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## TOPIC

# LEAN PRACTICE: A CASE STUDY OF REDUCING CYCLE TIME AT AN AUTOMOBILE FACTORY

## BACHELOR THESIS

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LEAN PRACTICE:  
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A Thesis Presented

By

Van Thanh Dat

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## ***ABSTRACT***

This thesis is about an automotive manufacturing corporation, Mercedes-Benz, which has been present in the Vietnam market as well as Asian and European nations, making a significant contribution to the market's growth and becoming one of the top automobile manufacturers in the globe. However, the expanding market demand and the group's objective to save cost operation on gasoline vehicle manufacturing put Mercedes-Benz Vietnam (MBV) constantly in a condition of continuous growth and improvement. In 2022, productivity in production lines such as Body Shop, Assembly, End of Line, and Finish Line has not yet met the factory's target. Therefore, MBV launched the Standardization and Continuous Improvement project to enhance production. The thesis explicitly explores the challenge that the firm is experiencing via data analysis and the use of Lean principles. By applying Lean expertise such as Yamazumi, Waste Analysis, 5S, Process standardization, Continuous Improvement (Kaizen), PDCA, and Pareto Charts to identify the heart of the problem, MBV can rebalance the line and subsequently boost the productivity of the business.

After integrating knowledge into practice:

- Average Cycle time decreased by 5.6%

**Keywords:** Lean Production System, Continuous Improvement, Yamazumi, Waste Analysis, 5S, Standardization, PDCA, Pareto, Line Balancing.

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During my internship at the company, I observed that Mercedes-Benz Viet Nam is a fantastic working atmosphere, always assisting and helping employees with different welfare programs. In addition, the company also has a management team with many years of expertise in the field, always caring for employees to generate a feeling of closeness and readiness to support each other to realize the objectives.

Despite my attempts, due to time limits in knowledge and practical experience, my work is tough to prevent inadequacies. I am looking forward to the sympathy and input of my colleagues and lecturers so that I can better this topic.

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06/2023

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## LIST OF ABBREVIATIONS

SWI:	Standard Work Instructions
LM:	Lean Manufacturing
CI:	Continuous Improvement
TM:	Training matrix
OP:	Operator



# **1 INTRODUCTION**

## **1.1 Current Situation**

According to the current World situation, the automotive industry is racing to convert to electric vehicles with the aspiration to protect the environment. As the European Union (EU) announces plans to prohibit the sale of combustion engine or diesel-powered automobiles beginning in 2035, European automakers are quickening their shift to vehicle manufacturing. Abnormally, by 2030, a German carmaker, Mercedes-Benz, wants all of its high-end models to be electrified. By 2039, it will have achieved that objective approximately ten years earlier than anticipated. As one of the nations that manufacture only pure gasoline vehicles, Vietnam must also bear a heavy burden due to the Mercedes-Benz Group's Policy to forego the expense of producing gasoline vehicles in favor of electric vehicles. To be well-performing with low investment, MBV (Mercedes-Benz Vietnam) decides to adopt LPS (Lean Production System) to enhance car capacity without wasting cost.

## **1.2 Reason for picking the topic**

In production, human resources occupy a crucial position and are the most valuable asset necessary in creating products for the company. Human resource also impacts the number of orders. If the employees make good product quality, the number of orders from clients for the business will increase, and the company's profit will improve. In manufacturing, whether employing human resources too much or too little impacts the development of products and the quality of products.

To attain such aims, the corporation has established various departments to suit the requirements and aspirations of the business. In particular, the Standardization and Improvement Project's primary purpose is to standardize, balance lines, and upgrade to assist lines with production challenges such as output and people.

## **1.3 Objective of the study**

- Analyzing the current manufacturing state and standardizing the production process at Mercedes-Benz Vietnam.
- Rebalance the production line, uncover the existing difficulties, generate challenging advantages and weaknesses, and propose solutions to increase the line's efficiency.

## 2 LITERATURE REVIEW

### 2.1 Lean Production System

One of the contemporary management strategies, the Lean Production System, or Lean Manufacturing, primarily builds on the Toyota Production System (TPS) to simplify production, minimize waste in operating, and maximize production efficiency. According to the Lean mindset, anything that does not bring value customers is willing to pay for is deemed waste. The Lean Manufacturing System has various advantages, but its essential features include lower production costs, higher output, and shorter lead times (Ohno, 1988).

In other words, the Lean Production System strives to increase the value of customers' purchases while using fewer resources by removing the seven kinds of waste: Transportation, Inventory, Motion, Waiting, Over-processing, Over-production, and Defects. We have Lean objectives (Sayid, 2017), such as:

- Process and production cycle times reduction by minimizing wait times between steps, preparation process time, and PLU conversion time.
- Higher plant layout implementation of control material flow configuration.
- Resource reduction is necessary for quality control.
- Closer relationships with fewer suppliers, superior quality, and reliability. Instead, suppliers may provide tiny quantities of materials and components directly for manufacturing processes, just enough for production, and eliminate inventory.
- Electronic communication usage with suppliers and customers.
- Product optimization excludes models that represent little extra value for clients.
- Product designs with fewer components are increasingly frequent.
- Product designs and services that can be customized by clients today based on standardized parts and modules as new as feasible.

### 2.2 Wastes of Leans

Seven sorts of waste and non-value-adding activities are as below:

- **Transportation:** Transportation is transferring something from one location to another. Transportation itself does not bring any value to the client; hence it should be reduced as feasible. Diminution may be accomplished by placing plants closer together and decreasing the cost of transportation.

- **Excess Inventory:** The items in a factory's inventories are manufactured, idle resources, or materials on hand. Additionally, excess inventory refers to retaining or producing more stock than is needed for the subsequent operation.
- **Excess Motion:** Motion waste is any movement executed that might have been employed for another reason. This leads to a sort of waste of it needless time. Wasted motion might be anything from the operator leaning down to pick something up to an unnecessary journey made.
- **Waiting:** Waiting describes individuals or objects waiting for the next activity. This frequently arises when material flow is poor, production cycle durations are too lengthy, and distances between work centers are too considerable. The Theory of Constraints asserts that an hour wasted in a bottleneck process is lost to the factory's production and can never be regained. It helps connect operations such that one activity feeds straight into the following with little delay.
- **Overproduction:** Overproduction describes manufacturing unnecessary things. Overcapacity leads to excess inventory. Mass production is costly to a manufacturing facility since it disturbs the material flow and may decrease the product's quality and overall productivity.
- **Overprocessing:** Overprocessing is acceptable that executing work or adding features to the product that the consumer does not demand. This involves utilizing pricey manufacturing equipment when cost-effective tools are just as adequate investing in smaller and more flexible equipment where feasible will permit us to save significant funds throughout the operation.
- **Defects:** Defects lead to a tremendous loss of time; the product must be thrown off and duplicated, which costs money. It also leads to lost clients and reputation.





*Figure 2-1 7 Forms of Waste [Kanbanize.com, 2020]*

### 2.3 Standardization

Standardization is a considerable matter; it may not win a popularity contest, but it has to be at the top of the adopted Lean Production System (LPS) tools. It is essential to succeed with LPS or Continuous Improvement until practicing Standardization well. Inhe Ohno, the founder, and architect of the Toyota Production System, famously remarked, “where there is no standard, there can be no Kaizen (Continuous Improvement).” If humans love to boost manufacturing and improve line production but do not integrate Standardization into standard work, it will not succeed. Hence, this issue is crucial that everyone must learn to accept with respect.

A Standard is simply a rule or guideline for the progress of completed things. It may be used to describe any characteristic of a process. Standardization is merely a process of generating or updating a standard. Standardization is when constructing a standard, taking an existing one, replacing it, or upgrading it with an improved one. Standard work is a different standard for the procedures utilized to perform something. People get work done in the work sequence on how much time; that is work standardization. It is not simply a concept or a hypothesis; it is something that has been verified and demonstrated (Jeffrey K. Toyota).

After having a standard, a target will arise, and everyone in the company may focus on the same objective, which provides consistency. It is challenging to instruct individuals successfully if

there is no standard. A training method without a standard generates varied results. A standard can be a baseline to assess performance, displaying the expected and actual levels to evaluate a gap. Solving difficulties can be more straightforward if individuals follow the standards since things go wrong when different from the standard. Moreover, to improve something, having a standard is needed since a standard helps people know if things will be better. Improvements will stick if the organization is standardized.

## 2.4 5s

The 5S method aims at creating order and cleanliness utilizing standardization. It has the most significant impact on the target dimension quality since strict adherence to order and cleanliness makes it easier to identify necessary equipment and deviations from the standard. Standardization has a stabilizing effect that can increase quality (Abdulmalek, 2007). A brief description for 5S might therefore read as follows: “Repeated execution of a systematic sequence of five steps comprising sorting, setting in order, sweeping (keeping the workplace clean), standardization of layout, and sustaining (maintaining) the practice (in Japanese: Seiri, Seiton, Seiso, Seiketsu, Shitsuke)”.

- Seiri (Sort): Remove unnecessary items from each area.
- Seiton (set in order): Organize and identify storage for efficient use.
- Seiso (Shine): Clean and inspect each area regularly.
- Seiketsu (Standardize): Incorporate 5S into standard operating procedures.
- Shitsuke (Sustain): Assign responsibility, track progress, and continue the cycle.



Figure 2-2 5S Method [Giáo trình Quản trị Sản xuất và chất lượng, p.80]



**2.5 Line Balancing**

The production is planned according to the "flow model" in the work assignment. It is separated into numerous steps, each owing to the high specialization, operators, machinery, and equipment. The progress of work allotted to each station is termed line balancing.

The goal of line balancing is to generate groups of process steps that have equal duration. A well-balanced line will reduce downtime, make smooth workflow, and boost production capacity (Adeppa, 2015).

**2.6 Yamazumi**

Yamazumi is a Japanese term that means to stack up. Yamazumi Chart is a visual tool indicating how value-added and non-value-added tasks “stack up” inside a process. As a visual tool, it may allow people to identify and prioritize opportunities for improvement, track improvement efforts, and balance work amongst workers or workstations (Talapatra, 2018). It is beneficial to understand the level (ratio) of line balancing where the problem is encountered to provide remedial measures or improvement methods to stabilize output. There is an example of Yamazumi chart below of four workstations. It is easy to recognize the cycle time in station 4 is higher than takt time, and there is much none value added time in this station. Reducing the cycle time by optimizing the non value added time can be considered.

