [14]. Line balancing works on some of the important terms, such as:

- Task performance;
- Tasks precedence;
- Task time;
- Cycle time;
- Productive time per hour;
- Number of workstations working;

- Minimum number of workstations = sum of all tasks/ takt time
- Actual number of workstations;
- Utilization = min no of workstations/actual no of stations

Regarding the line balancing, this description explains about the most relevant topics to the assembly lines such as tasks, cycle time, precedence, takt time and station time.

Tasks
The work carried out from job floor to the assembly line process in a respective time to perform a task without any external or internal disturbance [15].

Cycle time
The finishing of a product or process from top to bottom, i.e. the entire amount of time to fabricate a product, is generally addressed as the cycle time [15].
Precedence
The ordering of a task should be performed in a step to step process [15].

Takt time
The average start up time for a production process in a single unit or batch or workstation till the end up time is referred as the takt time. The assumption of takt time can be defined as the demand time kept for their product [16].

Station time
The processing of a task in a whole assembly line workstation is defined as the station time [15].

Setting up of lines and types of lines
The configuration of line must be pre-planned according to the material supply from job floor to the working lines. Ideally, this work deals with serial lines. Some examples of the line types are the following:

- Serial lines;
- U-shaped lines;
- Parallel stations;
- Parallel lines.

In general, all the automobile industries fabricate their products by adding operations in a sequential order, which means that serial lines are used [15]. A schematic example of this type of lines is shown in figure 8.

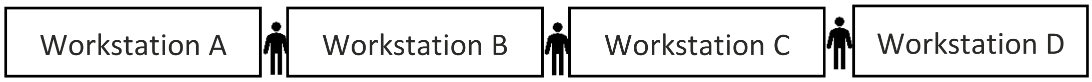

Figure 8 Example of serial line

2.2.2 Line balancing strategies

Line balancing strategies aim to make a production line feasible enough to take up external and internal irregularities. Strategy can be viewed as the planning of different methods to design the production, for a particular product to be constructed within a particular time frame.

Line balancing can be considered by hand solving methods using different approaches [17,18]. In order to achieve proper results, the planning is logically fed into data sheets to get the strategies more feasible and discussed with the team or organization, in order to carry out the planned optimization. The choice of a methodology to resolve this problem in a more efficient manner is highly important for the organization.

The building up of a strategic plan can bring an idea about threats, promises and engagements, and the flexibility of a line can be improved using this plan. Before implementing a new strategic plan in the organization forecasting should be taken into serious action [19].

It is necessary to perform the strategic plan in the company in order to check the upcoming threats. The adaptation of the strategic behaviour should be well thought in order to avoid internal threats. Actually, not all the strategic ideas can be successful though because the strategy moves and can also have both ways: raise or fall. This behaviour attracts the rivals' thoughts [19].

The best way of making a strong strategy plan can be addressed as "fire wall" to the organizations. After the strategic plan, the next step is to implement the tactics in which it makes a root way to the PDCA (Plan-Do-Check-Act) cycle that is a well-known methodology to implement continuous improvement (kaizen) [19]. The easier way to understand the PDCA cycle is to consider the traffic light signal seen in figure 9.

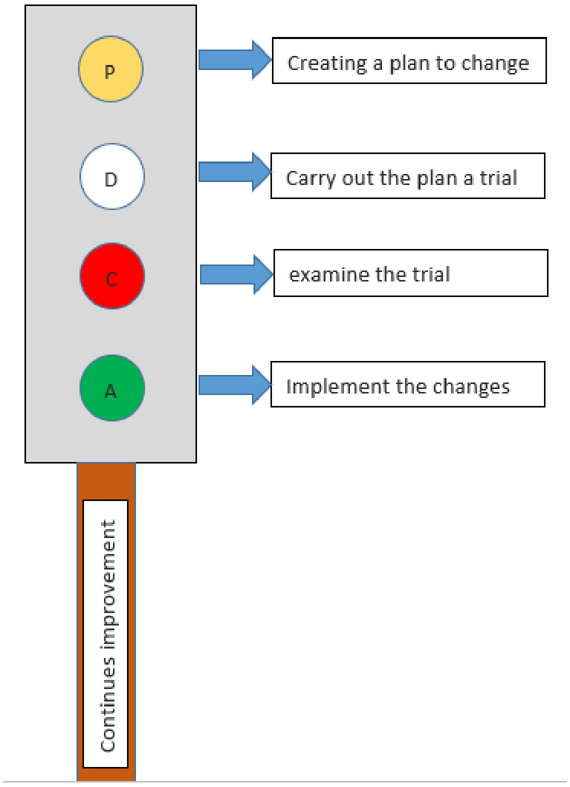

Figure 9 PDCA cycle

The continuous view of approaching this strategy is discussed in the upcoming further topic.

2.2.3 Line balancing recent models

From ancient times to the modern days, the concept of the line balancing model has significantly changed. The most important milestone in the line balancing model [18] is to ensure the correct flow in the assembly line and to identify the unnecessary waste. Equally, there is a certain path to follow to improve the current production in the Line Balancing methods, which can be innovative or can be a repeated methodology already used in the past.

In the automotive history, there are limitless implementations of new models, defined to improve the production processes in companies [20]. As mentioned earlier and depicted in figure 8, regarding the types of assembly lines considered in this literature review, a short overview is given about the topic.

Although the sequencing of operations in the designed workstations results in a realistic improvement in the process, line balancing can be redesigned by specific tools and concepts. In line balancing, each model has the capability to do its own task. Some balancing models are solved by hand, whilst others are solved by computers in order to achieve the best solution [21].

The acceptance of the modifications suggested by line balancing models can cause a huge change in the assembly line. Thus, by increasing the workloads in the line models, downplay can occur due to heavy task assignments. Moreover, it is necessary to ensure that equipment selection is the adequate to accomplish the line balancing goals [22]. The technique to achieve different model balancing process is to be well adapted to the serial lines [23]. The applied models can change according to the assembly line and to the company organization principles, and it is important to pick up the right model for balancing of a line at a given time.

2.3 Production optimization

2.3.1 Lean principles

Lean is a methodology that is used for many years, pristinely though Toyota or TPS (Toyota production system) [24]. Together with just in time production, these principles achieved many fabrication and process improvements in the most varied fields of industry.

Lean principles are used by small scale industries to large scale industries. Womack et al. (1992) first proposed the lean practice and, later, the Lean principles were used worldwide in process improvement, which enabled to increase the popularity of lean thinking [25]. In a simple term, the lean principles are the foundation of all existing lean house methods, presented in figure 10.

