

Minimising Non-Value-Added Activities in the Household Appliance Manufacturing Process Using Lean Manufacturing Tools*

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Abstract

The article concerns the application of Lean Management tools in a household appliances manufacturing company in order to reduce resource waste and improve process efficiency. The starting point is the need to increase competitiveness by eliminating activities that do not add value and implementing solutions that support sustainable development. The analysis presented in the paper consists of several stages, the most important of which are: the process of identifying inefficient areas of work, determining the key sources of losses, and the stage of implementing improvements and their evaluation. A review of the literature revealed a lack of detailed empirical analyses describing the actual implementation of Lean in Polish companies in this sector. The study used a case study method, including an analysis of the production processes of household appliances and their components, measurements of operation times at assembly stations, an assessment of material flow, and the identification of sources of waste. An assessment of the effectiveness of the implemented improvement measures using performance indicators was also planned. The results should make it possible to determine the impact of the Lean tools used, such as 5S, work standardization, and logistical improvements, on reducing losses, increasing productivity, and improving work organization. The results confirm that even minor organizational and technical improvements can significantly increase a company's productivity, reduce waste of time, energy, and materials, and improve the environmental impact of its operations.

Keywords: non-value-added activities, Lean Manufacturing, production process

Introduction

Today's market is characterised by dynamic change, increasing competition and growing consumer expectations, which poses numerous challenges for household appliance manufacturers. To address these demands, companies are constantly looking for ways to improve the efficiency of their processes, minimise costs and improve the quality of the products they offer. Meeting these challenges requires seeking solutions and strategies that will ensure market competitiveness. One such solution is "Lean Manufacturing", a well-known Japanese production method whereby all production personnel work together to eliminate waste (Ajam, Mounir 2018, Abdullah 2003). Lean Manufacturing achieves more for less by reducing wasteful use of resources, as well as eliminating production waste or non-value-added activities in the production process. In the household appliance industry, where processes are extremely complex and requirements for precision and quality are very high, waste can take many forms, ranging from overproduction, excessive energy consumption, and unscheduled downtime, large amounts of production waste and suboptimal use of employee time. In light of these challenges, it becomes crucial to develop and implement effective strategies to identify and eliminate waste in manufacturing processes. Practices such as Lean Manufacturing, Total Productive Maintenance or Six Sigma are gaining popularity among companies seeking to optimise their operations. These aim not only to reduce waste, but also to create a culture of continuous improvement, where employees across all levels are involved in identifying and eliminating waste (Tomislav and Nedeljko 2024).

A company located in southern Poland was selected for the study. The company's product line primarily includes: refrigeration (refrigerators, freezers), washing and drying (washing machines, dryers, washer-dryers), dishwashers, stoves/ovens/hobs, as well as small household appliances (vacuum cleaners, coffee machines, etc.). The company's share in the household appliances market is very high. In Europe, the company is considered a leader in the freestanding appliances category. In the global large household appliances segment, it has been ranked number 2 in the world. In Poland, the company is also one of the leaders in the production and supply of household appliances. The research was empirical in nature and was conducted in the form of a case study. Its aim was to identify sources of resource waste and to assess the effectiveness of the Lean Management tools implemented in improving production processes. The process of identifying inefficient areas of work took about eight weeks and included analysis of process documentation, observation of workstations, measurement of operation times, interviews with production workers and shift managers, and the development of a value stream map. On this basis, key sources of losses related to excessive material movement, downtime, operational errors, and improper workstation organization were identified. The implementation phase lasted approximately five months and included the application of selected Lean Management tools, such as 5S, work standardization, process visualization, setup time reduction (SMED), and improvements in material flow. After the implementation was completed, the effects were monitored for three months, including an analysis of key performance indicators.

Definition and typology of waste in Lean Manufacturing

Lean Manufacturing is a production and work organisation management concept that aims to identify and eliminate waste while increasing process efficiency. It also involves defining and delivering value that is key from the customer's point of view.

One vital element of this philosophy is identifying and minimising activities that do not add value from the customer's perspective, while generating unnecessary costs or increasing lead times.

The overarching goal of Lean Manufacturing is to optimise production by minimising resource consumption. This includes reducing production waste, labour inputs and production floor space, minimising investment in tools and shortening the time needed to develop new products to increase production process efficiency.