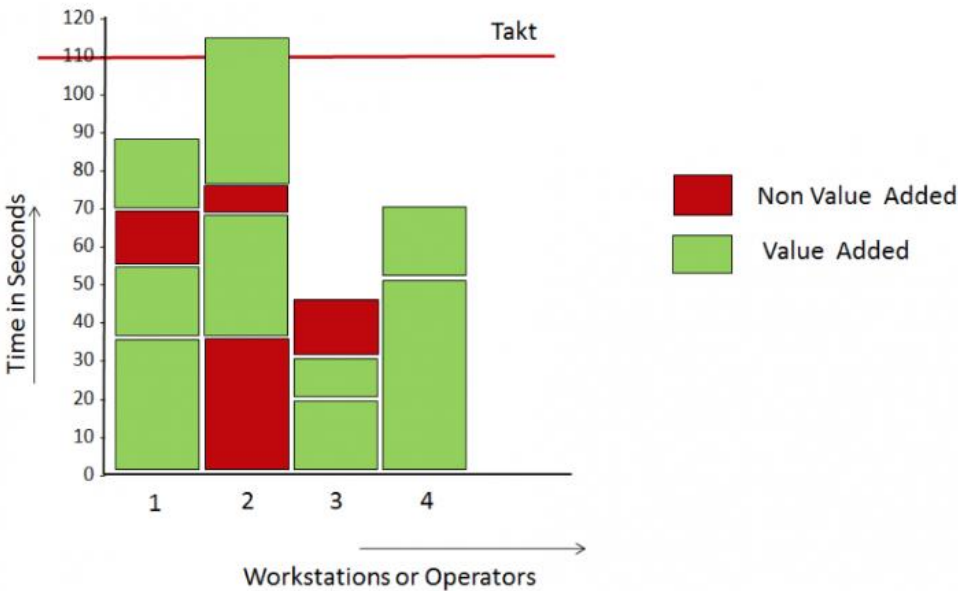


Figure 2-3 Example of Yamazumi [CRC press, 2018]

## 2.7 Pareto Chart

The analysis of the Pareto Chart is applied to the 80 - 20 concept. According to the study, 80% of the most affected problems will arise from 20% of the critical causes. Understood otherwise, the execution of 20% of the job will enable us to achieve 80% of the advantages compared to accomplishing the remaining task. Through the data of work orders from high to low, it is apparent that businesses will know which jobs should be the top priority, which is less critical and will be dealt with later.

Optimizing issue resolution is not simply about helping firms deal successfully with one occurrence or risk at a time. It also makes it possible for the business to search for particular goals and interpret the problem correctly; thus, problem-solving is also effective and accurate, saving maximum money and time (Abdulmalek, 2007). Focusing on significant goals and prioritizing them is crucial to many businesses' success. The most considerable modifications will contribute to beneficial improvements to the company's current position.

This idea is not accidental, and it has been tested by a series of analytical charts of millions of enterprises so far. With this idea, the manager may focus on resolving the most prominent risks affecting the complete project as early as feasible. From there, the task and the backlog are also addressed in the shortest way possible.

In the below example, the pareto chart show five defections in shirts. The first three reasons, which are botton defect, pocket defect and collar defect are accounted for more than 80%. Therefore, three reasons should be examined when decreasing defections.

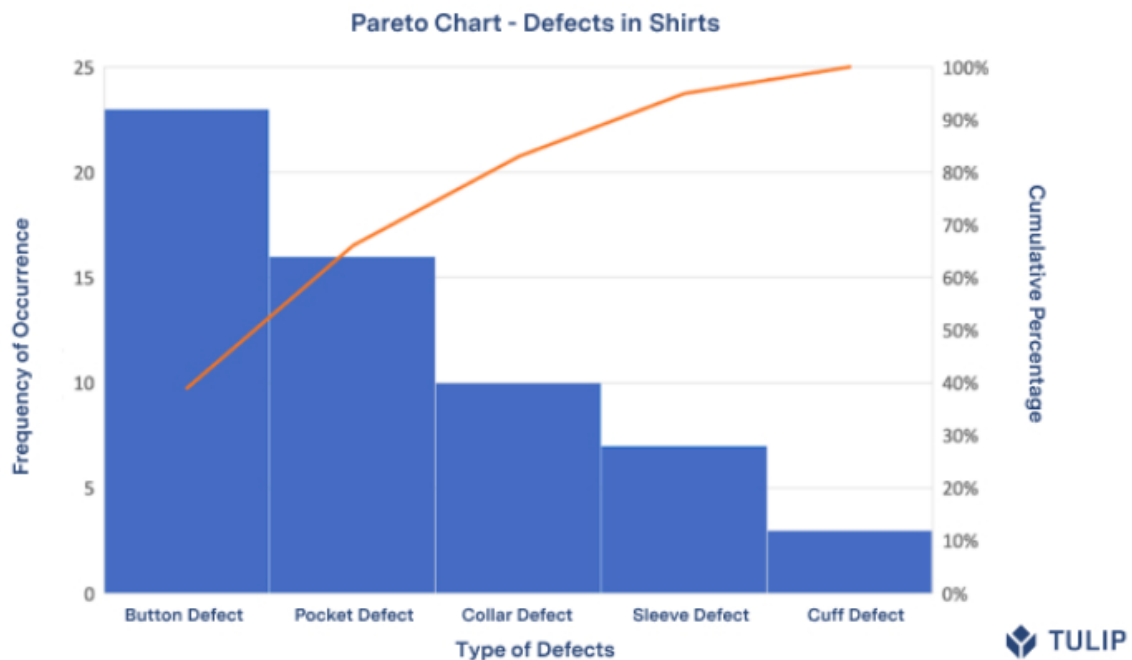


Figure 2-4 Example of Pareto Chart [Tulip.co, 2016]

## 2.8 Continuous Improvement

According to the book "The Idea-Driven ORGANIZATION," "80% of the potential to improve comes from frontline employees," indicating that minimal individual contributions consume up to 80% of the overall Improvement. Continuous improvement (CI) may be minor but cannot be underestimated; it may generate a considerably superior version after a period. CI is increasingly acknowledged as a potentially significant competitive advantage source. The primary benefits of quality, feature flexibility, and cost savings may emerge from CI activities. CI is adopted and validated by industrial enterprises throughout the globe (Damásio, 2018).

However, while theoretically simple, this system is tough to execute and sustain since it involves the stress of working for a relatively low income, which does not ensure social circumstances for most employees. It also requires small group activities - informal and voluntary- centered on CI and self-discipline.

Application technique of the CI method generally includes:

- Definition of the improvement area.
- Analysis and selection of the critical problem.
- Identification of the cause of improvement.
- Planning the remedial center measures.

- Measuring, analyzing, and comparison of the results.
- Standardization.

Process of CI concept application is closed in the PDCA cycle:

- Plan (P) relates to creating the target for improvement.
- Do (D) is related to executing the plan.
- Check (C) defines assessing if the implementation has delivered the expected gain.
- Act (A) characterizes standardizing as preventing the recurrence of the original issue or establishing targets for the new improvement.

CI is split into two steps; the first stage is based on recognition by each person. The most frequent and accessible technique to find issues is to monitor inconsistencies in performance and instead seek incompatibilities.

The second step comprises producing and presenting ideas, discovering alternate methods or procedures that are not suitable, and executing the new concept. Everyone in the company must perform their work based on conversing with new ideas and having a practical perspective.

Indicators for each employee on the route to CI implementation are:

- Giving up the generally established ideas.
- Revising how to produce it – why it hadn't been done.
- Immediate repair of the committed mistakes.
- Taking benefit of wisdom – reckless spending the money.
- Continuous finding of the solution to the “why?” query.

### **3 EXPERIMENTAL OVERVIEW**

#### **3.1 Company Introduction**

##### ***3.1.1 Mercedes-Benz Group***

Mercedes-Benz Group is recognized as one of the oldest automobile manufacturers. Daimler-Benz initially owned control of the firm. It belongs to the parent corporation, Daimler AG (previously DaimlerChrysler AG) (formerly DaimlerChrysler AG).

The company's original roots are said to have come from two independent branches. "Benz & Co. Rheinische Gasmotorenfabrik Mannheim" was established in 1883 by Karl Benz (Rhein Mannheim Benz & Co. Gas Engine Factory) (Rhein Mannheim Benz & Co. Gas Engine Factory). The firm made accessible the first automobiles with the Benz Patent Motorwagen trademark in 1886. The corporation has become one of the world's largest car manufacturers in just 15 years.

In 1890, Gottlieb Daimler and Wilhelm Maybach jointly created "Daimler Motoren Gesellschaft" (DMG - Daimler Engine Company) (DMG - Daimler Engine Company).

In 1901, the first automobiles under the Daimler-Mercedes name were initially offered by Daimler Motoren Gesellschaft.  Vietnamese-German University

On June 23, 1902, DMG chose to utilize the Mercedes name as a trademark for their automotive manufacture and legally filed the brand on June 26.

In 1907, Maybach quit the DMG. Daimler-Benz AG was created in 1926 by uniting two enterprises, Benz & Co. Rheinische Gasmotorenfabrik Mannheim and Daimler Motoren Gesellschaft (Daimler-Benz Joint Stock Company) (Daimler-Benz Joint Stock Company). The new firm is a merging between Mercedes-Benz and another well-known carmaker.

From 1907 until today, Mercedes Benz has been attempting to preserve its place in the car business. With the quality and credit earned over a century, the Mercedes Benz insignia is considered a luxury symbol.

##### ***3.1.2 Mercedes-Benz Vietnam***

The automobile company in the research was created in 1995, invests in the manufacturing and business of automobiles in Vietnam, has contributed immensely to the

expansion of the market, and has become a significant participant in the local automobile industry.

**Business sector:** Production and sale to the Vietnamese market of 5-seater, mini-bus, 16-seater, city bus, and tourist buses.

**Company size:** 105,000 m2

**Operation type:** 100% foreign investment

**Production capacity:** 7000 vehicles/year

**Main markets:** Asia, Europe



- **Company foundation:**  
Foundation stone was laid on 19-Nov-1995
- **Start of production**  
The first E230 (W210) car was launched in Aug-1996
- **Area of the premises**  
105,000 m2
- **Passenger cars produced**
  - C-Class: W202, W203, W204, W205 and W206
  - E-Class: W210, W211, W212, W213 and W214
  - GLK (X204) and GLC: X253 and X254
  - S-Class: V221 and V222



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- **Commercial vehicles produced**
  - MB 100 series (Van)
  - Bus
  - Sprinter (Van)
  - Fuso (truck and bus)

*Figure 3-1 Mercedes-Benz Vietnam overview*



Figure 3-2 Production model of Mercedes-Benz Vietnam

### 3.1.3 Production Overview

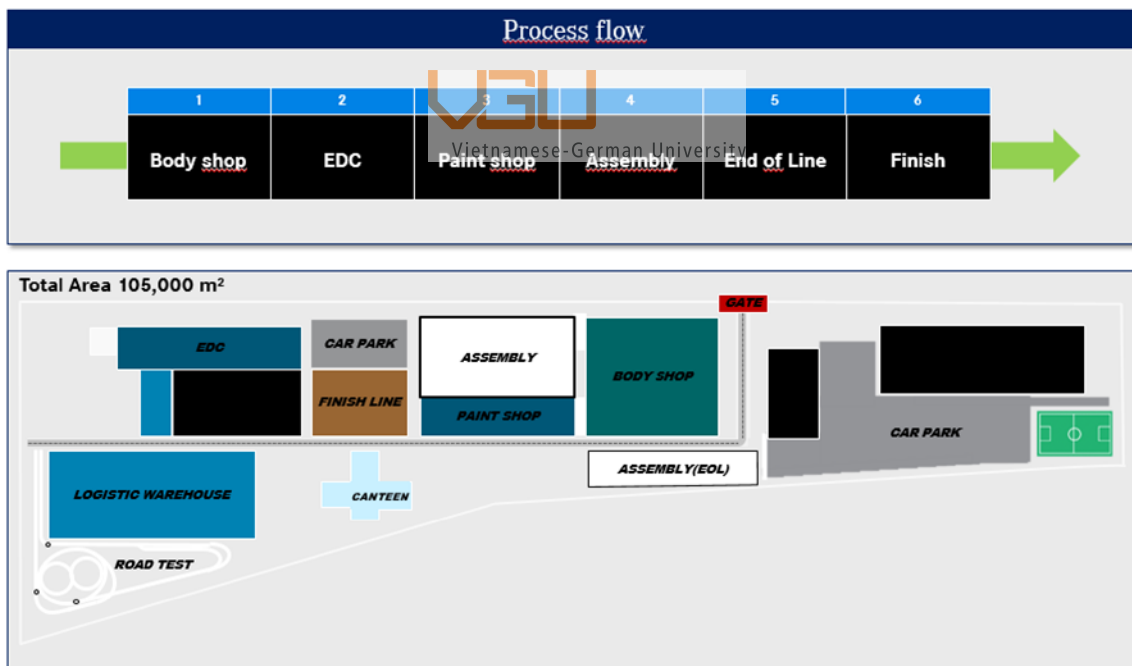


Figure 3-3 Process flow in Mercedes-Benz Vietnam

The assembled components will be packed and shipped by the worldwide logistics department. After being sent to the factory, the parts are randomly examined to assure quality before assembly.

