OPTIMIZATION OF THE PRODUCTION PROCESS IN THE AUTOMOTIVE INDUSTRY WITH VALUE STREAM MAPPING METHODOLOGY

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Abstract: *One of the most important ways to achieve a competitive advantage in the market is to meet customer needs. Nowadays competition is more significant than ever before so it is necessary to establish a safe and reliable relationship with customers and thus gain customer loyalty. One of the most effective lean tools which gives the possibility to see the entire process in a somewhat simplified way and can be the initiator of many further changes is value stream mapping (VSM). Based on the collected data during the VSM walk, a visual review of the process was made and takt time was calculated. In this study, it was necessary to balance the workplaces, so that they are all approximately loaded, and this resulted in a reduced cycle time on the assembly line and many other additional benefits presented in the paper. This study also covers how the application of VSM improves planning flexibility in the automotive manufacturing process.*

Keywords: *Value Stream Mapping (VSM), Lean tools, Automotive Industry, Takt time, Process Management*

1. INTRODUCTION

The automotive industry is considered one of the fastest growing industries in recent years, so it is necessary to set up a system that will be flexible and able to quickly react to the changes that are happening and be able to fulfill the required customer needs. Considering that the fulfillment of required delivery dates is one of the main goals of every company, it is important to have a production process whose duration will be in accordance with the deadlines when the products should be delivered to the customer. As it is a frequent case that various losses and delays occur during production, in situations where planned deadlines are not respected, it is necessary to analyze the causes that lead to delays and additional costs. In this regard, every company should strive to apply lean production.

Lean manufacturing is based on creating value for customers with as few resources as possible (Jordan et al., 2020). Over the last decades, this philosophy has been able to help companies in various industries work more standardized and efficiently and achieve better results with less investment (Cimermancic et al., 2022). The model that Shaman presented aimed to examine the nature of the relationship between lean thinking and value creation in supply chains, with the result that they are indeed closely related (Shamah, 2013). This concept allows flexibility, because, on the one hand, the focus is on what customers want, while on the other hand, the focus is on eliminating all kinds of wastage.

One of the very effective lean methods used in practice to solve these problems is value stream mapping. Jasti et al. investigated and proved the importance of VSM in finding different sources of losses in the auto a ncillary industry (Jasti et al., 2020). In this study, it will be shown how using it can help the company to reduce cycle and lead time, and additional costs and make sure that products will arrive at customers' plant when he expects them. Singh et al. made a comparison between the current and future states of the selected manufacturing unit, it has been found that there was a 69.41% reduction in cycle time, an 18.26% reduction in work-in-process inventory, and a 24.56% reduction in production (Singh & Singh, 2013). Vinodh et al. have improved labor productivity, quality and reduced flow time by applying the VSM method in the automotive industry (Vinodh et al., 2015). The goal of VSM is to identify areas for potential improvements, which will lead to reductions in costs, various types of wastage, waiting time, movement, and manipulation.

In section 2 will be shown a more detailed theoretical review of the VSM and the types of losses that occur. Then in section 3 are described the steps that were carried out during data collection and analysis of the current state of the process. In section 4 are shown the implemented changes that occurred as a result of the problem analysis from Section 3. Finally, in section 5 are stated conclusions of the VSM workshop.

2. LITERATURE REVIEW

In the lean methodology, the term 3M appears, which is an acronym of three Japanese words: muda, muri, and mura. In the Toyota production system, whose goal is to achieve better production productivity, the elimination of all wastages that don't add value to the products but affect the increase in production costs is one of the key points, and therefore muda, muri, and mura must be eliminated as much as possible (the ideal situation would be to eliminate 100%, but this is difficult to achieve in practice).

Muda is a Japanese word meaning waste. The most common wastes that occur during the production process can be classified into seven groups: transport losses, waiting losses, overproduction losses, storage losses, excessive finishing, scrap, and unnecessary movements. There are two groups of muda: activities that don't add value to the product but are needed in order to produce/deliver it to the customer and activities that don't add value to the product and aren't needed and they include the above-mentioned losses, so the application of the lean philosophy strives to reduce and eliminate them.