The application of lean still grows in various sectors in order to understand the values and the customer satisfactions. It is acceptable that lean is not always successful after its application in organizations, since sometimes there are drawbacks that prevent success. The performance of companies can be increased by using lean lab tools like the Yamazumi chart [26].

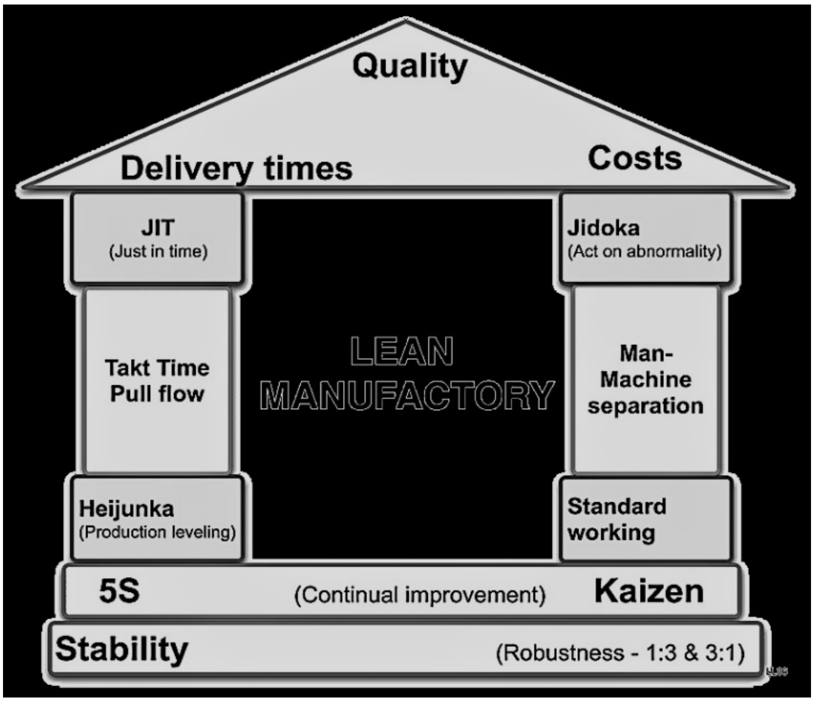

Figure 10 Lean house

Lean manufacturing (LM) is applied in various directions in several industrial segments. Apart from the automotive industries, lean thinking or lean philosophy or lean principles are also applied in non-mechanical societies, such as IT (computer companies) industries like Wipro.

The Study of lean manufacturing system or techniques can help in improving business models, to increase the competitiveness and eliminate the weaknesses [27]. The use of lean thinking in all process industries is necessary to efficiently deal with the customer demands. Lean always moves toward the customer's choice, and it allows the organization to identify importance of value, flow and waste [28].

Lean can work under any kind of situation in order to overcome the threats. However, it is necessary to use the correct lean methods, or concepts and lean tools.

What is lean?
Lean manufacturing or lean production is a set of tools and a systematic method that aims to continuously eliminate all waste (Muda) in the manufacturing systems. Lean accounts for the waste created by overloads (muri) and the waste generated through unevenness in the workloads (mura). All these principles are additionally referred to as lean thinking [29].

In a practical sense, lean technique techniques are introduced into the shop floor in order to eliminate the waste during the process. Lean thinking is considered as an effective practice in order to improve the overall productivity of processes [30].

2.3.2 Wastes

The strategy to control and measure the waste elimination in the industries is a challenging process. Lean manufacturing provides a well-coordinated way to eliminate the waste in the manufacturing system, more specifically in by the so-called "3M" principles (Muda, Muri, Mura). The 3M is technically divided into three stages:

- Muda (waste in the production system);
- Muri (workers' overload);
- Mura (unevenness in the system).

Waste is generated in all sorts of ways. Its composition and volume largely depend on the consumption patterns in the production process and structure of the company [31].

The Lean ideology helps companies in the reduction of costs and waste during supply chain process, by implementing of lean tools and technique that can be used in the line balancing of all kinds of supply chains [32]. A set of symbols are expressed in "lean languages" in order to improve the usage time and the reduction of all sort of wastes. In general, all automotive industries have two main components of production:

- Value added timing (activity in production);
- Non-value-added timing (no production activity).

In most of the industrial processes, the waste of time causes serious problems of production loss, and overloads can also lead to significant waste [33].

Manual assembly lines (with human labour) are also a major challenge to organizations. Here the Lean principles are particularly important because the work flow is typically slower in comparison with automated assembly lines.

Line pacing is the most important factor in manual assembly lines. Each task time is predefined, for the workers to complete the tasks within the cycle time. In these cases, the labour force should be under supervision to control the waste of time.

Different types of waste can be found in production processes:

- Stoppage of workers during the production flow and unnecessary movements;
- Production of defective parts;
- Over productions;
- Wasting of time in materials supply from the inventory section to the job floor;
- Unavailability of materials in the inventory (out of stocks) [34]. These are the most common wastages that industries have to deal with.

2.3.3 Yamazumi charts

The Yamazumi chart is a commonly well know Japanese term and it is a simple diagram that presents the immediate results of the process for both the organization and the customers. This lean software tool or stacked bar chart can be used for:

- Waste Elimination;
- Line balancing activity;
- To rearrange the assembly lines.

These visualization tools are inter-linked to the PDCA cycle and define a clear view of 3Mu’s, which are Mura, Muda are Muri. This chart has the ability to control the flow and improve the continuous flow of production by sorting out all of the waste [35].

DEVELOPMENT 1
(Line balancing)

3.1 Company presentation

3.2 Initial situation

3.3 Brainstorming

3.4 Selecting the best ideas

3.5 Implementing ideas

3.6 Measuring the corresponding impacts

3 Development

3.1 Company presentation

The roots of Grupo Salvador Caetano can be traced back to 1946, when Salvador Fernandes Caetano invited his brother Alfred and a friend, Joaquim Domingos Martins, to create a bus-body building company. Later, the company Martins, Caetano, Irmao, a manufacturing plant dedicated to the bus-body building that would be the embryo of Toyota Caetano Portugal, SA and of the Salvador Caetano Group itself.

Grupo Salvador Caetano is the parent company that controls the group and is responsible for managing the holdings, as well as determining the strategy and coordinating all actions of the clientele.

The first buses were exported to Great Britain in 1967. Later, in 1968, Toyota appointed Salvador Caetano as its exclusive Portuguese importer and distributor, with one of the best assembly lines been officially opened in Ovar in 1971.