In the Toyota concept, waste is considered to be any factor that hinders the company from achieving maximum efficiency in the production process (Samuel and Darril 2012). In the Lean Manufacturing approach, the pursuit of perfection takes the form of the Just-in-Time system, which is one of the two pillars of the Toyota Production System. Just-in-Time is a methodology in which production is based solely on current demand - only those products that are needed at the given time are manufactured, and only in the exact quantity required. The ultimate goal is to ensure that a given product is manufactured with optimal use of resources, including human, material and machine resources, and delivered to the customer at a precisely specified time. Anything that hinders this objective is deemed wasteful. This broad view of the production process makes it possible to identify all activities and events that negatively affect the organisation's efficiency.

According to Womack and Jones (Dall and Akçagün 2013) all processes involved in designing, ordering and manufacturing a product can be divided into three categories:

- operations that add value for the customer,
- operations that do not add value but are required by current product development, order fulfilment or production systems and therefore cannot be eliminated,
- operations that do not add value for the customer and can therefore be eliminated.

Lean Manufacturing is a comprehensive Japanese method that, in addition to eliminating Muda (waste), emphasises two other categories: Muri (overload) and Mura (unevenness), as presented by F. Damrath in the so-called "three MUs" (Liker and Lamb 2000) Muri, Mura and Muda are three key concepts that underpin the Lean and Toyota Production System (TPS) philosophies of production process management. Each of these terms refers to the various forms of waste that negatively affect the efficiency and quality of production processes. Understanding and eliminating them is key to achieving optimal operational efficiency (Abdullah 2003). Muri refers to overload, whether of workers, machines or other resources. Overloading occurs when a production system requires people or equipment to perform tasks that exceed their physical or technological capabilities. In practice, this can mean an excessive workload and overburdened workers, leading to fatigue, a greater risk of errors and

workplace accidents. For machinery, overloading often results in breakdowns, reduced equipment life and production downtime.

Mura refers to unevenness in production processes, which results in variability, irregularity and instability of work. Unevenness occurs when processes are not fully balanced and their flow is not smooth, leading to sudden load spikes or underutilisation of resources. Mura can take two forms:

- Variations in production schedules
- Uneven production load and work rate

Muda refers to classic waste or uselessness, i.e. any activity or resource that does not add value from the customer's perspective (Womack and Jones 2003) and that can be directly converted into lost benefits or incurred costs. These include two types:

- Type I Muda - includes all activities that are impossible to eliminate in the short term.
- Type II Muda - includes waste that can be eliminated quickly, e.g. by initiating KAIZEN workshops.

Muda also causes wastage over time, making it difficult to deliver the product in the correct and required timeframe (Bicheno 2018). Therefore, it is safe to say that non-value-added activities are one of the biggest sources of waste in Lean (though by no means the only one). Taiichi Ohno identified seven types of waste, which have become the foundation of the Lean philosophy (Andrés and Gonzalez and Alfredo 2015, Varvazovska and Prasilova 2015). These are overproduction, unnecessary transport, overstocking, extra-processing, unnecessary motion, waiting, shortages and defects, as shown in Table 1.

Table 1. Characteristics of the seven types of waste.

Waste type	Characteristics
Overproduction	Overproduction means manufacturing products in greater quantities than necessary or too early in relation to customer demand. It is the most costly and dangerous type of waste because it generates further types of waste, such as the need for storage, transport or managing excess inventory.
Waiting	Waiting time means unplanned downtime, e.g. due to the need to wait for the next production steps, deliveries or production plans or due to machine breakdowns.
Overstocking	Involves holding excessive quantities of raw materials, semifinished products and finished goods, beyond what is required by Just-in-Time manufacturing.
Unnecessary transport	Refers to the movement of materials, parts or vehicles to and from the warehouse over a greater distance than necessary.
Extra-processing	Refers to all non-value-added process steps or activities that are not important to the customer.
Unnecessary motion	Unnecessary (redundant) motion of people or machines in a production process, e.g. walking to pick up tools, looking for materials, shifting, bending, moving. Excessive motion reduces the efficiency of the overall process.
Shortages/defects	These include any shortages, errors, reprocessing, repairs or discarded products. This is a type of waste that should be prevented rather than repaired or removed.