Muri is a Japanese word that means overload, excessive production. Muri can arise from mura, but in some cases, it can be caused by excessive removal from the process (muda). Overloading also occurs when machines or operators are used beyond capacity to complete all scheduled work tasks. Muri over a period of time can lead to employee absenteeism, illness, and machine breakdowns. What also leads to such problems are the changing customer requirements, for example in the case that the customer increases the size of his order disruptions occur. Given that lean methodology doesn't support stock availability, it is necessary to have a reliable supplier of raw materials for production, which will be able to increase the distribution of materials until production. Standardizing work can help avoid bottlenecks by designing work processes that will spread the workload evenly and won't overload any employee or equipment (Ostojic et al., 2010).

Mura is a Japanese word that means deviation or irregularity. Deviation refers to activities that are not predicted in the main production plan. An example of a deviation can be a change in the customer's requirements or an uneven production process (when the capacity of one means of work is greater than another, there is a build-up or waiting), which can lead to the impossibility of fulfilling the customer's requirements. Within the production process, mura can be eliminated with good production uniformity (heijunka). Tools that can contribute to the good implementation of heijunka within production are SMED and the 5S method (Sartor & Orzes, 2019; Bhamu & Singh, 2014; Singh et al., 2018; Singh et al., 2010; Gupta & Kumar, 2013).

VSM is a method that visually shows the flow of products, materials, and information within a process. This method provides an opportunity to look at the wider picture of the process that needs to be optimized (Rother & Shook, 1999). Through VSM the process is analysed from beginning to end. Each activity is shown on a drawing and that first draft is a map of the current state. It is important to create an optimization proposal for observed deficiencies or bottlenecks, which are displayed on the map of the future state. Opportunities for improvement are highlighted on the map, after which they are implemented to make the production/service process more productive and simpler. The key for value stream mapping is to see the whole picture as the sum of the individual parts and see how that step fits into the overall process and how changing it will affect the overall process. Hussain et al. study showed that it is very important to identify all value streams and their connections in order to gain useful insight for managers to improve the performance of the entire production process. This allows for a picture of how different types of changes or combinations of changes at multiple points in the process will affect the entire system (Hussain & Figueiredo, 2023).

A study by Vamsi et al. clearly shows that VSM brings a positive impact on the lead time, process inventory level, line speed, total process time, and reduced manpower. It helps the company to satisfy its customers in terms of quality, price, and delivery (Vamsi & Sharma, 2014).

Devi et al. evaluated current state mapping and implement future state mapping in a wet grinder manufacturing system. Current state mapping was developed by observation of cycle time, change over time, and non-value-added activities. So, a very important element of value stream mapping is the times to be measured/calculated (Devi et al., 2018):

Changeover time - is the time it takes to set up a machine or production line so that it can switch from working on one product to another. By shortening this time, benefits can be realized in the form of shorter production of more products or saving money. In order to accurately measure the time required for a change, it is necessary to start measuring the time as soon as the production of one product is finished and stop the measurement when the production of the next product begins.

Lead time - is the time between the start of the process to its completion. Reducing lead times can streamline operations and improve productivity, increasing performance and revenue. Conversely, longer lead times negatively impact sales and production processes. In manufacturing, lead time is often the time it takes to create a product and deliver it to the consumer. Factors that can affect delivery times include shortage of raw materials, breakdown of the means of transport, shortage of labor, natural disasters, and human mistakes (Ostojic et al., 2011).

Cycle time - a term that occurs in lean manufacturing and represents the amount of time it takes to complete a specific task from start to finish. In supply chain management, this time refers to how long it takes to fulfill an order for a particular product. Some of the key advantages of determining cycle time are increased profitability, more consistent production, satisfied customers, the ability to outperform the competition, better understanding of business spending.

Takt time - the time for which the customer requires a certain quantity of the product to be produced for him. Takt time has to be greater than cycle time, in order to meet customer requirements in time.

By monitoring these parameters, a clear picture of the process flow is obtained and after creating the desired state, a goal that needs to be reached is set, and whose achievement can be accurately monitored by monitoring the specified parameters. The recommendation for value stream mapping is the creation of maps on paper, without the use of software, so with teamwork, everyone becomes familiar with the method, but also with the complete process being mapped.

This research introduced how to improve a car seat assembly line using value stream mapping analysis, Kanban pulls production management, and process flow analysis. In this regard, the results that can be achieved with the VSM method are:

- Lead time reduction;
- Productivity and income increasing;
- Less work related injuries;
- Quality improvement.