Later on, the company began internationalization of the group, with the focus on England for marketing and after-sales services. In order to properly meet all demands, Caetano Bus planted their company over various nations in Europe, Asia and Africa. The group works with more than 150 companies and gathers up to 7000 workers.

Work has been done to further expand, by improving products and services through an efficient management system and construction of bus-bodies that fully conform to the demands of the clients.

The values of Caetano Bus are based on what the company is and what it wants to become:

- With tolerance …with respect;
- With strictness…with cooperation;
- With innovation…with tradition;
- With quality and;
- Always customer-oriented [36].

3.2 Initial situation

Layouts

The foremost step to control any production system is to be aware of the planned layout of the entire section. Layout refers to the configuration of departments, work centres, working lines and equipment, with particular emphasis on work flow (workers or materials) through the system.

This part of this work aims to improve the layout facilities, establishing a new workflow and cell workload, reallocating tasks to the cells corresponding to the balancing principles. adopted

The description of the layout serving as basis for this case study gives a detailed information about the working line in which the tasks are carried out (Figure 11).

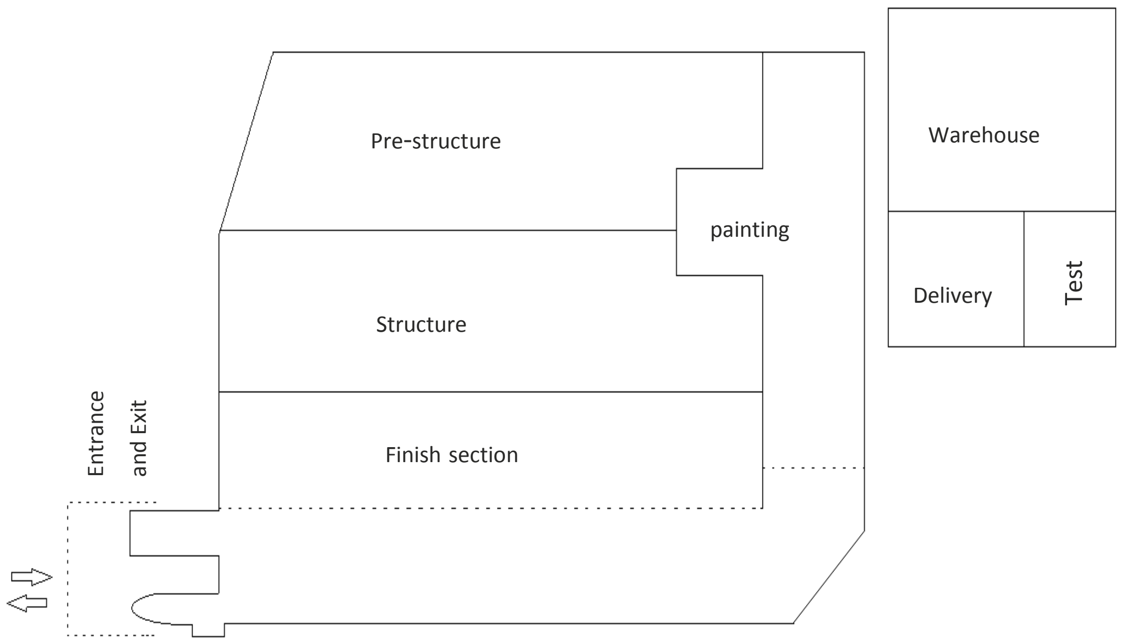

Figure 11 Layout of the line under study

In industries, the most basic common needs are to create the best layout plans as possible, which should be understandable by everyone, including the new employees. Actually, modification of the layouts causes a significant confusion to the entire organisation.

Internal view of manufacturing units

Table 7 explains about the whole internal divisions of manufacturing units. This table shows the overall manufacturing operations of a bus from the beginning to the end of the process. Sequencing of workstations enables to better understand the line structure. The work developed was focused on Workstations G05.01.1 to G05.03.1, where the bus manufacturing finishing tasks are performed, as shown in Figure 13.

Table 7 - Internal divisions of manufacturing units

LINE 1	WORKSTATION-G01.00.1	Pre-structure
LINE 2	WORKSTATION-G01.01.1 WORKSTATION-G01.02.1 WORKSTATION-G01.03.1 WORKSTATION-G01.04.1 WORKSTATION-G01.05.1	Structure section
LINE 3	WORKSTATION-G05.01.1 WORKSTATION-G05.02.1 WORKSTATION-G05.03.1	Finish section

General manual production flow of a bus

This section explains the manual production flow of the construction, which is a necessary step of any production process. The flow of production is mapped, designed or computerized through any form of diagram (Figure 12).

The process flow diagram of a process varies between companies. A flow diagram is an instrument for keeping track of the different steps in the fabrication of the bus.

In this principle, the production flow can also be used for time control. i.e., how much time it takes to finish a certain production process.

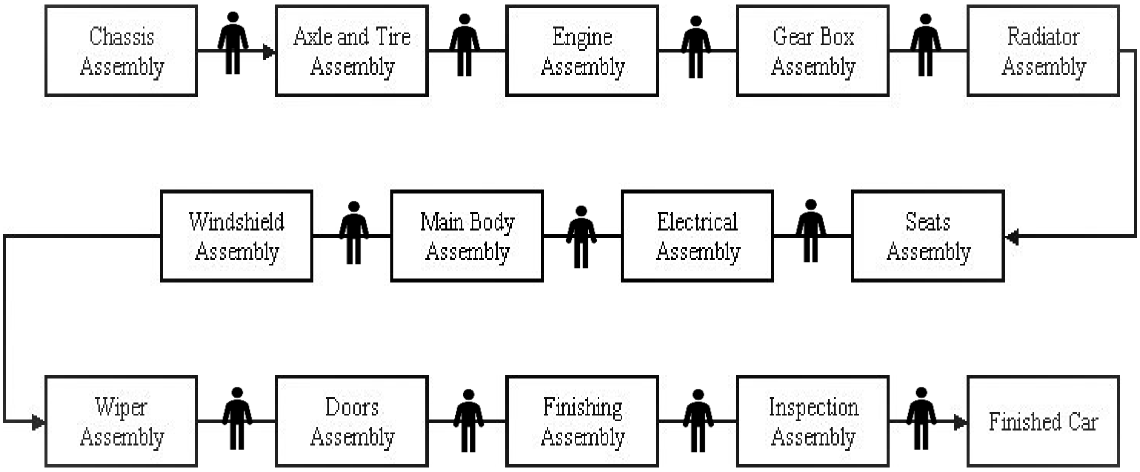

Figure 12 Production flow chart of a bus manufacturing

Sections worked in details

The finishing section of a bus is comprised of six workstations (Figure 13). Each workstation has its own task to be performed in a given period of time, which is the given takt time for each work in each station. In line balancing, the major and common problem occurrence is related to the time management and unbalanced workers. Caetano bus has currently some major unsolved problems.