Source: own study based on (Pawłowski and Pawłowski 2010)

Wastes are a key element to be analysed and eliminated in the process of continuous improvement (Kaizen). Their identification is the first step in increasing a company's efficiency and productivity. Each type of waste has a significant impact on production efficiency and their elimination is key to achieving operational excellence.

Value-added and non-value-added activities

An organisation that strives to optimise its processes must distinguish between value-added activities (VA) and non-value-added activities (NVAA). This distinction is central to the Lean Manufacturing methodology, which aims to eliminate all activities that do not contribute to adding value for the end product (Janczarek 2011).

Value-added activities directly contribute to the creation of a product or service that meets customer needs and expectations. According to the classic Lean definition, added value is anything that the customer is willing to pay for.

Non-value added activities do not directly contribute to the creation of value for the customer, but only increase costs or production time. Lean Manufacturing aims to eliminate or minimise them. Two types of NVAA can be distinguished:

- Pure Waste - activities that provide no benefit, either to the customer or the organisation, and should be completely eliminated from the process. Examples include overproduction, extra-processing, unnecessary transport and inventory or production errors that lead to additional repair or reprocessing costs.
- Necessary Waste - activities that also do not add value from the customer's perspective but are necessary and result from the normal production process or organisational or technical issues. These include necessary inspections or downtime due to technological constraints. Their reduction requires major changes in the organisation, e.g. through automation or the introduction of new technologies.

Identification and elimination of waste areas related to contamination and its sources

In the company under study, the 5S activities started with a comprehensive analysis and baseline assessment to identify problems related to contamination and its sources. To this end, checklists consisting of a series of questions to assess the condition and degree of contamination were used. This also involved the preparation of contamination maps to precisely locate problem areas. Thus, it was possible to determine where contamination occurs most frequently, what its nature is, and what sources it comes from.

One of the main problems identified during the initial assessment phase was the significant build-up of dirt and the lack of orderliness in the workspace. The lack of clearly designated areas for materials, tools and other work items led to chaos and complicated daily work. Moreover, there were no standards for cleaning and housekeeping, resulting in irregularity of such activities.

An assessment based on the checklist for step one showed that workplace organisation and cleanliness were at a very low level. An initial score of 45% indicated that there were many areas for improvement.

The quantity and percentage share of contaminants, broken down into categories, is shown in Figure 1.

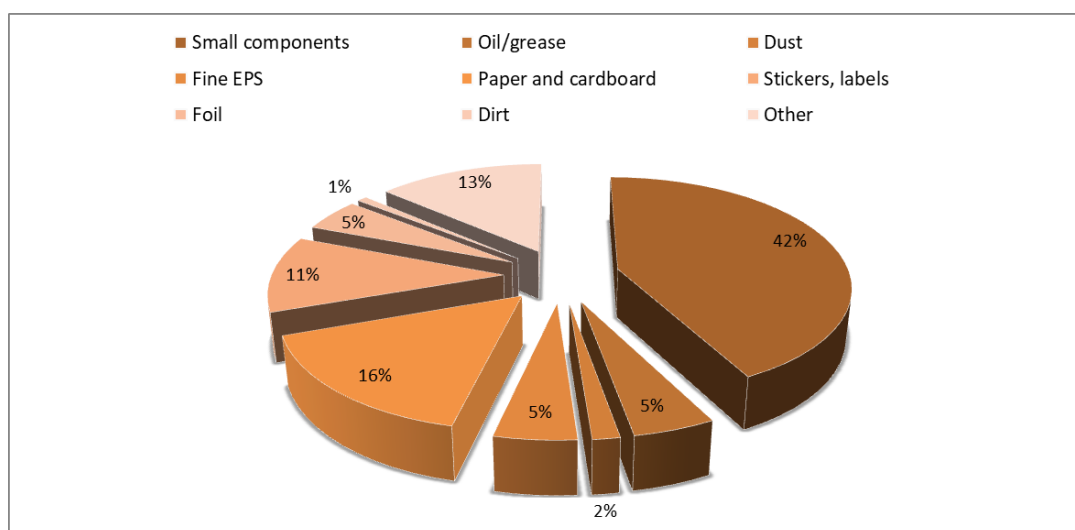




Figure 1. Contaminant share by category - own elaboration based on company data. Source: own study

The analysis identified 124 contaminants present on the assembly line. The largest groups of identified contaminants, amounting to as much as 42.7%, were small components. These included screws, washers, bands

and small electronic parts. The second-largest contaminant category was paper waste and cardboard, which accounted for 20.2%. These originated from the packaging of components delivered to the assembly line. 5S measures were implemented to improve the situation, starting with Sorting - all unused items were collected in a quarantine zone; areas for all materials, tools and equipment were then marked with corner pieces and labels.