The steel and aluminum pieces at the Body shop will be united due to electrical insulation from pneumatically operated welding grippers. Before leaving the body shop, the above-mentioned process will be examined at the quality inspection gate.

Next, the welded chassis will be carried through the paint workshop. Here, the frames will be electrostatically embedded. This is a modern and environmentally friendly electrostatic painting technology. Next, the chassis will be coated with paint and anti-corrosion coating. Areas with a high risk of leaking shall be covered with PCV. Then it will be applied to the foundation layers for coloring and polishing. After painting and drying, the body is randomly examined at the quality inspection gate. Finally, all vital spots are coated with a wax coating to prevent the inside out.

At the assembly line, the chassis will move through 15 stations to assemble vital components, wiring, furniture, and engines, then refuel and test run based on quality standards; the tests on measurement and test run are replicated on the objective circumstances to assure the quality of the car.

At the end of the line, there will be a quality inspection gate for cross-checking all cars. After assembly, in addition to the employees' self-inspection and the inspection at the end of each line, each car will be examined by the production department, the quality department, and a random in-depth quality inspection of the final vehicles depending on the customer's point of view.

### **3.2 Scope of research**

When the new series was launched, the technical processes changed, especially the chassis. Hence, the Bodyshop Line needs an intervention in Standardization and Line Balancing.



### 3.2.1 Bodyshop Line Workflow

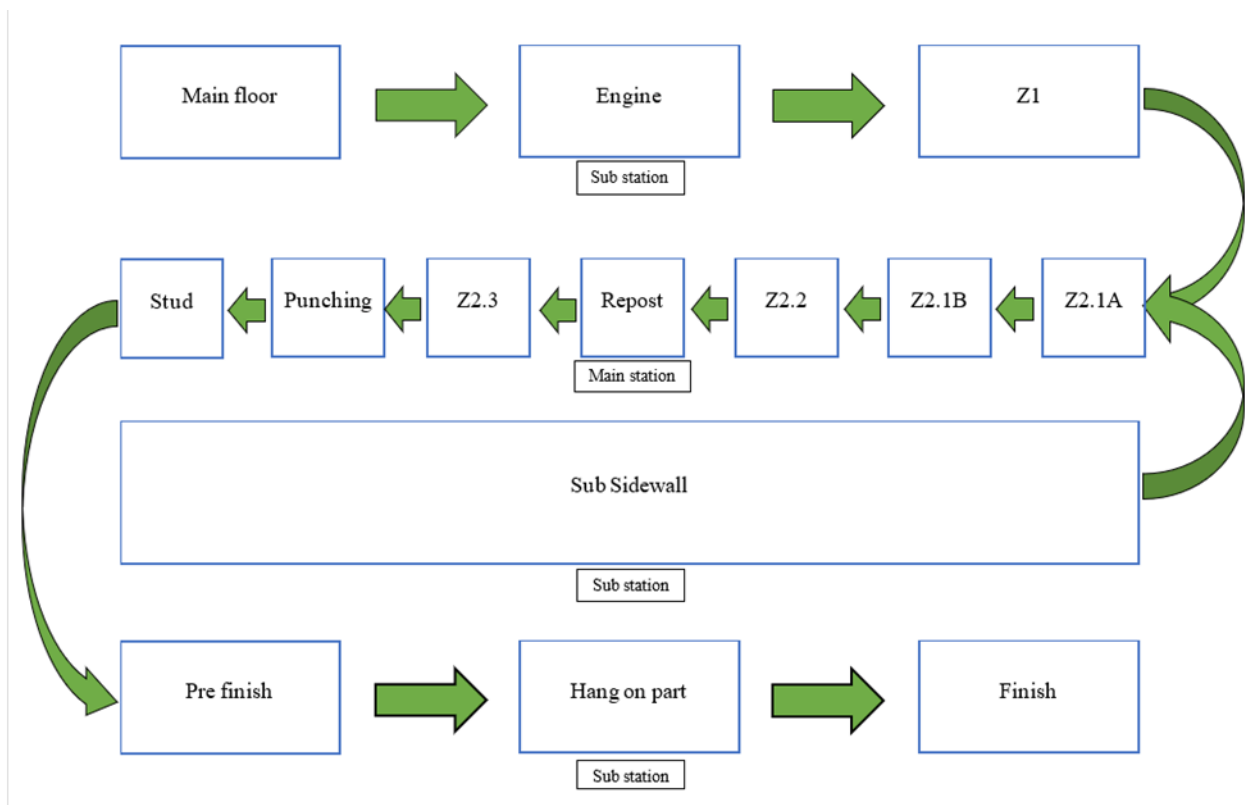


Figure 3-4 Bodyshop Line Workflow  
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In Body Shop, the workflow will be started first with all the Sub station after all the foil has taken shape. Then, it will merge into the mainline and transfer to the Finish line, which is situated on the finish line.

The main line is responsible for merging all components delivered by the Substations. Ranging from Main Floor to Z1, they are responsible for forming the chassis of the construction. In sub side wall, they are responsible for developing and installing all the side and the roof frame of the automobile. Once finished, the chassis will be shipped to Finish Line to recheck the sealer and gaps.

### 3.2.2 Manpower, Equipment demand

The demand of manpower and other equipments in order to work is list in table below. However, this can be modified after improvement in the right quantities.

<b>List</b>	<b>Quantity</b>
Manpower	10
Equipment	Welding robot: 3
	Welding gun: 32
	Sealer gun: 20
	Jig: 56
	Crane: 26
	Trolley: 4

*Table 3-1 Demand of manpower and equipment of Bodyshop*

### 3.2.3 Operation parameter



Below table presents the operation time of operators in Bodyshop. Operators work one shift per day, which means 9 hours; 5 days per week; and approximately 20 days a month. Operation time parameters is fixed in this research.

<b>Index</b>	<b>Time</b>
Shifts	7:30 - 16:30
Hours per day	9 hours
Days per week	5 days
Days per month	20 days

*Table 3-2 Operation time of Bodyshop*

### 3.2.4 General work process

All main work processes in Bodyshop of each station after analyzing are shown in below table. Those are parent processes, and child processes have not been considered in this research yet. Each work process has standard time, with error of less than  $\pm 0.3\%$ . This work processes are also the foundation of the improvement in research.

For instance, in station main floor, there are five main work processes that is Parts cleaning and loading, sealer gun betamating, floor GEO welding, floor respot welding, and jobcard stamping. When do the lean application in this station, only main steps are reviewed in order to reduce cycle time in each station.

Order	Station	Process
1	Main floor	Parts cleaning and loading
		Sealer gun betamating
		Floor GEO welding
		Floor respot welding
		Jobcard stamping
2	Engine	Stirnwand welding
		Firewall crossmember welding
		Front end welding
		Jobcard stamping
3	Z1	Sealer prepair
		Sealer Glass frame welding
		Sealer gun betamating
		GEO welding
		Respot welding
		Jobcard stamping
4	Sub sidewall	A-pillar welding
		B-pillar welding
		Fender welding
		Inner sidewall welding
		Sidewall roof frame welding

		Longmember welding
		Sidewall integral welding
		Jobcard stamping
5	Z2.1A	Sealer gun betamating
		Inner wall GEO welding
		Inner wall respot welding
		Luggage compartment bone welding
6	Z2.1B	C-pillar GEO welding
		C-pillar respot welding
		Rear car resport welding
		Welding slag removing
		Job card stamping
7	Z2.2	Border cover sealer betamating
		Border cover welding
		Front car drilling and rivet applying
		Sidewall and cover of carriage connection welding
		Rear capo chassis welding
		Fender border cover drilling and river applying
		Job card stamping
8	Respot	Luggage hold and tail-light connection welding
		Left-hand chassis welding
		Right-hand chassis welding
		Rear-car chassis welding
		Joint checking
		Job card stamping
9	Z2.3	Left-hand frame welding
		Right-hand frame welding
		Lamp position drilling and enlarging
10	Punching	Car chassis welding by KUKA robot
11	Stud	Roof and windscreen frame MIG welding
		Car chassis welding by KUKA robot
12	Pre-finish	Welding slag removing

		Rear car sanding
		Roof assembly
		Job card stamping
13	Hang-on- parts	Door assembly
		Rear capo assembly
		Torque wrench checking
		Front capo assembly
		Fender assembly
14	Finish	Car chassis checking and adjusting
		Front and rear capo checking and adjusting
		Job card stamping

*Table 3-3 General process in stations of Bodyshop*

## 4 EXPERIMENTAL PROCESS

### 4.1 Data acquisition

To perform the standardization and balance of the transmission, the work process and the time to complete them are necessary. For Mercedes-Benz globally, there is an app called CGIS that contains all the above-mentioned essentials. However, the time taken to perform the work at each factory worldwide differs due to the different layouts. In addition, the work at the Body Shop line is complicated because of technical issues, so observing and recording videos is the best way to have specific process work and time for each job. The video recording techniques are relatively straightforward; each operator has to be filmed at once and independently. The recording phase has to be undertaken as soon as all station operators start to work from the beginning till they are done. After recording all the process, data is analyzed by all members in charge. Then a final standard procedure is with least idle time is given. The example of standard time data at Bodyshop is shown below (data is blur regarding to company regulations).

To get the most objective data, Operators are required to work generally as always rather than faster or slower, as it will affect the standard for the whole plant when SWI is completed. The finished video will be sent to the company's security file, which will then be identified by the station name, the operator's name, and their ID for future classification and analysis.



*Figure 4-1 Data collecting*

## 4.2 Data analysis

### 4.2.1 Work element

The primary purpose of video analysis is to create a work standard with a reasonable amount of time from which to apply the knowledge of line balance to achieve lean manufacturing goals. Speaking of lean production, it is impossible not to mention the fundamental errors that cause waste during the production process, so the product follows the theory of 7 kinds of waste.