3. METHODS

Steps that were carried out during the VSM workshop are:

- Forming a team for the workshop;
- Choosing the material to be followed;
- Checking the stock material in the warehouse;
- Monitoring of the material flow through the entire production process;
- Summarizing the collected data and sketching the current situation;
- Data analysis and improvement suggestions.

Before organizing the VSM workshop, it was necessary to assemble a relevant team that will analyze the current state of the process and make proposals for its improvement. After the team was formed, a gathering of members was organized as part of the first day of the workshop. Then, it was necessary to choose which material would be monitored and for which would be done the process mapping and subsequent process optimization. The decision was made based on the criteria of the size of the project, its impact on the entire range of production, frequency, and quantity of manufactured goods. Another criterion for the selection of monitored material was the number of operations through which the material goes, so the material that goes through the largest number of operations and is part of the largest number of products was chosen. The team went through the warehouse and the production plant in order to gather information and gain insight into the entire process, after which they created a value stream map and analyze the current state. The mapping process included activities from the exit of the material from the warehouse to the production, its entire movement through all operations in the production process, to the shipment and storage of finished goods in the warehouse. In order to gain insight into the entire production process, it was necessary to physically go through each operation and measure its duration in order to determine if there were any bottlenecks and intermediate stocks. Based on the collected data, sketching VSM of the current state (figure 1) was done and lead time and value-added activities were calculated.

The figure 2 shows a summary of the number of operations according to the following classification: a circle indicates add value activities, a square is check activity, a horizontal arrow is any movement within a process, a circle in a square is non value added activity, an inverted letter e is kanban location and a triangle is symbol for stock. Next to each type of operation are indicated the time it takes, the amount of material, and the distance between locations/workplaces.

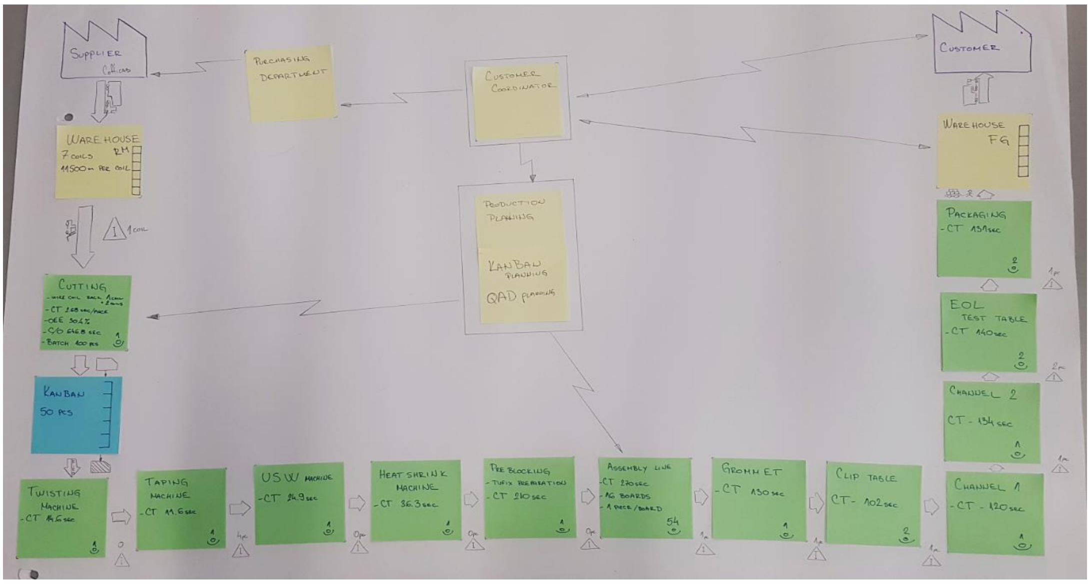

Figure 1: VSM of current state of the process flow

Based on the stock material, it was possible to produce 28,025 finished goods (for one part is necessary to spend 4.66 meter of wire). Considering that on average daily basis 1200 finished products are sent to the customer, this means that the stock coverage is almost 24 working days. Work in regular conditions takes place in two shifts, five days a week, which means that the time capacity for production on a daily basis is 54,000 seconds. Value added activities are 0.09% of the total time necessary for production.