The next step was cleaning, which involved all personnel working on the line. During the cleaning, all non-compliances on the line were identified. Cleaning was then standardised, with appropriate procedures put in place, along with a cleaning calendar to ensure that the area is tidied up regularly. Finally, checklists and 5S audits were introduced to help create and maintain baseline conditions and high-quality workstations. Table 2 shows selected examples of measures taken that resulted in real savings are detailed. Measures were taken to implement contamination reduction solutions for small components based on Quick Kaizen and in accordance with the PDCA cycle.

Table 2. Example of a solution to reduce contamination with small components

Contamination reduction	
Problem definition	Solution implementation
Small components lying on the floor and resulting in contamination. 	Installation of new trays/covers and a component collection magnet. 
Standardisation and expansion	Checking the solution's effectiveness and impact
Expansion: Line 3-workstation 90 Line 4-workstation 90	Reduction in cleaning time (min/year) - 6,760 Savings in PLN - 7,000 Cost in PLN - 6,500 B/C - 1.07 * safety aspects - high risk of slipping



Source: own study

The solution implemented, i.e. the new C-type feeders and under-line covers, have made it possible to reduce cleaning time on line 6 by 6,760 minutes per year. This has resulted in savings of PLN 7,000. The B/C ratio was 1.07, which shows that the project has brought benefits.

The second solution aimed to eliminate the large amount of paper and cardboard boxes that cluttered the line and involved working with the logistics and procurement department to develop ideas to reduce contamination - these are shown in Table 3.

Table 3. Example of a solution to reduce contamination with paper packaging

Contamination reduction	
Problem definition	Solution implementation
Clutter in and around workstations (numerous paper boxes and cartons)	Introduction of returnable plastic packaging.

	
Standardisation and expansion	Checking the effectiveness and results of the solution
Expansion: The solution can be introduced on the remaining assembly lines: L1, L2, L3, L4 and L5.	Reduction in cleaning time (min/year) - 2,760 Savings in PLN - 3,500 Cost in PLN - 2,800 B/C - 1.25

Source: own study

The introduction of returnable plastic packaging has made it possible to eliminate the clutter caused by the large number of paper and cardboard boxes accumulating around the assembly stations. The solutions implemented have reduced cleaning time by 2,760 minutes per year, resulting in savings of PLN 3,500 and a decrease in non-value-added activities (NVAA). With the solutions in place, cleaning time in step 2 has been shortened by 84%. 17 contaminants have been eliminated; 14 have been reduced thanks to the development of Quick Kaizens. Table 4 summarises the reduced contaminants.

Table 4. Number of contaminants reduced

<i>Contaminant type</i>	<i>Quantity</i>	<i>Eliminated</i>	<i>Reduced</i>	<i>Under control</i>
<i>Small components</i>	53	0	9	44
<i>Oil/lubricant</i>	6	0	4	2
<i>Dust</i>	2	7	0	2
<i>Fine EPS</i>	6	2	0	6
<i>Paper and cardboard</i>	20	5	0	20
<i>Stickers, labels</i>	14	0	0	14
<i>Film</i>	6	0	1	5
<i>Dirt</i>	0	3	0	0
Total	107	17	14	93

Source: own study

The changes implemented have eliminated contamination and reduced cleaning time, and have had a positive impact on the company's finances, bringing real savings and reducing non-value-added activities (NVAA). The solutions have also improved safety, minimising the risk of tripping or other hazards that could cause accidents.

Mura analysis - irregularity of production processes

Mura, meaning irregularity in production processes, is caused by dynamically changing production schedules and the resulting interruptions or rushed work. Mura refers to any inefficiencies that arise due to production process variability and instability. This applies to variability in both workload and resource availability. The basis of Mura analysis is the observation of the work cycle, as it enables direct monitoring of production processes in real conditions. In the event of irregularities, the average cycle time for two operators is taken into account, followed by an in-depth analysis of the results obtained to determine the source of the difference.