Total number of workstations in finish section of bus manufacturing

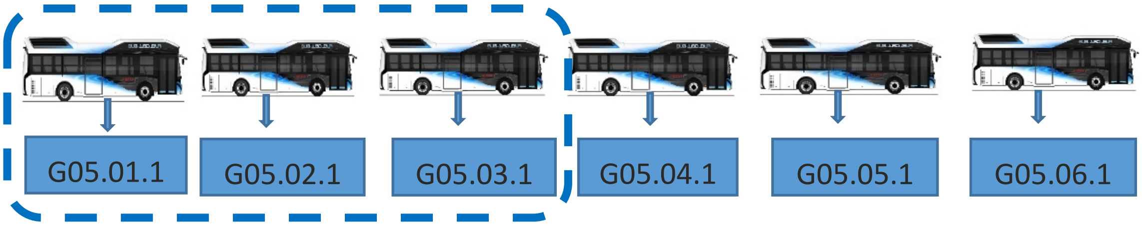

Figure 13 Total number of workstations in finish section

Describing the problems

Globally industries face many problems and failures in a daily basis in order to describing about the problems in many manufacturing assembly lines do not have infrastructures or the tools to identify problem areas and analyse the entire assembly. The most common problems can occur by the misplacing of workers or over acceptance of demand, which affects the standard takt time. This scenario undergoes some problems in line balancing of first two workstations in the finishing section. The occurrence of problems is listed below and can be observed in the charts presented in Figures 14 and 15.

- Lack of real time information;
- Unbalanced station workloads or misplacing of workers.