Value Stream Mapping Process Summary					
Symbols/Elements	# of Steps	Time (Seconds)	Distance (Feet)	Inventory (Pcs.)	% Value Added
Operation	12	1126,98			
Necessary Non-Value Added	1	3600			
Inspeciton	1	140			
Transportation	6	0	470		
Inventory	16			27975	
Supermarket	2			50	
Buffer	0			0	
Total	38	4866,98 Seconds	470 Feet	28025 Pieces	0,089
Parts (Pieces) Shipped Per Day	1200				
	Hours	Minutes	Seconds		
Operating Time (Less Breaks & Lunch)	15	900	54000		
Dock To Dock =	Total Inventory (E-35) / Parts Shipped Per Day (B-38)	=	28025 / 1200	= 23,35	Days
				350,31	Hours
% Value Added =	Operation Time (C-5) / Total Time	=	1126,98 / 1265992	x 100 =	0,089

Figure 2: Summary of the process flow

4. RESULTS AND DISCUSSION

Based on the obtained data, it was observed that the cycle time needs to be reduced, in order to ensure that the required needs of the customer will be satisfied in the time in which he expects it. The takt time calculation is shown in the figure 3.

Takt/cycle time calculation	
Required quantities on weekly level from customer	1,200
Required quantities on daily level from customer	240
Number of working days in a week	5
Number of shifts in a week	10
Number of hours in a shift	8
Break time	0.5
Number of hours per shift reduced for breaks	7.5
Number of working hours in a day	15
Number of working minutes per day	900
Number of working seconds per day	54,000
Takt time	225
Planned cycle time	198

Figure 3: Takt/cycle time calculation

The takt time is the number of working seconds per day divided by the required quantities on a daily level from a customer. The planned cycle time is obtained when the coefficient for occurring losses, which is 12%, is applied to the takt time. This means that from the initial 225 seconds that are planned for the production of one piece, it is necessary to produce it in 198 seconds when factors that lead to certain losses in time are taken into account, in order to satisfy the requirements set by the customer. During the VSM audit, the cycle time was 210 seconds per piece.

Figure 4 shows a graphical representation of the duration of all operations in the production process, where the horizontal lines indicate the current cycle time and the takt time to be achieved. Workplaces that are overloaded are marked with red circles, and workplaces that are not fully loaded are marked with green circles. Using production tracking software and based on the data that the software pulls through the implemented information system in production a graphic representation of the current state of all operations was formed, where the light green line represents the average duration of individual operations.