Theory and practice are always a problem for automobile production, especially Mercedes-Benz. To find the waste, the company decided to classify the work process into elements:

- **Moving (M):** Includes two types of tasks, such as moving to Kanban or trolley, unpacking, and checking whether materials or parts are defective or not. This element can be improved by redesigning the layout or redesigning the movement of the operators to have the most appropriate and shortest time.
- **Installing (I):** This type of work involves mainly engineering to connect parts into a block, such as assembly, welding, cavity, glue, etc. After this type of work ends, the operators often mark the green pen according to the factory standards, which is a benefit in video analysis work. In Lean, this element can be defined as value-added work. Because it is a high-value job and significantly affects technical standards, the company will not intervene too much in reducing time.
- **Document (D):** Document-related tasks such as barcode scanning, document recording, and document stamping will be considered document work. Documentation is an equally important type of work because it helps control workflow deficiencies and keep track of who is responsible for those processes.
- **Waiting (W):** This type of work is basically a waste, so most of this time will be lost in the analysis process. However, there will be mandatory waiting periods due to technical factors. Therefore, after data analysis is completed, alignment with operators and group leaders is essential.
- **Equipment (E):** work performed by self-operating machines that are considered equipment, such as welding robots, flashing machines, and shower machines. Because it is automation, in order to make improvements, it can only upgrade the machine. But

that seems impossible because the machines have been most carefully designed by the Mercedes-Benz Group.

Work elements ID
E
W
D
C
M
I

Figure 4-2 Main Work Elements in SWI

As seen above, MBV utilizes two categories of waste according to the seven kinds of waste theory. In addition, implementing the 80-20 approach, concentrating on immediate wastes, is straightforward yet offers excellent efficiency. Instead of spending too much time on technological waste, MBV intervenes on the human waste that is waiting and moving.

#### 4.2.2 Time Analysis

Time analysis is about understanding the work process and its actual time to assess what time is valuable and wasted. To make this easy, the Yamazumi chart is an indispensable tool in the time analysis process. The Yamazumi Board visualizes all work processes of an operator along with the time taken for each work process to be executed.

The Yamazumi Chart is a compilation of boundary bars that display jobs with time stacked on top of each other. Work processes are numbered from start to finish according to the operator's workflow to filter and search data while eliminating waste. Yamazumi illustrates the duration of each operator's single action during a work cycle with calibration measured in seconds so that the most profound intervention can be made in rebalancing the line.



For easy access to everyone, MBV decided to denote all the data on the excel software. For easy access to everyone, MBV decided to denote all the data on the excel software. The eHPV (an engineered hour per vehicle) and MV (manufacturing variable) activities are categorized by color based on the type of work. Based on the Yamazumi chart, these wastes are easily identified. It plays an important role in cutting and rearranging the work between stations.



### **4.3 SWI Implementation**

A basic Standard Work Instruction was developed to analyze the current situation and current state of the whole factory. Thus, to provide the solutions to increase the productivity of line. First, a SWI Workbook component is built in supporting to make a Standard Work Instruction. All the work processes were recorded and analyzed then aligned with operators and supervisors to get the most satisfactory standard work instruction. Plus, the data of standard time of work process is used to make a dashboard by data visualization. The details of implementation are shown below.

#### **4.3.1 SWI Workbook components**

Standardization Work Instructions are instructions and guidelines specifically designed for operators to perform a certain number of tasks with standard time, positions, and several operators needed for a specific job. Standardization Work Instructions are the first and most important step to achieving Lean manufacturing. It refers to documentation, the name of the processes needed to be completed, and the time to finish one task.

Creating a Standardization of Work Instruction helps to minimize redundant operators in the process. Furthermore, the word standardization means that all of the procedures must be sorted and visualized so that everyone can use them efficiently. During the observation and recording period, we can easily see whenever there is a considerable amount of time wasted by operators, such as waiting for other operators or hidden waiting in moving and shopping steps.

The standardization work instructions create a standard form for the document based on the standard guidelines for documents of the Daimler AG standards. The instructions also connect the real observation standard time of a specific process, and the training level of the operators also knows the training matrix. Because of the connection between different data to identify waste, Microsoft Excel is used for easy decorating.

The complete excel standardization work instructions workbook for one station includes four important sheets, Yamazumi time analysis (YTA) used for analyzing the process and time of operators, Standard time (Std time) used for recording standard time of process steps after analyzing and aligning with the operators or supervisors, Standardization Work Instructions (SWI) using for assign work for operators, Training Matrix (TM) supporting supervisors catching operators level of working and maintaining in the specific station area.

Mercedes-Benz Vietnam		Standard Work Instruction (SWI)													WORKPLACE LAYOUT
Dist.	PRODUCTION	Work Elements		Model	Subtime	Sequence	Cycle-time	Cycle-time	Cycle-time	Cycle-time	45				
Step	ASSEMBLY			SEC	Sec	Sec	Deviation	Deviation	Deviation	Deviation					
Acc.				PSS	Process ID	Std. Time	OP1	OP2	OP3	OP4					
Ref.	1.0			mark		(min.)	A170	A174	A180	A185	A170	A174	A180	A185	
No. Step no.	Process Step (English)	Process Step (Vietnamese)	PSS mark	Process ID	Std. Time (min.)										

Figure 4-3 Complete template of standard work instructions

The first top segment of the SWI contains the title, which includes the company name in the top left corner, the name of the SWI in the middle, and information about the elements required in the instructions.

The second top segment contains a column that shows the standard time a process is estimated to complete. Following are cells that display the cycle time, which is the longest among the selected operator's cycle times, and the deviation between the highest and lowest cycle time between operators. After the supervisors are assigned process steps to operators, the number of cycle times and deviation will automatically appear based on the excel formula.

The third segment on the right of the worksheet is the working layout of the station. According to the station, a suitable layout will be used for the operators or supervisors to locate parts and components. Finally, a miniature model of a Mercedes-Benz car is printed following the position according to the place where operators execute the process.

#### 4.3.2 Alignment with operators and supervisors

After fully analyzing the process of all operators in one station, the process steps are transferred to the SWI sheets. However, it is not ready for use; we need to work with the operators to confirm that all of the analysis is corrected. Based on the information, we align

with the Supervisors who are familiar with their in-charge stations using the observation video and using time analysis tools to identify the process steps and time to confirm the most significant factor: the standard time. The data and information are published and visualized for future Continuous Improvement processes.

The area where the process steps are executed around the car is also put in order to follow the positions of the operators. We need to insert the correct standard time for each process step because it will contribute to creating the total cycle time of the station, and based on that cycle time, we will be able to recognize the bottleneck of the Body Shop process and move forward to the innovation process.

A Work Element ID for each step is also assigned using the format that we created that could give comprehensive instruction on what properties the process steps performed in that station. The following work element ID is used to analyze the specific station's decomposition based on the standard category.

E	Equipment
D	Documentation
C	Checking, adjusting
M	Moving, shopping, unpacking
I	Installing/Assembly (eHPV)

*Table 4-1 Work element ID categories*

Although each station has its specific responsibilities for installing specific parts, each cycle of installation in each station shares certain parts including:

- M: The action is that operators walk to trolleys or kanban boxes to search and collect parts and then bring them back to the car.
- I: The action that the operators take responsibility for installing the parts onto the car body also includes attaching the parts onto the fixture, tightening the screws, positioning brackets, and routing and connecting electrical wires,... In general, these processes are called eHPV: engineering hour per vehicle or as I understand it the value-added process.
- C: The action includes visual check, final check, and second-hand check-in which visual and final check are the processes carried out when finished each cycle work. While

second-hand check performs checking the condition of the installing parts to make sure that parts are installed correctly and meet the corporation requirements.

- D: The action that operations checking, writing, and stamping Job card which is the paper follows with each car during its assembly process.
- E: Robots execute these activities A finishing SWI will contain the Cycle time of each operator, and it will take the highest time to become the cycle time of that station.

A finishing SWI will contain the Cycle time of each operator, and it will take the highest time to become the cycle time of that station.

According to the work element of the example station, the category of each process step is divided and summed all of the standard time. We use the analyzed work element to identify the amount of each type of process step in that specific station and how it affects the cycle time of the operators.

## 4.4 Visualization data

Data visualization is the process of transferring information into a visual context, such as a map or graph, to simplify the data for the human brain to comprehend and extract insights from. The primary objective of data visualization is to facilitate the identification of patterns, trends, and outliers in massive data sets. Information graphics, information visualization, and statistical graphics are often used interchangeably.

When data has been gathered, processed, and modeled, it must be displayed to draw conclusions according to the data science method. Data visualization is also a component of the broader subject of data presentation architecture (DPA), which strives to discover, find, modify, package, and convey data as efficiently as feasible.

In this case study, data is translated into a graph to see the bottleneck easily. There are features such as takt time, cycle time, total time of processes, and the deviation between operators in each station that are presented in the graph, which is used to analyze the current situation.

### 4.4.1 Takt time

Takt time is the rate at which needed to complete a product in order to meet customer demand. In manufacturing, takt time is an essential measure of output against demand (Lam, 2016).

$$\text{Takt time} = \frac{\text{Operational time per shift}}{\text{Production quantity required pershift}} = \frac{7.5 \times 3600}{6} = 4500(s)$$

### 4.4.2 Cycle time

Cycle time is the time spent working on producing a product until it is ready to ship. It is the amount of time required to execute one job/product. In this case study, a cycle time of line is the longest time to finish tasks in one station (Ohno, 1988).

### 4.4.3 Total time

Total time or processing time can be defined as the time taken for the entire procedure to run and end with the resulting number of processors and cycles.

#### 4.4.4 Workload deviation

The deviation in workload between operators is shown to get the general view of the whole process. When the deviation between operators is imbalanced, the cycle time of stations is high. eHPV + MV Chart

#### 4.4.5 eHPV + MV Chart

To assess the percentage of each station, tasks are divided into 5 categories (including: installing; moving, unpacking, and shopping; waiting; checking and adjusting; documenting). Additionally, work elements are separated to 2 groups:

- eHPV: Tasks that add value directly, including assembly, under Installing category.
- MV: Tasks that do not directly add value (Moving; Checking; Waiting; Documenting)

An eHPV+MV Chart is used to analyze the proportion of eHPV and MV, therefore the author can give the proposal of solution for the current situation. There are five colors representing five categories. The green part is Installing, red is Moving, yellow is Checking, orange is Documentation and blue one is the processes are done by equipments (no need to support by operators).



In the below example, it is represented that there are some operators who work in two stations simultaneously.