The irregularity analysis included observations of 30 complete cycles performed as per the standard operating procedure (SOP) for each operator at a given workstation. Next, the duration of each operation performed at the workstation was recorded, and the necessary indicators were calculated to determine the scale of process variability.

Based on the observations made, a cycle time summary was prepared for each workstation, with a breakdown by shift. Selected results are presented in Table 5. The results obtained made it possible to diagnose which workstations had the greatest fluctuations in the average cycle value and which required action to improve and reduce Mura.

Table 5. Results of Mura analysis

	<i>Shift A</i>							<i>Shift B</i>			<i>Shift C</i>			
<i>Workstation</i>	1	2	3	4	5	6	7	8	9	10	11	15	16	17
<i>10 Kit Market</i>	48.3	43.1	58.4	42	50.6	49.4	45.6	51.1	51	65	51	49.2	53.1	50.5
<i>15 Luce/CM</i>	42.7	41.3	38.3	39	41	40.3	41.5	39.8	41.3	40	42.7	41	40.3	41.5
<i>20 Motor</i>	45.9	45.9	42.9	47.3	41.7	52.5	52	42.5	54.9	44.6	44.2	49.3	44.3	42.4
<i>30 Power cable installation</i>	39	43	43.3	36.7	37.5	57	40	51.7	49	47.7	51	51	49	48
<i>40 Water supply line installation</i>	27.5	30	31	30.3	32	38	31	32.3	30.9	31.2	27.5	32	38	31
<i>50 Water softener installation</i>	47	49	49.7	45.9	44.4	45.6	43.6	45.1	48.2	48.4	47	51	49	48
<i>60 Timer connectors</i>	44.9	48.9	45.2	45.7	46.5	46.1	46.7	45.3	47.6	44.6	50.6	51.3	48.6	50.8
<i>70 Frontalino line installation</i>	39.9	41	43	42.3	48	42	49	43	42.2	45.9	39.9	48	42	49
<i>80 Hinges</i>	50.7	48.3	45.5	42.1	43.3	43.9	46.7	45.3	41.3	49	42.7	44.5	43.4	42.8
<i>90 Condotta</i>	43.6	46.3	45.7	43.1	47.6	53.3	47.2	41.1	42.5	49.6	47.1	41.4	51.2	41
<i>100 Sfiato</i>	49.1	42.4	51.9	44.4	46.9	46.9	50.4	41	42	45.9	52	43.5	52	43

Source: own study

The company considers variability above 4.0 to be high. Therefore, the analysis covered workstations where process variability exceeded 4.0. The Pareto chart was used to help identify irregularities based on work cycle observations. This statistical method is shown in Figure 2, with workstations ranked from the highest to the lowest variability in average cycle time.