Workstation G05.01.1

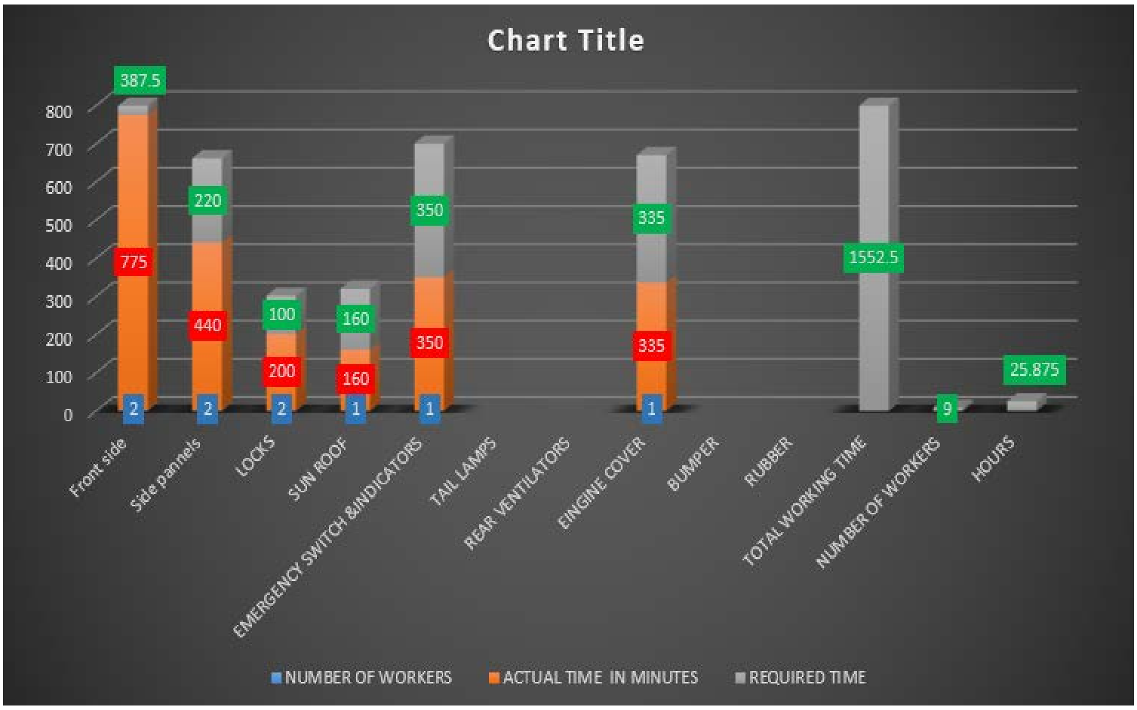

Figure 14 Workstation G05.01.1

Workstation G05.02.1

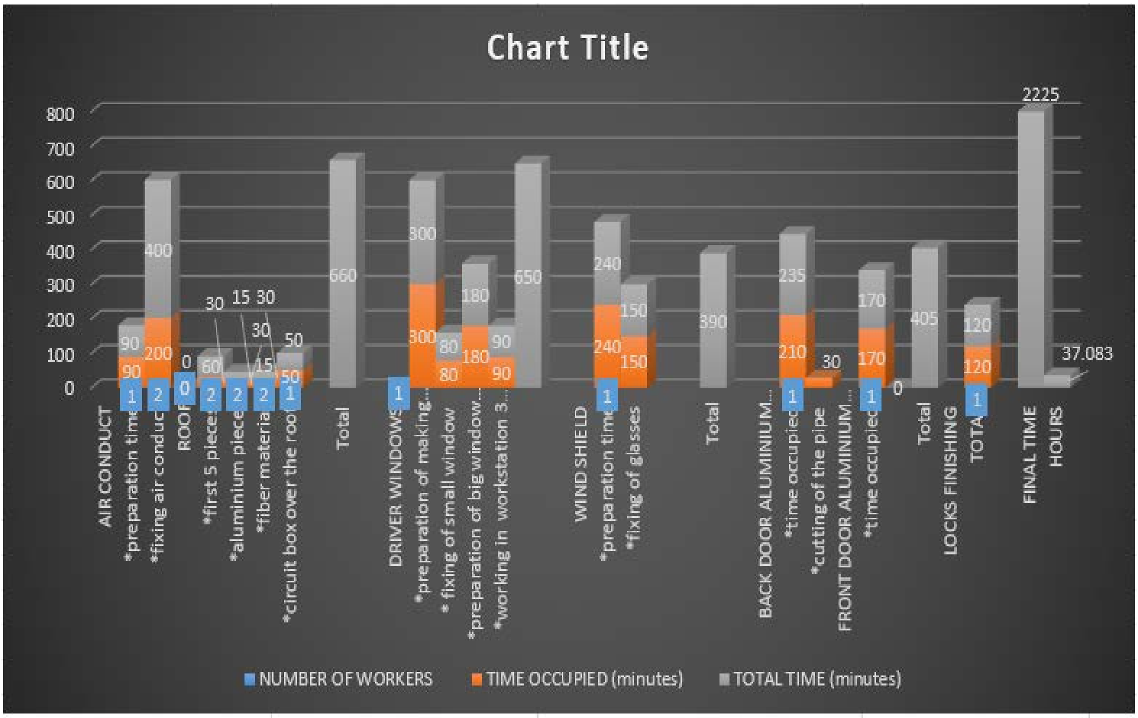

Figure 15 Workstation G05.02.1

Line balancing of first two workstations

In this section it is intended to promote the line balancing in the cells G05.01.1 and G05.02.1, as depicted in Figure 16.

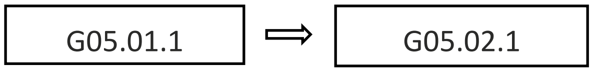

Figure 16 Balancing of lines worked in detail

3.3 Brainstorming

The way of finding the conclusion for a particular problem can be listed out by many ideas and by picking up a right idea for a problem. In this work, line balancing can be undertaken by various methodology and concepts. Generally, the 5S methodology plays a significant role in all industries around the world.

3.4 Selecting the best ideas

The brainstorming and discussion of ideas leads the new possibilities in introducing the tool for line balancing and in order to help in the study of new methods and strategies.

Yamazumi chart
In the history of automotive industries, Japanese was pioneer in improving, measuring and eliminating. Although the word yamazumi is a Japanese word, it actually means to stake up. It is a simple lean software tool that measures or balances the cycle time workloads in a typical assembly line.

The chart can be categorized as either Value added time, Non-value-added time and waste.

These charts are represented as simple graphs with two axes, namely:

- X-axis, can represent the workers or operations;
- Y-axis, can represent the time.

This tool is intended to support teams of process improvement and it is used by lean improvement teams. This chart shows the balance between the cycle time workloads and each one of the operations in a production line. Sometimes this chart is called as "takt time bar chart".

3.5 Implementing ideas

The selection of ideas is important and most of these ideas are starting points to improve a process. In every brain storming sessions, gathering of ideas is main point to implement changes in a production line.

In this work, the main task is to do line balancing in an effective way in order to achieve and overcome the work overloads that currently occur in the assembly line. As there is an unknown problem in the finish section, this should be tackled with by using a Yamazumi chart, which is presented in Figure 18 and described next in topics.

Current problems:

- Unplanned works are done;
- Too many workers in a single task;
- More workers than necessary in each workstation.

Problems solved by the Yamazumi chart:

- Rearrangement of workers, task, and line assembly;
- Planned works are done in sequence;
- Reduced to six workers for two workstations.

3.6 Measuring the corresponding impact

This topic covers the detailed information gathered for the line balancing for the first two workstations.

The current project is thus analysed with the aid of a tool called Yamazumi chart. The Yamazumi chart is one of the known tools, which helps in balancing the line workloads and the management of the times.

The chart presented in Figure 17 explains the balancing process and the rearrangement of workers in the bus manufacturing company. This chart is consists of the individual evaluation of each worker's working time on their task in the workstations, in order to perform the line balancing.

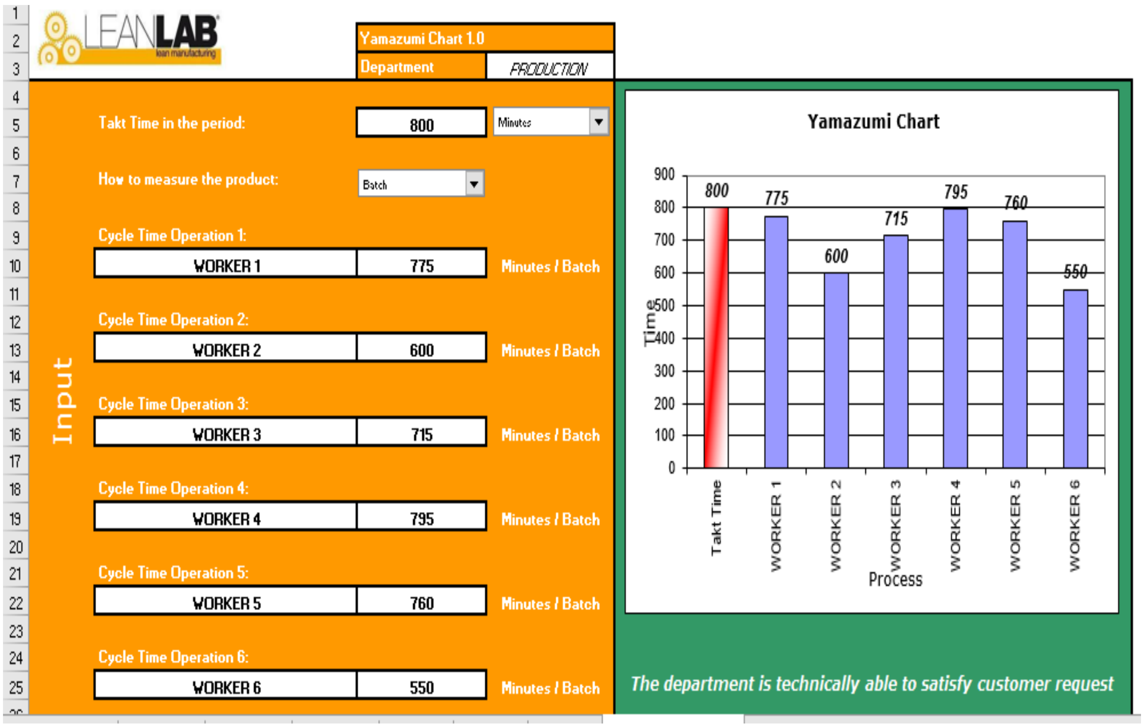

Figure 17 Yamazumi chart

The use of the Yamazumi chart in the finish section of first two workstations for bus manufacturing is explained as follows:

- The red bar indicates the takt time - 800 minutes (13.3 hours);
- The blue bar indicates the occupancy of time by workers;
- Rearrangement of workers resulted in a reduction from nine to six workers for the two workstations.