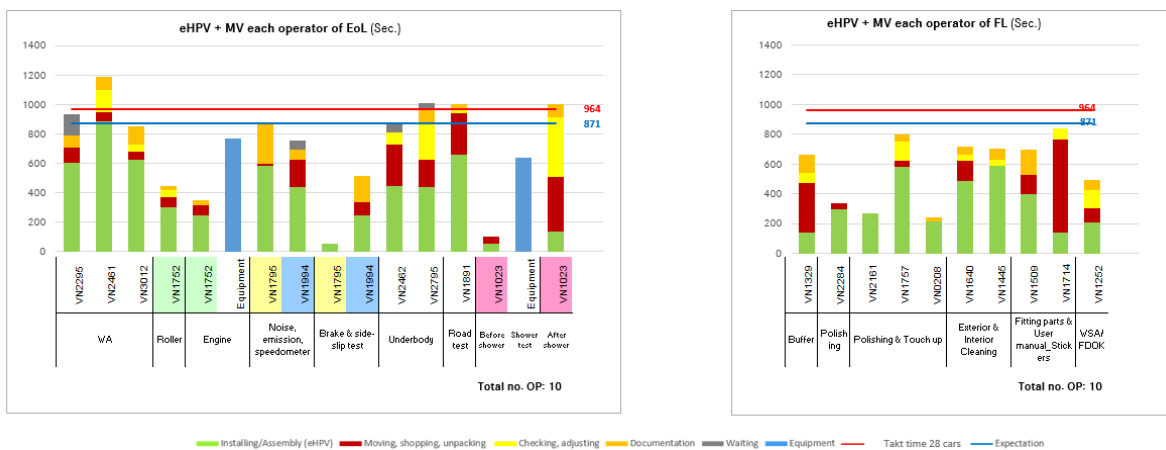


Figure 4-4 Example of eHPV+MV Chart

**4.5 Dashboard**

According to the General Statistics Office, it is estimated that in January 2022, the total number of domestically manufactured and assembled cars is 38,300 units, up 7.9% compared to December 2021 (with about 35,500 units). However, Mercedes-Benz Vietnam now is having a productivity issue. The Bodyshop line's productivity is still below the company's aim in 2021, and the Bodyshop line's actual production volume numbers are displayed below:

	21/7	21/8	21/9	21/10	21/11	21/12
Daily making (car/shift)	3	3	4	4	4	4
Actual capacity (car/shift)	6	6	8	8	10	10

*Table 4-2 Production volume of Bodyshop per shift*

The performance of the Bodyshop line in the final six months of 2021 did not meet expectations, and each line's capacity was not fully utilized. The company must find ways to increase both productivity and line efficiency to aid the Bodyshop line reach the company's target of 8 cars per shift (increasing 2 cars/shift) and satisfy consumers' expectations.

Then, we look at the dashboard to see the overall of each station and identify the most time-consuming processes. Furthermore, the bottleneck station can be identified based on the dashboard which visualizes every station's cycle time and the deviation of the longest and fastest operators in each station.

The below Chart shows the cycle time of stations in Bodyshop. The grey part is represented for cycle time, while the yellow one is deviation time of operators in one station.



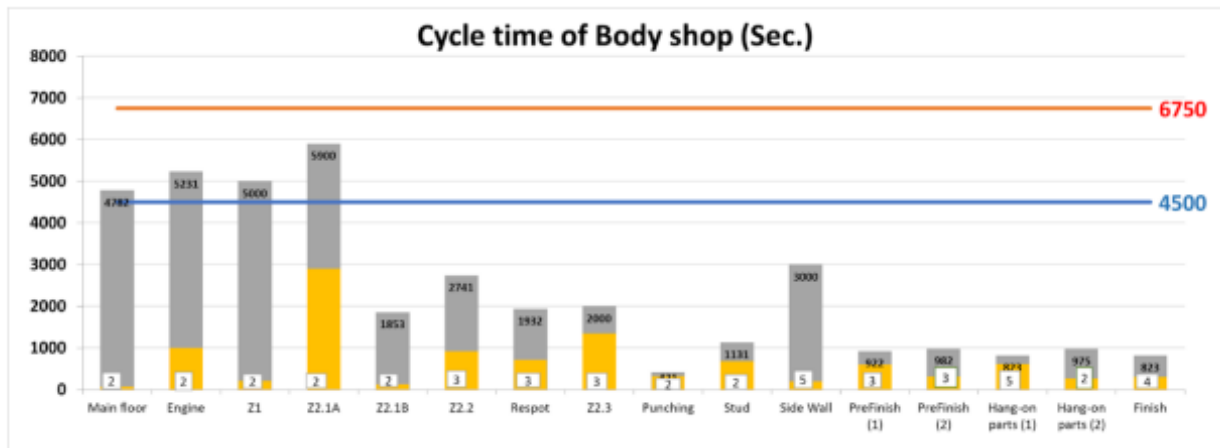


Figure 4-5 Bottleneck and deviation visualization

According to the production plan and the total working time of a day, the corresponding takt time of 4 and 6 cars is calculated and demonstrated by the red and blue lines respectively. Because during the data collection period, the factory was only producing 4 cars a day, so takt time had changed to 6 cars. The chart shown here has a cycle of each station filled with grey, If the cycle time is higher than the takt time (6 cars) it indicates that the station is having a bottleneck. Also, the yellow fill indicates the deviation, the larger the gray fill the larger the deviation will be.



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From the chart above, we can see those stations: Main floor, Engine, Z1, and Z2.1A are having bottlenecks. Therefore, to ensure the productivity that the company expects, it is necessary to reduce the cycle time of these stations.

## 5 Improvement and Result

### 5.1 Problem statement

The term "bottleneck" refers to the typical shape of a bottle and the fact that the bottle's neck is the narrowest point, which is the most likely place for congestion to occur, slowing down the flow of liquid from the bottle (Aadarsh, 2015).

A bottleneck can have a significant impact on the flow of manufacturing and can sharply increase the time and expense of production. Companies are more at risk for bottlenecks when they start the production process for a new product. This is because there may be flaws in the process that the company must identify and correct; this situation requires more scrutiny and fine-tuning.

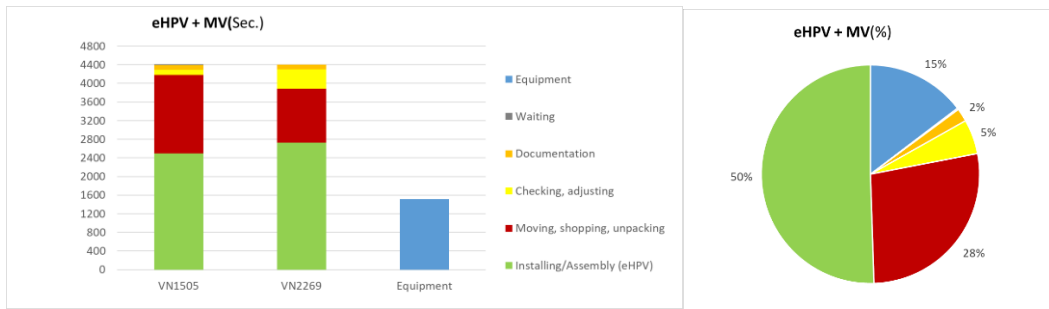
Based on data observation and SWI, those charts below can be drawn. We first focus on what kind of process steps consume a large amount of time and have actions on them. Normally in many stations, installation is the most time-consuming process, however it is the eHPV process (Adding value), so we only focus on the others. Furthermore, in practical situations waiting is not clear, it usually hides in other not adding value processes so if we can cut down its time, we can also eliminate the waiting time of the bottleneck station.

  
Vietnamese-German University

We divided the categories into two different charts to show two different pieces of information. The pie chart shows the work elements distribution of the station while the bar chart describes the number of work elements of one operator.

For instance, there are pie and bar charts of work elements of station Z2.1A below. The pie chart shows the percentage of eHPV and MV of stations, while the bar charts present the eHPV and MV time of operators. In pie chart, it is easy to see there are 81% of whole process is Installing time, while Moving time is only account for 16%, checking time proportion is 6% and only 1% is documentation time. Almost the whole process in station Z2.1A is value added time.

Besides, the bar chart shows the operation time of operators. There are two operators in station Z2.1A. When visualizing, the differences in workload of operators is shown more obviously. In the example below, the first operator works more than the second one approximately 400 seconds.



*Figure 5-1 Example of pie and bar charts of work elements*

We will conduct deep analysis, depending on the work elements. There are eight types of waste, but rarely are we aware that waste can be hidden among our processes that are required. In MBV, those kinds of actions can be categorized as Checking, Moving, and Documentation. Furthermore, using the bar charts of the work elements distribution can also be visualized to balance the work in the particular stations.

**5.2 Proposal of solution**

After doing experimental process in Bodyshop, especially the visualization steps, there are bottlenecks which are mentioned in previous part. Some proposals of solutions were given to optimize cycle time in bottleneck stations. Solutions were based on the categories of work processes (Installing, Moving, Checking, Documents, and Equipment). According to Lean Manufacturing and 5s method, an importance rate of those categories was built. Then, waste was preferentially reviewed and considered to be solved. The top priority is Moving category due to its motion and waiting time. The least prioritized is Equipment because it is hard to execute and incurs a lot of costs for modifying.

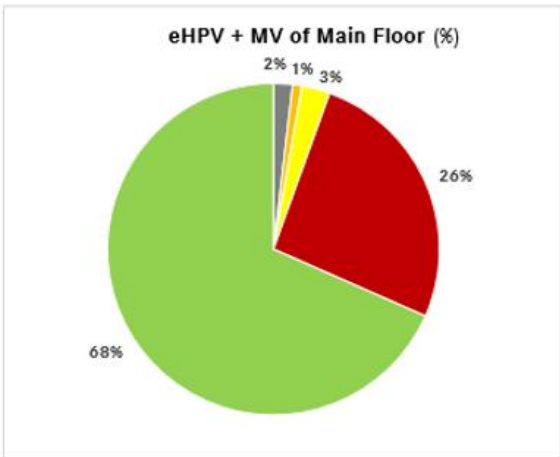
We will find the wastes in order of priority:

- 1. *Moving*
- 2. *Checking*
- 3. *Documents*
- 4. *Installing*
- 5. *Equipment*

**5.2.1 Station Mainfloor**



An eHPV + MV Chart of the station Main Floor was generated to get a general view of this station.



*Figure 5-2 eHPV+MV Chart of station Mainfloor*

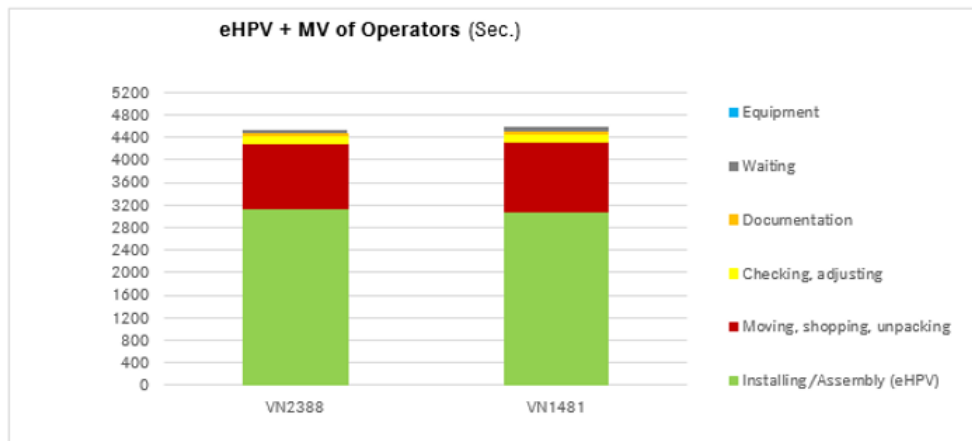


Figure 5-3 eHPV+MV Chart of Operators in station Mainfloor

Same as example above, we would consider the proportion of each category in this station. The workload of operators here is equal, so it is needed to be examined the moving performance only.