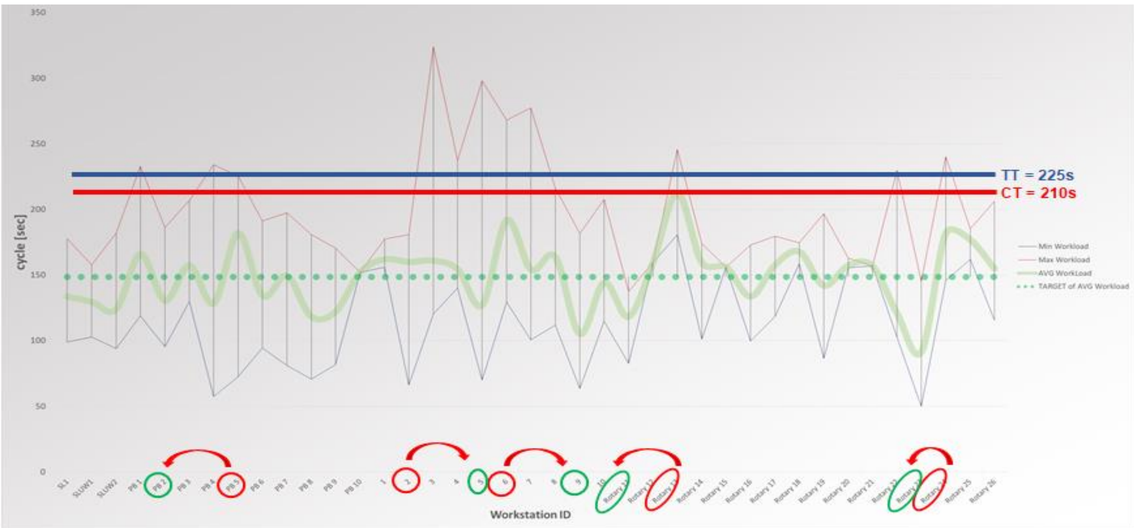

Figure 4: Summary balancing chart – current state

On the previous graph, deviations were observed regarding the workload of the workplaces, so it was necessary to transfer the workloads from certain workplaces to those that weren't too loaded, in order to balance the process. A team of process engineers was tasked with deciding which conductors would be transferred from one to processing at another workplace. Based on the five changes that occurred in the average duration of operations, a new graphic representation (figure 5) was obtained where it can be clearly seen that workplaces are much more closely loaded than was the case, and no large peaks or deviations can be observed. In this way, the planned cycle time of 198 seconds was achieved.

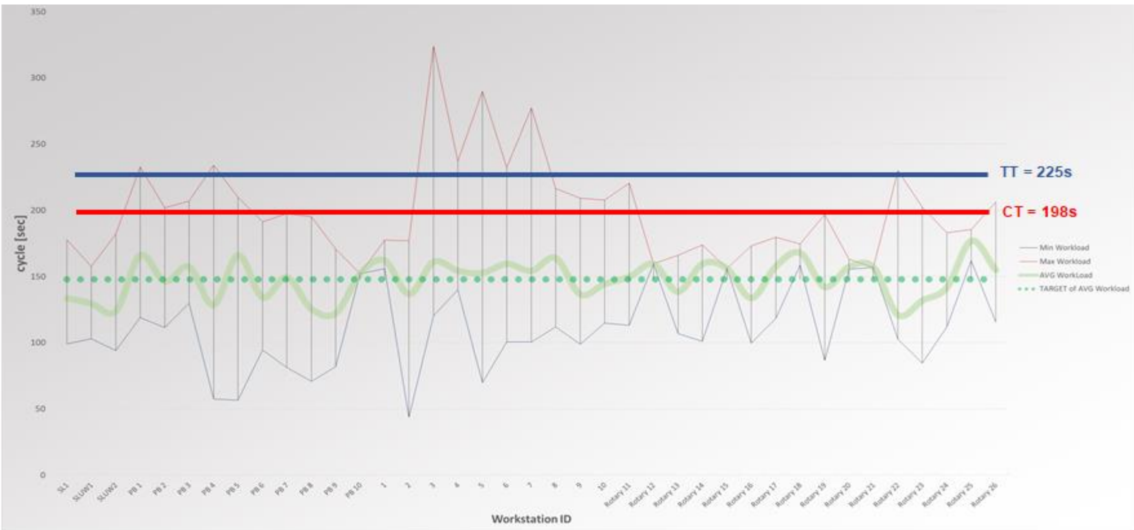

Figure 5: Summary balancing chart – after

For a better understanding of changes that occurred after the balancing, two graphs are shown below, where the first one (Figure 6) represents the display of the average duration of each operation before balancing and the second (Figure 7) represents the duration of operations after balancing, where it is easy to see there are no large deviations between the duration of operations, as well as where the cycle time has been lowered from 210 to 198 seconds. After the changes in the operation duration, the change that occurred in the VSM drawing is the data related to the cycle time on the rotary line for the assembly of conductors, which is now 198 seconds.