Management techniques to control bus production

A typical management technique control aims at achieving defined goals within an established timetable and usually realized that management control includes the following steps

- Actual performance is compared with planned performance
- The difference between the two is measured
- Causes contributing to the difference are identified and
- Corrective action is required to do away with or downplay the conflict.

Therefore, the system helps in bringing stability to manufacturing process.

DEVELOPMENT 2 (Glue optimization)

4.1 Introduction

4.2 Sika flex – 263

4.3 Types of packages

4.4 Skeleton structure of a bus

4.5 Pre-structure

4.6 Structure section

4.7 Finish section

4.8 Actual quantity of sika flex-263 600 ml packs in each workstation

4.9 Implementation on structure sections for guns

4.10 common implementation of pumps

4.11 Final proposal pumps

4 Glue optimization

4.1 Introduction

The chapter explains about the consumption of a specific glue brand in overall bus manufacturing organization. Glues are available in various types with different properties. In this chapter, a glue of the brand SIKA AG (Sikaflex 263) [37], which is commonly applied in the automotive industry and in civil engineering, is considered. SIKA AG is a chemical industry and its head office is located in Baar, Switzerland. This manufacturer supplies products for bonding, sealing, damping, reinforcing and for the building sector and the automotive industry.

4.2 Sikaflex 263

The Sikaflex®-263 is a 1-component elastic high-performance direct glazing adhesive with gap-filling capabilities based on humidity-curing polyurethane technology. It has been designed for bonding and sealing applications in the commercial vehicles business. The good tooling properties and the enhanced weathering resistance allow the realization of exposed joints.

4.3 Types of packages

This adhesive is provided in the following forms:

- 600 ml in single tubes;
- 195 litres container;
- 23 litres container.

4.4 Skeleton structure of a bus

Before fabrication of frame structure of a bus, there are a several steps to be undertaken, included in the design process.

Design is a prediction and simulation process which uses computers, namely CAD software tools that enable to understand how the product will behave. Figure 18 shows a bus frame drawn in a CAD software.

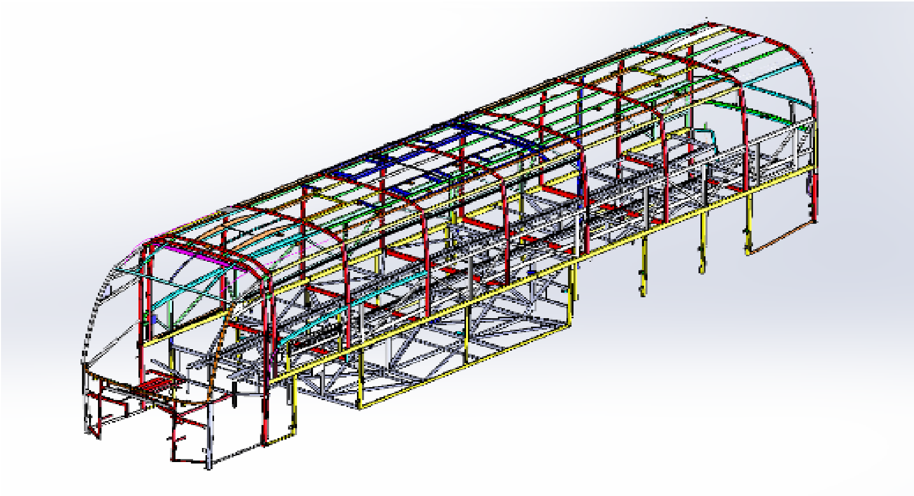

Figure 18 3D view of a bus

The fabrication of the bus frame is divided into six workstations, as shown in Figure 19.

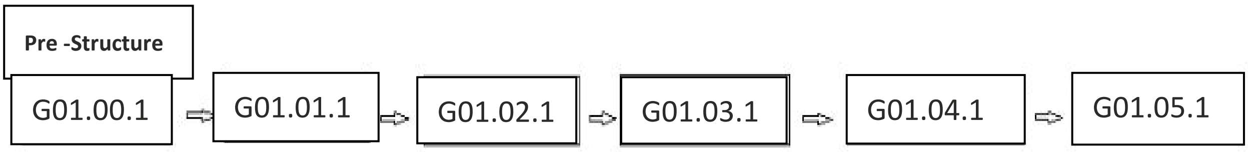

Figure 19 Structure sections

4.5 Pre-structure

The framework of a bus is a self-bearing structure made from steel welded profiles. The basic part of the bus monocoq is the chassis frame, and it also includes the full body of the coach.

WORKSTATION G01.00.1

In this section the chassis (Volvo) and the body are assembled (Figure 20). The structure of the monocoq bus that is prepared for the installation and fitting of the coach chassis and the body systems, and it should take into account the places where the engine, the transmission gear, the suspension, the axles, the steering system and the other equipment will be fitted. As per the European standard, EURO 6 motorization is strictly advised to be utilized in all European lands.

Figure 20 Skeleton of a bus and chassis

WORKSTATION G01.01.1

This station refers to the installation of the body in the chassis frame mountings, for heavy vehicles (Figure 21). This fabrication step does not include certification of omnibus buses.

Figure 21 Mounting of frame into chassis

This workstation is the first of the structural workstations, in which the pre-structure (skeleton) of a bus is formed and is welded to the chassis to form a single structure.

Modifications that can be made in this workstation:

- Change of body type;
- Change of body size;
- Extended or shortened wheelbase;
- Inclusion of an additional axle;
- Placement of chassis reinforcements and/or acceptance;
- Chassis extension, such as increased rear overhang.

WORKSTATION G01.02.1

In this workstation, installation of electric cables lines is performed. Modern buses have separate thin wires embedded in flat plastic strips. These slips are thick, and are used for many devices and accessories in the bus (Figure 22).

Figure 22 Cables installations

Wires and bundles of wires are trimmed to the bodywork to keep them out of the way and, where they run through a hole, the sharp edges should be protected with a rubber grommet. Sometimes the structure is divided into sections joined by multi-pin plugs and sockets, so that it can be taken out and refitted section by section.

WORKSTATION G01.03.1

Mud flaps or mud guards are assembled in this workstation (Figure 23). These components are employed to protect the vehicle, passengers, engines, other vehicles and pedestrians from mud and other flying debris thrown into the air by the rotating tire.

Figure 23 Fixing of mudguards

Mudguards typically consist of a rubber strip or a thin metal sheet that is not easily damaged by contact with flying debris, the tire, or the road surface.