Based on the figure 5-2, the proportion of moving time is accounted for 26%, which is the first element that needed to be considered. The deviation in workload between operators is balancing; therefore, we do not need to consider it.

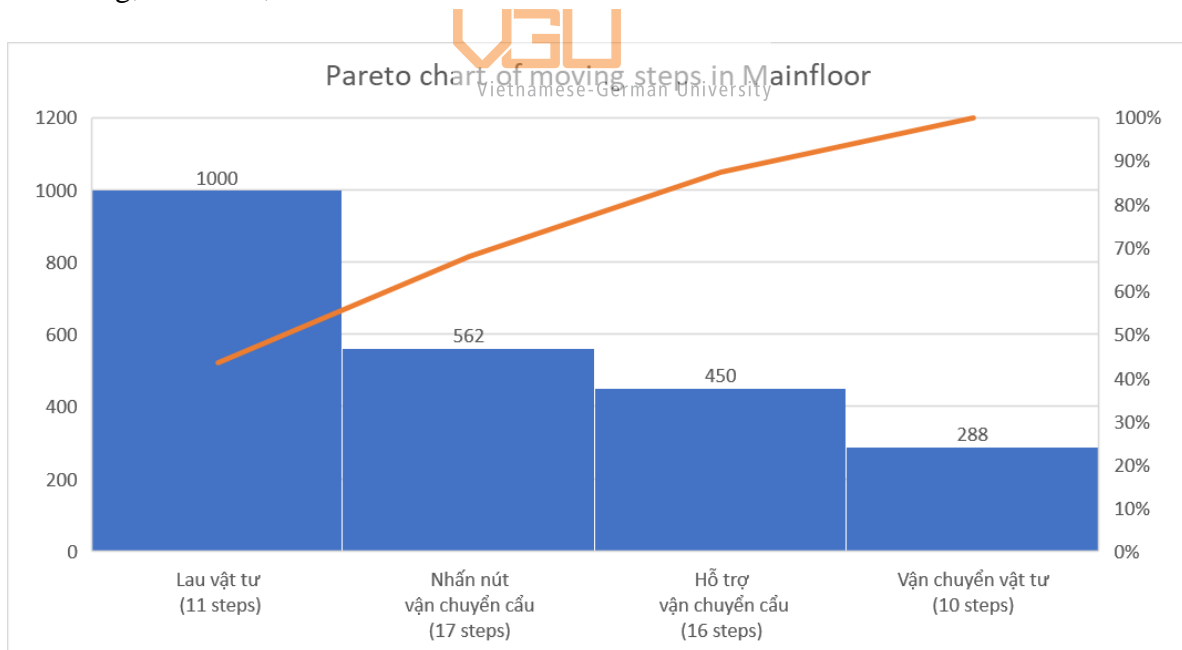


Figure 5-4 Pareto chart of moving steps in station Mainfloor

The Pareto chart was used to point out that the step cleaning parts take a large percentage of the whole moving step, which is 1000 seconds. Respectively, pushing a button and supporting

moving cranes is also a large amount. Moving parts is the slowest step, with 288 seconds. Those moving steps are considered to be reduced.

After experienced staff and group leader review, the step cleaning parts could be assigned to outsourced staff. That leads to the 1000 seconds cleaning could be reduced totally. The step of pushing botton and supporting in moving crane can be combined together. Moreover, some easy pushing processes can be assigned to outsourced staff.

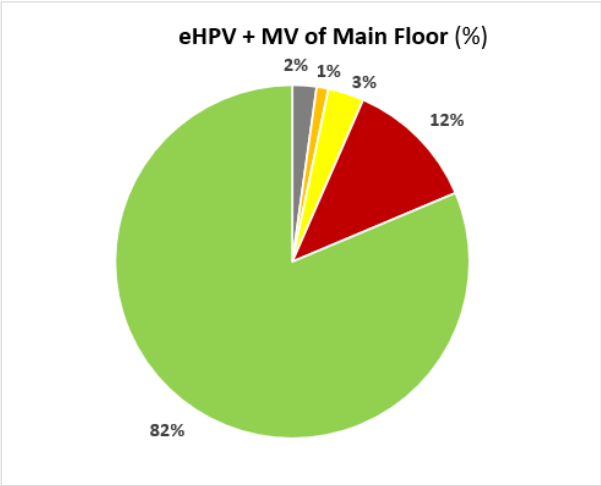


Figure 5-5 eHPV+MV Chart of station Mainfloor after improvement

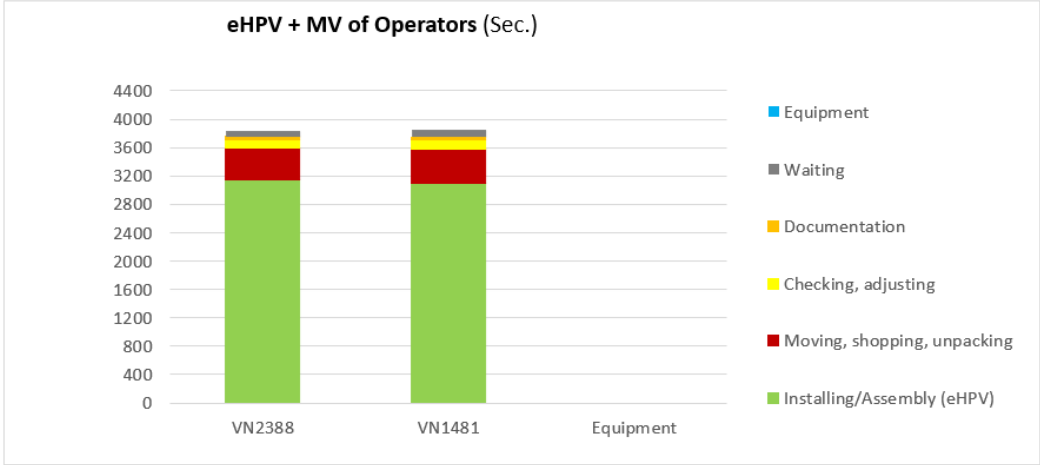


Figure 5-6 eHPV+MV Chart of Operators in station Mainfloor after improvement

After implementation, the moving time is shown a significantly decreasing by 14%, while the cycle time is reduced to approximately 3900s seconds.

	<b>Before</b>	<b>After</b>	<b>Decreasing</b>
--	---------------	--------------	-------------------

Moving proportion	26%	12%	-14%
Workload of 1 <sup>st</sup> OPs	4615s	3968s	-647s
Workload of 2 <sup>nd</sup> OPs	4762s	3847s	-915s

Table 5-1 Detailed results of improvement

### 5.2.2 Station Engine

In station Engine, the percentage of Installing was almost 80%, which is an ideal rate. Moving time only accounted for 17%, while document and checking represented a low rate.

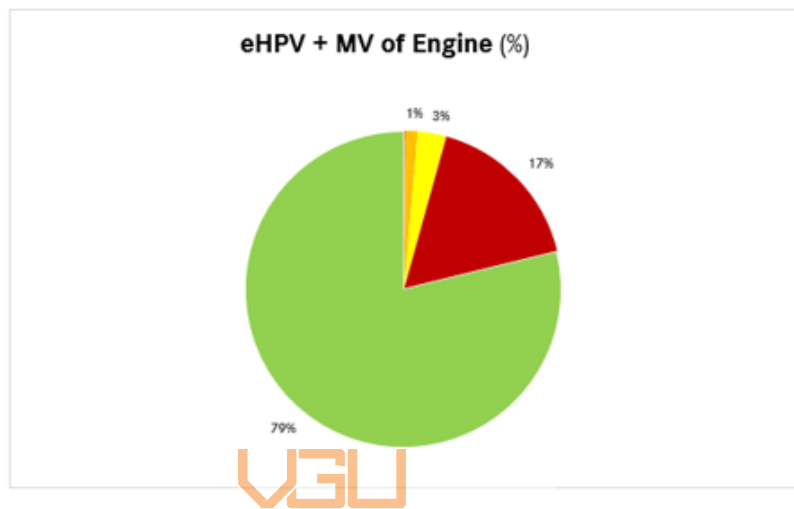


Figure 5-7 eHPV+MV Chart of station Engine

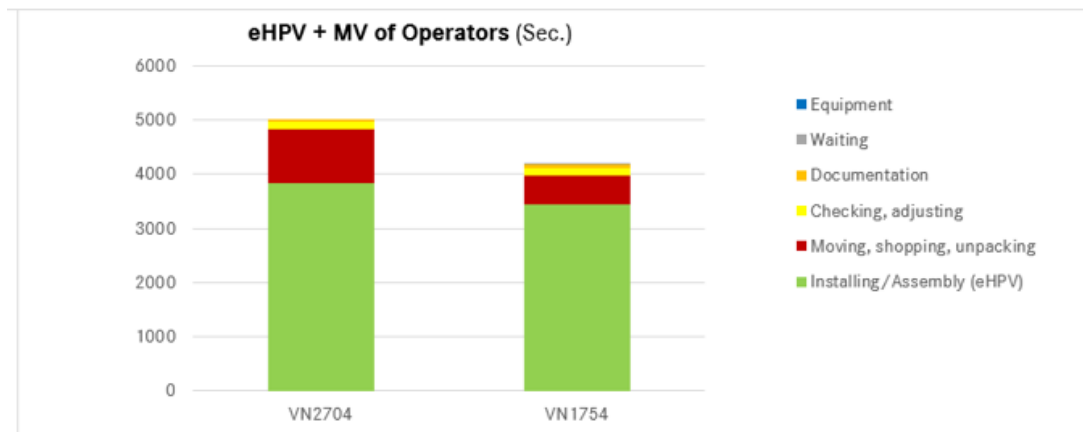


Figure 5-8 eHPV+MV Chart of Operators in station Engine

With the Station Engine, the Moving time accounted for 17%, and Installing was 79%. Moreover, the deviation in the workload of operators was also unbalancing; therefore, it was essential to rebalance the workload of manpower in the Station Engine.

In moving time, the step moving parts for gluing accounted for the longest time. It could be reduced the moving parts time by combining more parts together (currently, the operators shopping many single parts individually). With installation, the welding time could be decreased by improving the equipment. Upgrading equipment was suggested and executed by engineers. After upgrading, the welding time showed a significant decrease by approximately 700 seconds. The workload of the two operators also was rebalanced. The cycle time in station Engine was reduced from 5231 seconds to 4103 seconds.