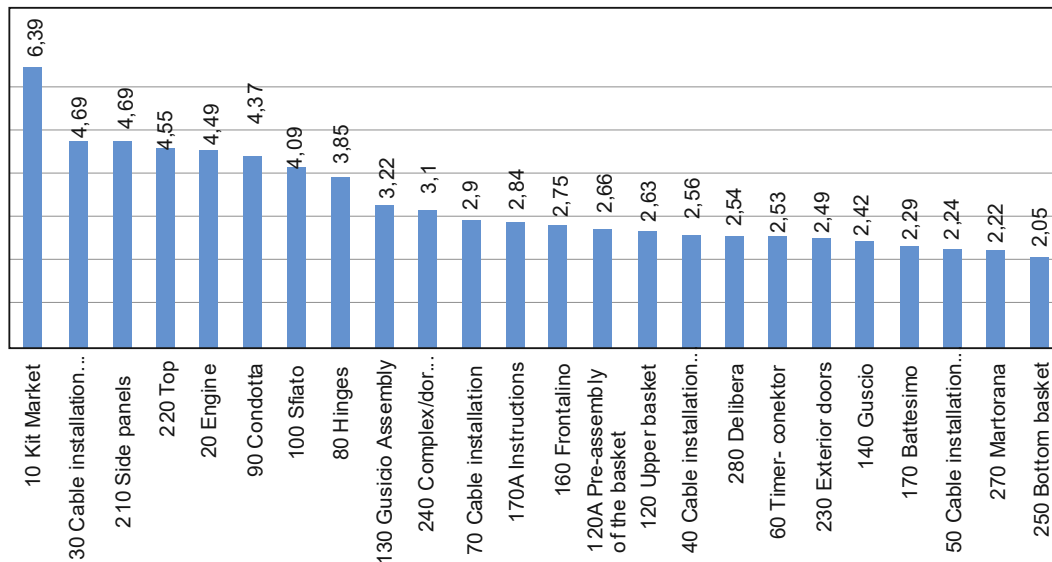


Figure 2. Graph of average cycle time for 30 observations. Source: own study

The analysis made it possible to identify the workstations with the greatest irregularities in cycle time. The highest variability-6.39 - was observed at workstation 10 - Kit Market. High variability of 4.69 was also observed at workstations 30-Power cable installation and 210 - Side panel installation. The fourth workstation considered was 220 - Top installation, which had a variability of 4.55. The fifth one was workstation 20 - Motor; its variability was 4.49. The next one was workstation 90-Condotta, with a variability of 4.37. Workstation 100-Sfiato had a variability of 4.09. Measures to reduce Mura would also need to be carried out at these workstations.

Implementation of measures to reduce waste in the assembly process

This chapter details the measures taken to reduce waste and improve the overall efficiency of the assembly process. All the solutions presented are broken down into several steps and implemented based on the Deming cycle (PDCA) and using other Lean Manufacturing tools. Solutions aiming to improve work ergonomics and process efficiency have been implemented in order to reduce Muri and eliminate non-ergonomic activities at the assembly stations. Changes have been made to the Basamento workstation, where the polystyrene base for the dishwasher tank is retrieved and placed. Previously, Basamentos were delivered to the assembly station on pallets and were placed in various orientations and at different levels. This resulted in non-ergonomic motion - bending over, lifting the arms or turning the body more than 90 degrees. Such movements lead to overload and reduce work efficiency. The solution to reduce Muri during Basamento retrieval was to install a gravity roller conveyor, which has enabled easy and comfortable retrieval of the pieces, effectively eliminating the 3 Muri occurring during this activity. Figure 3 on the left shows the state before the solution was implemented, while that on the right shows the implemented solution.

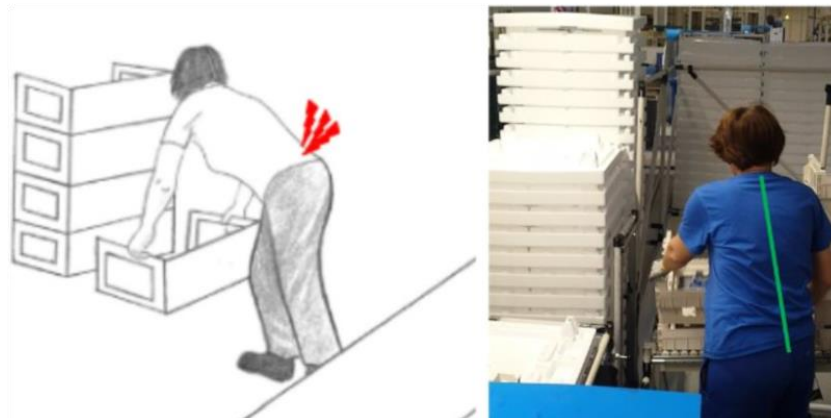


Figure 3. Before and after solution implementation

The installation of the gravity roller conveyor has significantly improved working conditions and increased assembly process efficiency, making this innovation a key element in reducing waste and improving ergonomics. Further, process efficiency has been improved and 2.7 seconds of non-value-added activity (NVAA) have been eliminated during the retrieval of a single Basamento.

After analysing and diagnosing the occurring anomalies, solutions have been implemented at the individual workstations where the greatest irregularities and deviations from the standard operating cycle time were generated. At station 10, characterised by the highest standard deviation, the problem was the assembly of the Basamento wire harness. This operation required the wire harness to be removed from a plastic bag, untangled and then mounted into the Basamento base. This resulted in an irregular operation due to tangled wires, leading to a varying task duration, with a minimum of 11 seconds and a maximum of 22 seconds. The implemented solution has involved changing the method of packaging and delivering the cable harness to the workstation. The packaging has been changed to shorter plastic bags of 10 cm in length, and labels have been affixed to the wire harness to prevent tangling. The implemented solution is shown in Figure 4.