WORKSTATION G01.04.1

This workstation builds the body of the bus in several steps and, thus, the operations are more time consuming comparing to other stations (Figure 24). The next figures give an overall idea of these operations.

Fixing of lateral panels to right and left sides, and roof

Figure 24 Fixing of lateral panels on both sides

Sheet metals is used for outer panelling, between metals and angles (Figure 25), thermocoal is placed to resist heat and then completion of roofing work, after the electrical works, is accomplished by applying a roof rail to increase roof strength.

Fixing of front fibre glass panel **Fixing of rear fibre glass panel**

Figure 25 Fixing of front and rear fibre panels

The panels are fixed to their respective places with the adhesive SIKA FLEX-263 (Figure 25). Once the panels and the other body are attached, the bus is moved to the last part in structural line.

WORKSTATION G01.05.1

This workstation is the final step of structural bus assembly. After the outer body of the bus is constructed, the bus is moved to a painting section where initially a coating is applied to prevent rust and other damages to the bus.

Painting is one of the most important sections and all automotive manufacturers use separated workstations for this operation.

Figure 26 Cutting, adjusting and assembling the luggage doors in the buses

Although in this workstation the aluminium sheets are cut to the respective dimensions and built into a variety of luggage door and wheel guards that they are secured to the bus, as can be seen in Figure 26.

4.6 The structure sections

Sika flex-263 is used in various structure workstations to fabricate the buses, as presented in the following tables. Table 8 shows the information about the workstation G01.03.1.

Table 8 – Workstation G01.03.1

STRUCTURE OF BUS	NUMBER OF GLUE PACKS	TIME OCCUPIED (Minutes)	TOTAL TIMING (Minutes)	WORK HOUR COST (€)	NUMBER OF WORKERS	REAL QUANTITY (ml)	COST OF 600 ml 70032727 (€)	COST OF 195 L CONTAINER 70032727 (€)	COST OF 23 L CONTAINER 70032726 (€)
EXTERIOR LATERAL PANNEL (LEFT SIDE)	9	20	40	16.6	2	550	4.95	3.00	3.38
EXTERIOR LATERAL PANNEL (RIGHT SIDE)	9	20	40	16.6	2	550	4.95	3.00	3.38
INTERIOR									

LATERAL PANNEL (LEFT SIDE)	3	25	25	10.415	1	550	4.95	3.00	3.38
INTERIOR LATERAL PANNEL (RIGHT SIDE)	3	25	25	10.415	1	550	4.95	3.00	3.38
INFERIOR ZONE (NEAR THE WHEELS)	7	90	90	37.494	1	4100	4.95	5.39	5.17

TOTAL COST OF (SIKA FLEX -263) IN EACH WORKSTATION

COST OF 600 ML BAG 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
56.70	34.40	36.68

TOTAL TIME OF WORKSTATION - 220 MINUTES (or) 3.6 HOURS.

Sika flex-263 is used also in worksation G01.04.1. The corresponding information can be seen in Table 9.

Table 9 – Workstation G01.04.1

STRUCTURE OF BUS	NUMBER OF GLUE PACKS	TIME OCCUPIED (Minutes)	TOTAL TIMING (Minutes)	WORK HOUR COST (€)	NUMBER OF WORKERS	REAL QUANTITY (ml)	COST OF 600ml 70032727 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
FRONT FIBER GLASS 1	1.5	10	10	4.166	1	450	4.05	2.46	2.76
FRONT FIBER GLASS 2	1.5	10	10	4.166		450	4.05	2.46	2.76
REAR FIBER GLASS 1	1	20	20	8.332		550	4.95	3.00	3.38

REAR FIBER GLASS 2	1	10	10	4.166	1	550	4.95	3.00	3.38
SANCAS (CROWN MODELLING 1)	4	60	120	49.992	2	500	4.50	2.73	3.07
SANCAS (CROWN MODELLING 2)						500	4.50	2.73	3.07
PECOLITE ROOF	22	90	270	112.482	3	12600	113.40	8.80	7.36

STRUCTURE OF BUS	NUMBER OF GLUE PACKS	TIME OCCUPIED (Minutes)	TOTAL TIMING (Minutes)	WORK HOUR COST (€)	NUMBER OF WORKERS	REAL QUANTITY (ml)	COST OF 600ml 70032727 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
REAR SIDE OF (SIDE WINDOW 1)	1	10	10	4.166	1	300	2.70	1.64	1.84
REAR SIDE OF (SIDE WINDOW 2)	1	10	10	4.166		300	2.70	1.64	1.84

TOTAL COST OF (SIKA FLEX -263) IN EACH WORKSTATION

COST OF 600 ML BAG 70032725 (€)	COST OF 195 L CONTAINER 70032727 (€)	COST OF 23 L CONTAINER 70032726 (€)
145.80	88.45	99.47

TOTAL TIME OF WORKSTATION: 460 MINUTES (or) 7.66 HOURS.

Sika flex-263 is used also in worksation G01.05.1. The corresponding information can be seen in Table 10.

Table 10 – Workstation G01.05.1

STRUCTURE OF BUS	NUMBER OF GLUE PACKS	TIME OCCUPIED (Minutes)	TOTAL TIMING (Minutes)	WORK HOUR COST (€)	NUMBER OF WORKERS	REAL QUANTITY (ml)	COST OF 600ml 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
FRONT STAIR FIBER GLASS	1.5	30	30	12.498	1	450	4.05	2.46	2.76
REAR STAIR FIBER GLASS	1.5	30	30	12.498		450	4.05	2.46	2.76
INTERNAL PECOLITE	7	30	60	25	2	4200	37.80	22.93	25.79

TOTAL COST OF (SIKA FLEX -263) IN EACH WORKSTATION

COST OF 600 ML BAG 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
45.90	27.85	31.31

TOTAL TIME OF WORKSTATION: 90 MINUTES (OR) 1.5 HOURS.

4.7 Finish section

Sika flex-263 is used also in Finish Section, corresponding to workstation G05.03.1. The corresponding information can be seen in Tables 11, 12 and 13.

Table 11 – Workstation G05.01.1

STRUCTURE OF BUS	NUMBER OF GLUE PACKS	TIME OCCUPIED (Minutes)	TOTAL TIMING (Minutes)	WORK HOUR COST (€)	NUMBER OF WORKERS	REAL QUANTITY (ml)	COST OF 600ml 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
ROOF VENTILATORS	3	60	60	25.00	1	1700	15.30	9.28	10.44

TOTAL COST OF (SIKA FLEX -263) IN EACH WORKSTATION

COST OF 600 ML BAG 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
15.30	9.28	10.44

TOTAL TIME OF WORKSTATION: 60 MINUTES (OR) 1HOUR.