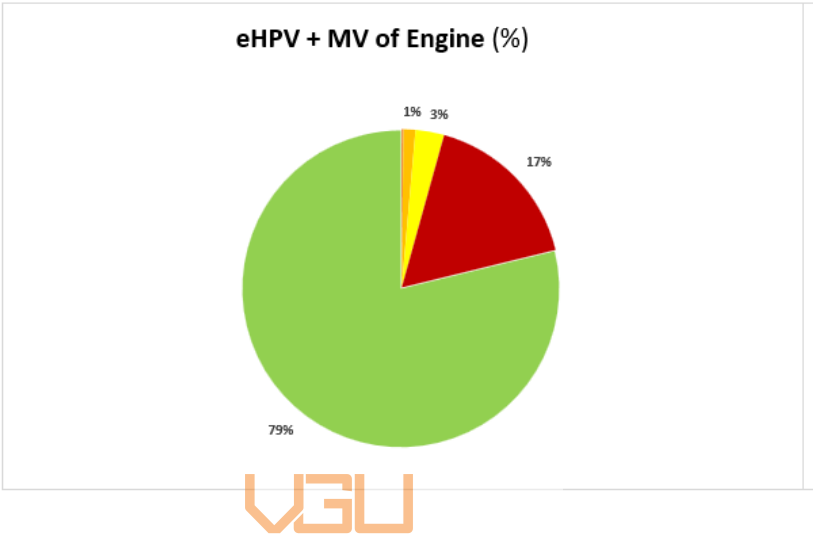


Figure 5-9 eHPV+MV Chart of station Engine after improvement

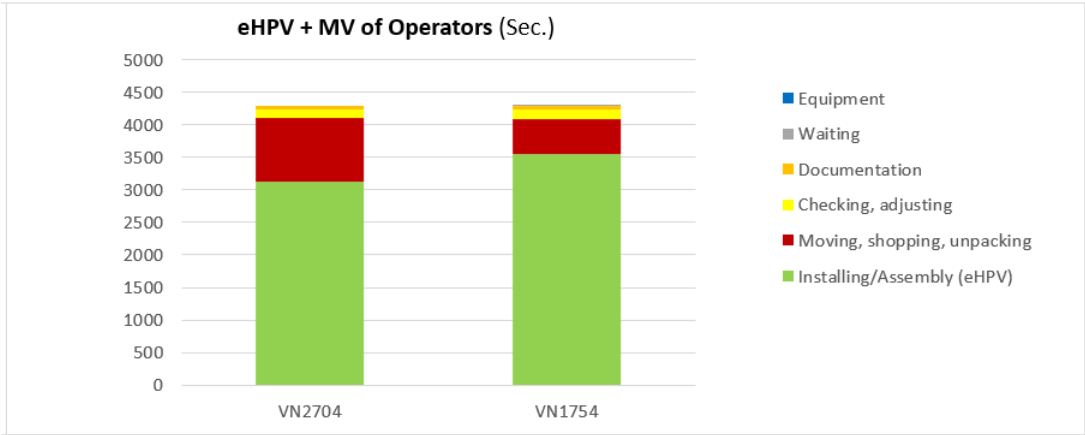


Figure 5-10 eHPV+MV Chart of Operators in station Engine after improvement

	Before	After	Decreasing
Installing time	7258s	6558s	-700s

Table 5-2 Installing time after equipment upgrade



### 5.2.3 Station Z1

There is a difference between station Z1 with other bottlenecks that is equipment is used. The equipment time accounted for 9% of the whole process.

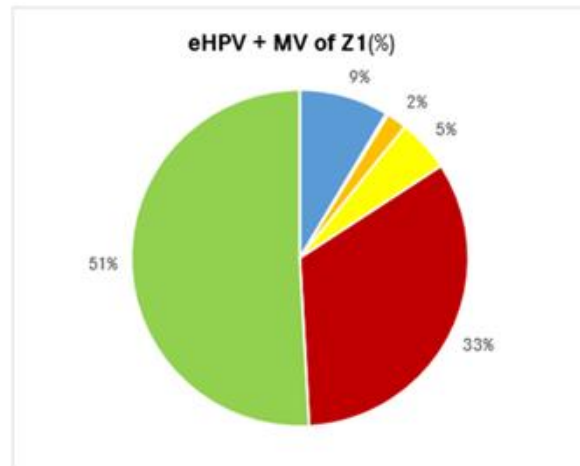


Figure 5-11 eHPV +MV Chart of station Z1

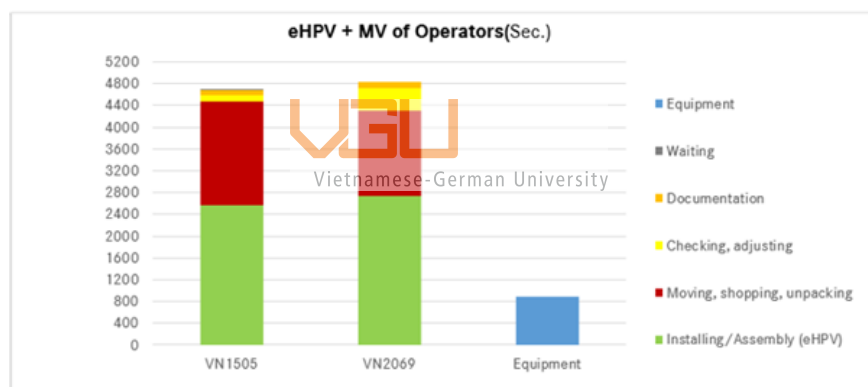
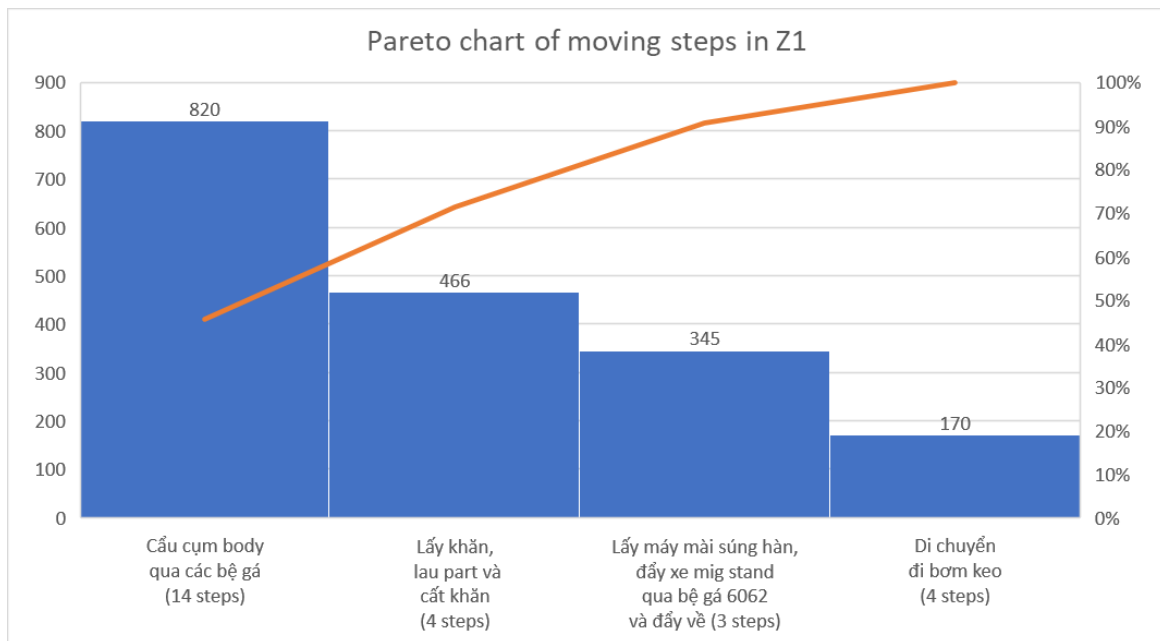


Figure 5-12 eHPV +MV Chart of Operators in station Z1

According to the eHPV+MV Chart of station Z1, the proportion of moving time is 33%. Therefore, the top priority is reducing the moving time. The workload is balancing. Therefore, it is no need to consider the workload between the two operators. A Pareto chart is used to analyze all movements in station Z1.



*Figure 5-13 Pareto chart of moving steps in station Z1*

In the Pareto figure, the author sorted four moving steps, which accounted for the most significant part. Those steps were considered to be reduced. More in-dept about steps, the moving body to jigs took more than 800 seconds and cleaning parts was about 466 seconds. Those steps could be integrated. After reviewing the whole processes, it was observed that the operators can clean part while moving body processes. In addition, the steps number 3 could be reduced by layout. The jig 6062 could be moved close to the equipment to reduce the moving time. Similar to step number 4, the position for glue pumping could be moved closer.

After that improvement, the cycle time of station Z1 was reduced by 21%. The moving proportion was reduced from 33% to 21%. The details are shown in figure 5-9.

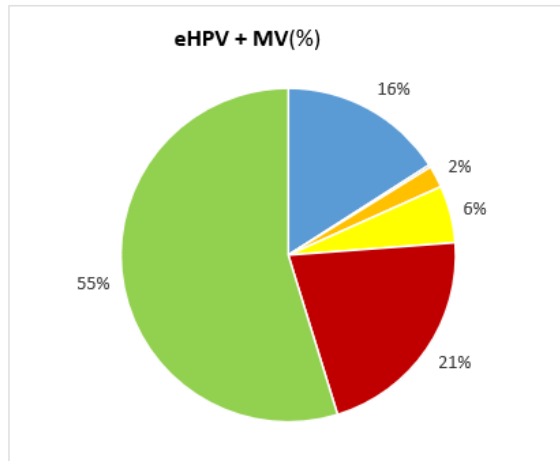


Figure 5-14 eHPV +MV Chart of station Z1 after improvement

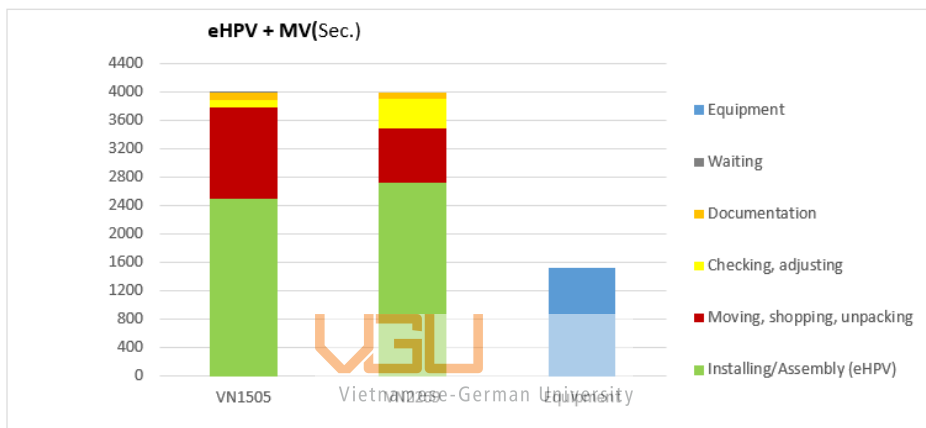


Figure 5-15 eHPV +MV Chart of Operators in station Z1 after improvement

#### 5.2.4 Station Z2.1A

According to the analyzed dashboard, station Z2.1A had the highest cycle time. Therefore, this station was mainly focused on. Due to the eHPV+MV Chart below, some proposals of solutions are considered and decided to execute. The proportion of Installing time

is 81%, while moving time is only accounts for 16%. This is one of the biggest challenges when optimizing because the Moving time is almost optimal.