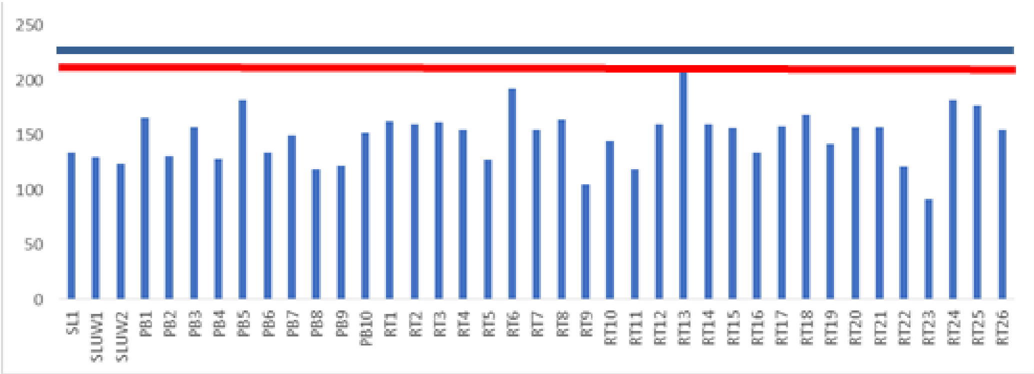

Figure 6: Average time of operations – before balancing

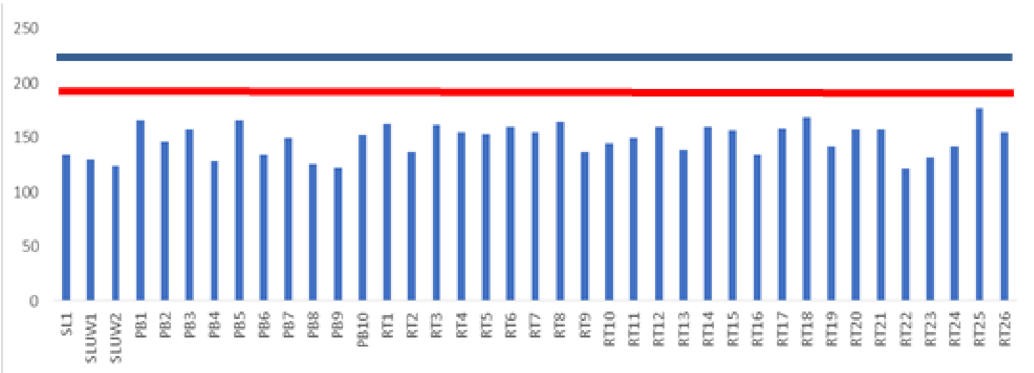

Figure 7: Average time of operations – after balancing

In the end, the lead time and value-added activities were calculated again and were made the comparison with the calculation that was performed at the beginning of the VSM workshop. Figure 8 shows a summary overview of operations, duration, inventory, and distance. Based on the current inventory, 13,209 finished goods can be produced, and considering that on a daily level 1,200 finished goods are delivered to the customer, the stock coverage is equal to 11 working days. The time capacity on a daily basis stayed unchanged and is 54,000 seconds. Value-added activities are now 0.19% of the total production time which led to the reduction of lead time by 52% (from 23 to 11 days).

Value Stream Mapping Process Summary					
Symbols/Elements	# of Steps	Time (Seconds)	Distance (Feet)	Inventory (Pcs.)	% Value Added
Operation	12	1101,45			
Necessary Non-Value Added	1	3600			
Inspeciton	1	140			
Transportation	6	0	470		
Inventory	16			13159	
Supermarket	2			50	
Buffer	0			0	
Total	38	4841,45 Seconds	470 Feet	13209 Pieces	0,184
Parts (Pieces) Shipped Per Day	1200				
	Hours	Minutes	Seconds		
Operating Time (Less Breaks & Lunch)	15	900	54000		
Dock To Dock =	Total Inventory (E-35) / Parts Shipped Per Day (B-38)	=	13209 / 1200	= 11,01	Days
				165,11	Hours
% Value Added =	Operation Time (C-5) / Total Time	=	1101,45 / 599246	x 100 =	0,184

Figure 8: Summary of the process flow after balancing

5. CONCLUSIONS

Lean way of thinking has become one of the main advantages today, and it is important to know and properly apply the methods it offers. The lean way of thinking in Serbia is still at a low level, but there is certainly an increasing interest and recognition of its benefits in the last few years, and the assumption is that this trend will only record growth in the future.
VSM method can be used to fulfill the set customer requirements in terms of the time he requires for product delivery, and also can be the initiator of various changes in the production process. The factory had problems with the time it takes to produce and deliver the goods, so had additional costs because it had to hire special deliveries in order to get the goods to the customer as soon as possible. By calculating the real cycle time, and balancing the load at the workstations on the assembly line, it was easier to fulfill the expected timing defined by the customer. The company didn't have extraordinary costs anymore, because of special transport and also there was no longer a need for working Saturdays and the costs for overtime wages were also reduced, which had a positive impact on the company's profit. Also, in addition to reduced cycle time, the lead time was reduced, the value-added activities have increased, and most importantly the goods have been delivered at the time they requested, which has resulted in increased customer satisfaction.
This method is also useful when a customer has a query, for example, he wants to introduce some changes to the existing portfolio, how much time does the supplier need to start manufacturing and delivering the changed products that the customer requested?

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