Table 12 – Workstation G05.03.1

STRUCTURE OF BUS	NUMBER OF GLUE PACKS	TIME OCCUPIED (Minutes)	TOTAL TIMING (Minutes)	WORK HOUR COST (€)	NUMBER OF WORKERS	REAL QUANTITY (ml)	COST OF 600ml 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
STICKING GLASSES INNER (LEFT)	4	60	60	25	1	2200	19.80	12.01	13.51
STICKING GLASSES INNER (RIGHT)	4	60	60	25	1	2200	19.80	12.01	13.51
SEALING GLASSES OUTSIDE (RIGHT)	12	240	240	100	1	6450	58.05	35.22	39.60
SEALING GLASSES (LEFT)	12	240	240	100	1	6450	58.05	35.22	39.60
SEALING REAR GLASS	3	120	120	50	1	1800	16.20	9.83	11.05
SEALING DRIVER GLASS	1	20	20	8.33	1	600l	5.40	3.28	3.68
SEALING WIND SHIELD GLASS	7	480	480	200	1	4200	37.80	22.93	25.79
ENTERANCE WINDOW RUBBER	1.5	20	20	8.33	1	900	8.10	4.50	5.53

TOTAL COST OF (SIKA FLEX -263) IN EACH WORKSTATION

COST OF 600 ML BAG 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
223.20	134.99	152.27

TOTAL TIME OF WORKSTATION: 1480 MINUTES (OR) 24.66 HOURS.

Table 13 – Workstation G05.05.1

STRUCTURE OF BUS	NUMBER OF GLUE PACKS	TIME OCCUPIED (Minutes)	TOTAL TIMING (Minutes)	WORK HOUR COST (€)	NUMBER OF WORKERS	REAL QUANTITY (ml)	COST OF 600ml 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
LUGGAGE	2	40	40	16.66	2	1200	10,8	6,552	7,368

TOTAL COST OF (SIKA FLEX -263) IN EACH WORKSTATION:

COST OF 600 ML BAG 70032725 (€)	COST OF 195L CONTAINER 70032727 (€)	COST OF 23L CONTAINER 70032726 (€)
10,8	6,552	7,368

TOTAL TIME OF WORKSTATION: 40 MINUTES.

4.8 Actual quantity of sika flex -263 600 ml packs in each workstation

To measure the consumption of sika flex -263 in all workstations, it was only possible to measure manually for the Sika Flex - 263 (600 ml) packs (Table 14).

Table 14 – Comparison of SAP quantity and Actual quantity

WORK STATION	ACTUAL SAP QUANTITY (Packs 600ml)	REAL QUANTITY Verified (Packs 600 ml)	SECTION NAMES	RESULT SAP QT-REAL-QUANTITY (Packs 600ml)	Difference by SECTION (Packs 600ml)	Total Difference (Packs 600ml)
G01.03.1	0	31	STRUCTURE	31		
G01.04.0	0	29	STRUCTURE	29	33	
G01.04.1	30	10	STRUCTURE	-20		
G07.A1.1	7		STRUCTURE	-7		
G01.05.1	0	3	FINISH SECTION	3		53.5
G05.01.1	4	3	FINISH SECTION	-1		
G05.02.1	1	44.5	FINISH SECTION	43.5	20.5	
G05.03.1	25		FINISH SECTION	-25		
G10.00.1	2	2	FINISH SECTION	0		
TOTAL	69	122.5				

4.9 Implementation of guns in the structure section

The implementation of bonding guns improves the output speed in each structure section, and on each workstation. In order to increase the pace of production, multiple guns should be inserted in each pneumatic extension cable in each workstation. This modification increases the speed and efficiency of the process, compared to the manual application of glue.

4.10 Common implementation of pumps

Graco pump (old pump) 23-liter sika flex-263

Figure 27 shows the gruco Pump aspect, as well as the usual package where the Sika Flex - 236 is supplied.

Figure 27 Graco old pump

New alternative pump

An alternative pump may be used, the Lincoln pump, with the aspect shown in Figure 28.

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Figure 28 New electric pump

Table 15 – Comparison of pumps

EQUIPMENT	SPECIFICATION	ADVANTAGES	DISADVANTAGES	COST (€)
GRACO (30 LITRE)	• Pneumatic pump • Pressure: 7 -10 bars, (400) 0.7 MPa (100 psi)	• same in cost • Easy availability in the markets	• Occupies more space • Lack in speed • No portability • Heavy and larger in size • Higher cost	10,417
LINCOLN (30 LITRE)	• voltage supply • pressure: 7-10 bars, (400) 0.7 MPa (100 psi)	• Lower cost • Small and compact to use • Portable to use • More user friendly • Can work with tough glues like Sika flex and Mastic etc.	• Moderate availability in the market	4,200

By comparing the equipment's continues usage during the fabrication process provides another means to improve the production rate, by implementing a new equipment or using an alternative pump for the 23-liter Sika container. Implementing this pump makes the work easier and faster. Thus, this modification increases the production rate.

4.11 Final proposal

The proposals mentioned above are valuable information for this project about finding the final proposal to make improvements to the company and accomplish cost savings, as can be seen in Table 16.

Table 16 – Monetary value

Graco pump (30 L)	10,417 €
Lincoln New pump (30 L) (-)	4,200 €
Total	6,217 €
Maintenance cost per usages	2,968.1 €
Profit in pumps	(-) 6,217 €
Total	3,248.9 €

As a suggestion for improvement, multiple guns can be added to each workstation, which helps in managing the work easier and faster.

On the other hand, suggesting an electrical pump which can be used for the all workstations reduces the effort of the workers and reduces costs to the company.

CONCLUSIONS

5 CONCLUSIONS

After this work some conclusions can be drawn as follows:

Line balancing

Through this work some tasks were changed between workstation, allowing to obtain time savings regarding the workers' occupation in the production line. The two main general aspects in the industrial organization are

- Reduction of cost;
- Reduction of time.

In this instance, the word reduction of cost may refer either to monetary profit or reduction of fabrication time.

By bringing up the previous scenario (Figure 18), the Yamazumi chart has, as brainstorming output, the reduction of time to the given takt time.

Glue optimization

The glue consumption was optimized by changing the quantities of the glue packs and the corresponding packages. Thus, a saving of 3,248.9 € was achieved by each bus.

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