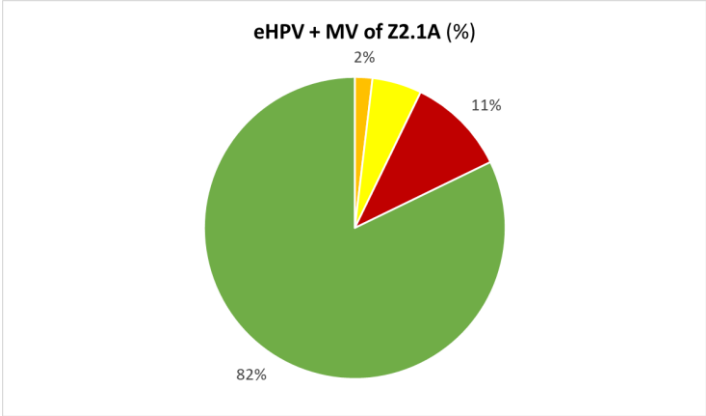


Figure 5-16 eHPV+MV Chart of station Z2.1A

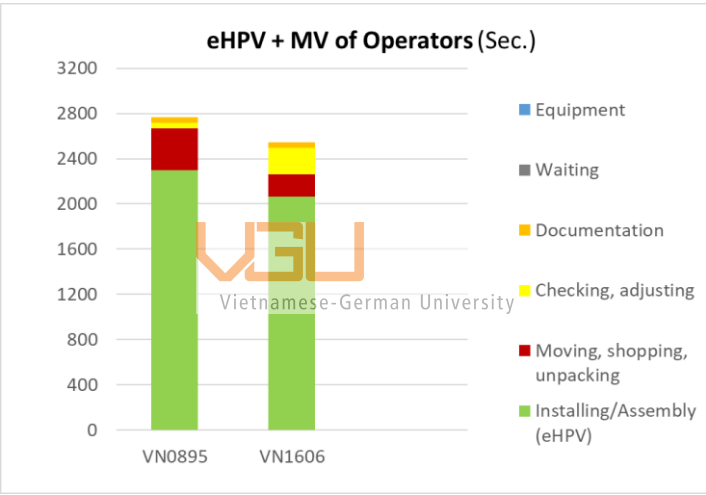


Figure 5-17 eHPV+MV Chart of Operators in station Z2.1A

In terms of moving time at the Z2.1A station, welding guns should be arranged near the place of operation to reduce the time to get the guns. Moreover, it is possible to pump many bottles of glue (used for welding cars) at once, instead of having to move and inject glue many times. We also can consider outsourcing for the cleaning part process. Installing time accounts for 81%, which is exceeding the ideal process from 65% to 80%, so we can rebalance the Installation time of this station by adding more workers or moving work to other stations. However, lowering Installing time will be harder than reducing Moving and Checking time since Installing time also depends on worker expertise.

On the other hand, there is a significant installing difference between the two operators. Therefore, it is necessary to balance the Installing work between the 2 OPs. In addition, we

should encourage and motivate OPs so that they have more motivation to work faster. Moreover, it is possible to switch from daily pay to product pay to create more opportunities for employees to develop. Since the information about one specific station is too large, it's a must that we go on the right track. The elimination of waste process isn't easy; rather it is a kind of task that needs cooperation from those who identify waste and the core team that is responsible for conducting the process.

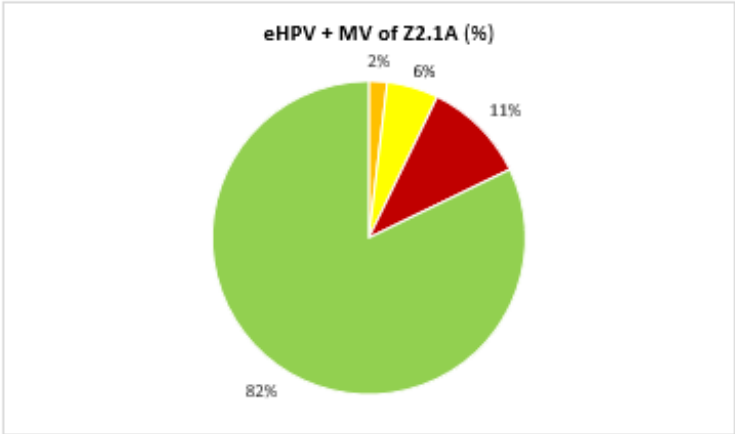


Figure 5-18 eHPV+MV Chart of station Z2.1A after improvement

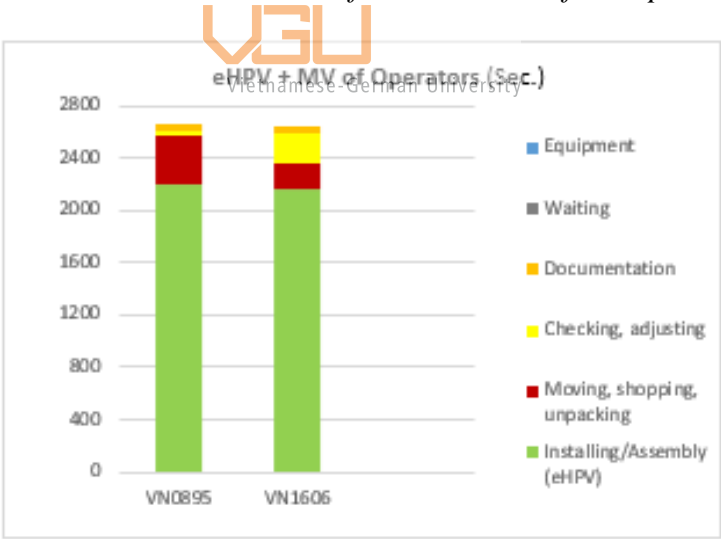


Figure 5-19 eHPV+MV Chart Operators in station Z2.1A after improvement

### 5.3 Results

Before improvement, there are 4 bottleneck stations that lead to high cycle time in Bodyshop. The high cycle time made Bodyshop could not meet the demand of company. In figure 5-12, the blue line is the company’s target. However, the high cycle time made the company set a new demand for production.

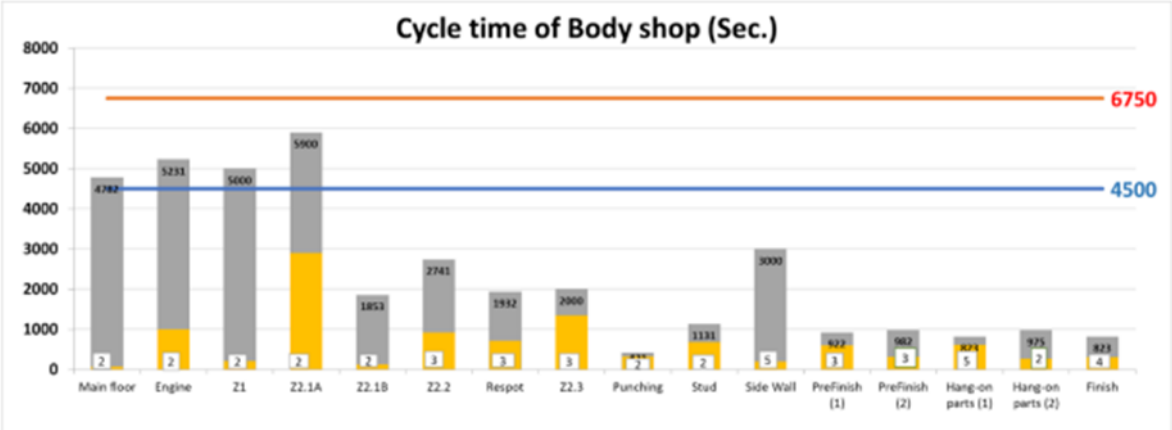


Figure 5-20 Cycle time of Bodyshop before

After negotiating with the Group leader and Manager of the Bodyshop, many proposals for improvement were given. There is reduced waste to decrease the lead time. A new dashboard with new standard work instruction is updated to evaluate the new process of Bodyshop.

Additionally, the standard time of processes could be decreased if the skills of operators were improved. The company should have a plan to train operators every year with an annual examination.

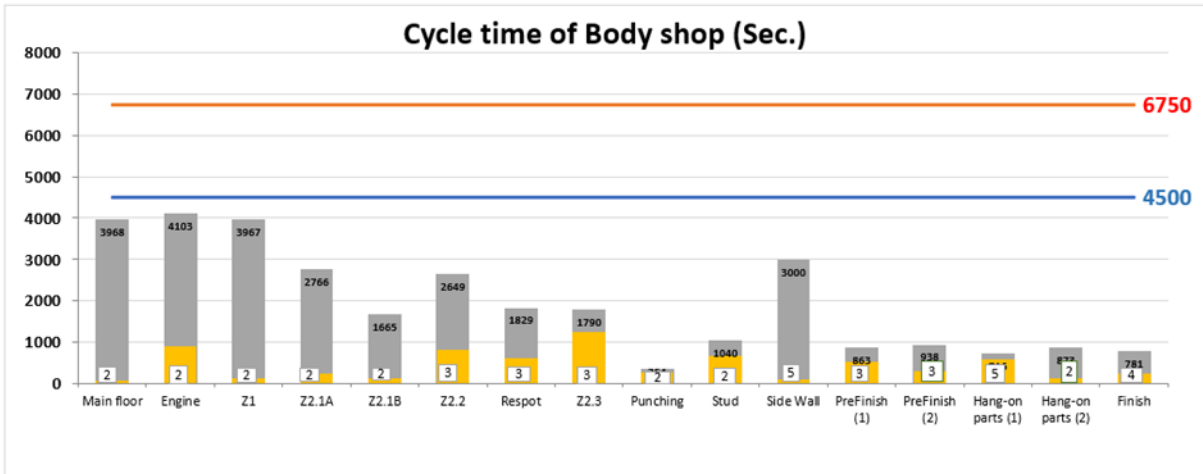


Figure 5-21 Cycle time of Bodyshop after

All bottleneck stations are improved by reducing the cycle time to meet the company's target. Furthermore, the deviation of workload between operators is more balancing.

## 5.4 Conclusion

The table below summarizes the results after implementation to decrease the cycle time of the Bodyshop.

Station	Cycle time		
	Before (s)	After (s)	Decreasing (%)
Mainfloor	4782	3968	17
Engine	5231	4103	22
Z1	5000	3967	21
Z2.1A	5900	2766	53

*Table 5-3 Cycle time of bottleneck stations after improvement*

After improvement, the cycle time of all bottleneck stations is reduced, meeting the company's target, which is 4500s. However, the deviation in workload of operators is not balancing exactly in stations, which can be the premise for future research.



## **6 SUMMARY AND FUTURE WORK**

### **6.1 Summary**

Many companies worldwide, including Vietnam, have adopted Lean production and are seeing fantastic benefits. Lean implementation, however, calls for consistency and teamwork. All employees, not just one, share the company's aim, so all employees must always strive to benefit the business. After being applied to Mercedes-Benz Vietnam, Lean helps to identify some already-existing waste of the bottleneck stations.

The paper has applied Lean Manufacturing tools and Continuous Improvement to optimize the automotive Bodyshop:

- Identify the main causes leading to unproductive problems
- Collect data, standardize station procedure
- Identify and eliminate wastes, optimize lead time by improving routes and deviation for each station
- Build new standard work instruction
- The paper has analyzed the current problem: Achieve the goal set out: Reduce the cycle time to meet the company's target.

  
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### **6.2 Future work**

Processes of other stations can be considered to be reduced by applying the mentioned method in this paper. On the other hand, SWI and Continuous Improvement are recommended to be applied to all shops in the factory.

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