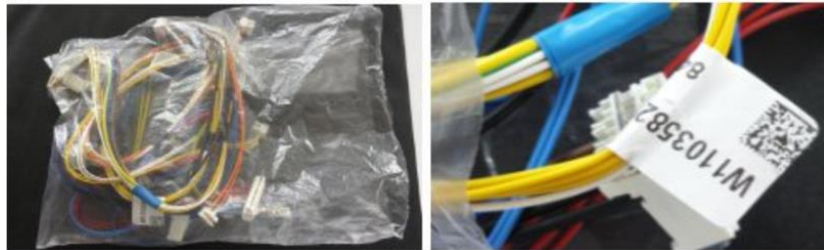


Figure 4. Solution to reduce Mura irregularity at workstation 10

The improvements have translated into increased efficiency and optimised task completion times. Further, they have brought greater repeatability of a given activity, reduced the average operation time by 6 seconds per NVAA and increased added value. This, in turn, has increased operational efficiency and optimised the time spent on this activity.

Another solution to improve productivity and reduce non-value-added activities (NVAA) has been implemented at workstation 60, where saturation was 98.5%. This workstation was a bottleneck that prevented increasing line productivity. As much as 70% of activities at this station were NVAAs, with 12.5 seconds taken up by "Product Motion", i.e. product handling. The analysis started with a 5W+1H analysis, which made it possible to describe the problem in a clear and precise way and to find out the reason for the low productivity and the high number of non - value-added activities.

As per the SOP, the operator had to rotate the product twice - at the beginning and at the end of the work cycle - to correctly perform the operation inside the Basamento.

The solution has been to move the operator to the opposite side of the assembly line, as shown in (Fig. 5). This has optimised the assembly process and eliminated unnecessary motion, thus improving the operational efficiency of the entire production line. Moving the operator to the opposite side of the line has removed the need to rotate the dishwasher twice, which previously had been part of the standard assembly process.

Rotating the dishwasher twice generated additional downtime and exposed the process to potential errors due to inaccurate alignment. Moving the operator has minimised these operations, enabling a smoother and faster transition between assembly steps.

By moving the operator to the opposite side of the assembly line, the NVAA has been reduced by 10 seconds.

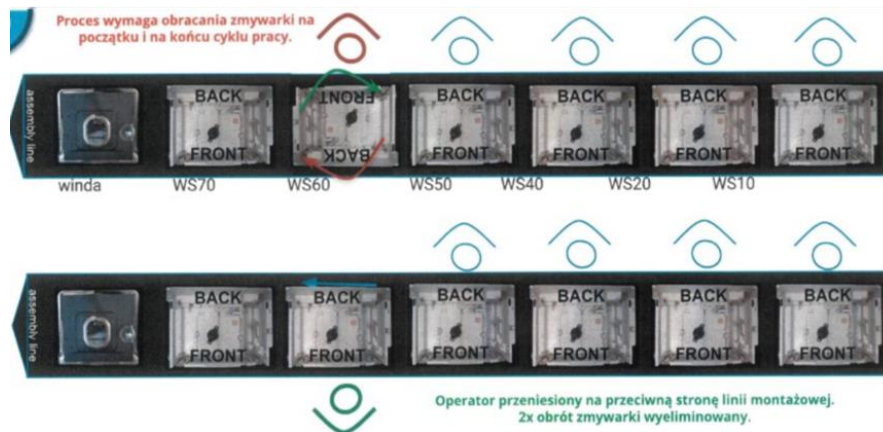


Figure 5. Location of the operator before and after the solution's implementation

The changes aimed not only to improve the ergonomics for the operators, but also to optimise the entire assembly process. Moving the operator to the opposite side of the assembly line has made it possible to eliminate such unnecessary activities as having to rotate the dishwasher twice, which has directly contributed to reducing assembly time and NVAAs, while increasing production efficiency and eliminating a bottleneck.

Solutions that would bring the greatest benefits have been selected and implemented to reduce material consumption and prevent the defects.

Door covers with screw holes have been installed at workstation 160, where panel scratching had been an issue. These covers are key to improving the efficiency and safety of the assembly process. Not only do they make it easier to align with the hole, but they also prevent defects and scratches on the panel. The solution is shown in Figure 6, where the location of the covers has been marked.

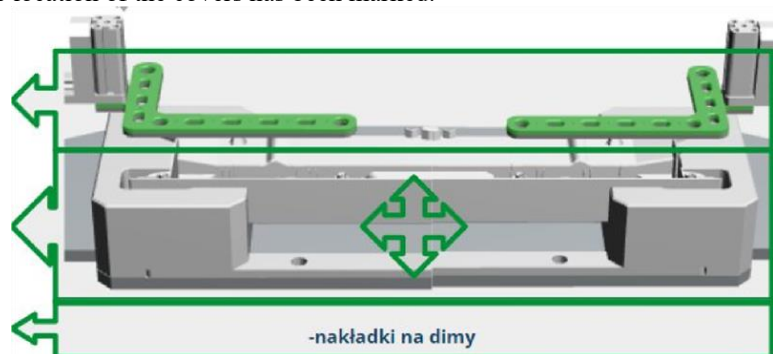


Figure 6. The solution implemented at workstation 160

Conclusions

The analysis of the production processes made it possible to identify the key sources of loss and the various wastes occurring in the company under study. The identified problems included waste resulting from the presence of contamination, unnecessary motion, construed as performing non-value-added activities, as well as underutilisation of workstations and material losses caused by inappropriate assembly methods and errors resulting from operator inattention. Based on the data obtained and the observations made, a decision was made to implement optimisation measures in selected production areas. The actions taken aimed to eliminate the identified sources of waste and minimise the losses impacting the company's operations. They included the use of Lean Manufacturing tools and techniques, which enable effective management of production processes in the spirit of continuous improvement (Kaizen). The application of selected Lean methods and tools, such as value-added analysis, standardisation of work, balancing the production line and elimination of losses according to the principles of Muda (waste), Mura (irregularity) and Muri (overload), has yielded tangible results. It was also particularly important to identify and reduce material losses, which had a significant impact on the total cost of production. Solutions to eliminate sources of contamination included the introduction of magnets and screw trays and the replacement of paper packaging for components with reusable plastic boxes. The solutions introduced have

eliminated contamination and reduced clean-up time. To eliminate overloads, i.e. Muri, a gravity roller conveyor has been installed to deliver the polystyrene bases to the workstations analysed, enabling the bases to be moved easily and eliminated non-ergonomic motion. Another solution to eliminate non-ergonomic motion has been the implementation of a suitable container with a platform to allow access to the component from all sides - this helps to avoid danger and overloading and reduces the waste associated with NVAAs. To eliminate irregularities related to cable retrieval, the method of delivering the component has been changed, with appropriate labels applied to prevent tangling. Another solution implemented at the power cable assembly station has involved transferring the cable to the pre-assembly area and delivering the pre-assembled cable directly to the station, which has eliminated irregularities and thus improved efficiency. Two key optimisation solutions have been implemented at the assembly stations of the production line to increase productivity and reduce NVAAs. At station 60, which was a bottleneck with a saturation of 98.5%, the issue was having to rotate the dishwasher twice, which generated a 12.5 second NVAA. After analysis using the 5W+1H method, it was decided to move the operator to the opposite side of the line, eliminating unnecessary movements and reducing cycle time. As a result, the NVAA has been reduced by 10 seconds, thereby increasing VAA time by 10 seconds. The second improvement has been implemented at workstation 170A, where automation of the label retrieval and application process has eliminated the issues resulting from the manual application of labels while wearing gloves and the variable number of items per set. The solutions implemented at workstations 160 and 20 have been effective in reducing defects, improving quality and increasing the efficiency of the production process. The use of assembly covers at workstation 160 has eliminated panel scratching, as confirmed by B/C ratios of 2.5 and a 0.1% increase in FPY. At workstation 20, the signalling system in the crimping machine has helped reduced the risk of leaks, achieving a B/C of 4.0 and an increase in FPY of 0.2%. Both measures have brought tangible benefits, qualitative and economic alike, confirming the effectiveness of the improvements. The improvements made have resulted in a clear improvement in operational efficiency. The number of workstations has been reduced from 24 to 21 thanks to an appropriate balancing of the workload of individual operators and the transfer of operations to undersaturated workstations. This has made it possible to make better use of the human and technical resources available. Moreover, there has been a noticeable reduction in NVAA time, which has directly translated into an increase in overall process efficiency and a reduction in operating costs. In summary, it can be concluded that the implementation of Lean Manufacturing in the examined company has not only made it possible to identify and eliminate significant sources of losses, but has also contributed to a more flexible and efficient production environment, which is conducive to further improvement and adaptation to evolving market conditions.

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