Lean Six Sigma DMAIC Implementation to reduce Total Lead Time Internal Supply Chain Process

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Abstract

Covid-19 outbreak has forced many manufacturing to create more effective and efficient business processes due to decreasing market demand and the economic slowdown. And total lead time process in a company's business processes is an indicator of the company's effectiveness and efficiency (Ridwan, Rifaitulloh, and Purba 2019). In this study, the Lean Six Sigma DMAIC approach has been successfully used as a tool to reduce process lead time in the overall internal supply chain. Before the application Lean Six Sigma DMAIC, total lead time process internal supply chain for 14 days 397 minutes, with a total value of NVA (non value added) or waste for 4 days 29.7 minutes. Based on statsitical analysis using ANOVA (analysis of variance) result, waste administration, transportation/motion, and waiting are the three primary wastes that cause a long lead time entire internal supply chain. It eliminates the NVA or waste in the internal supply chain process after applying a lean six sigma approach with improvement process, such as: re-layout, re-design process, yamazumi chart, and job leveling.

Keywords
Total Lead Time, Internal Supply Chain, Lean Six Sigma and ANOVA.

1. Introduction
In terms of increasing manufacturing capacity, the automobile industry in Indonesia faces fierce competition, particularly in the four-wheeled sector. However, after the COVID-19 outbreak spread wide in Indonesia in March 2020, sales orders have decreased and production capacity has decreased. According to data from GAIKINDO, the Indonesian automobile industry organization, total yearly total production decreased by 50% in 2020 compared with the previous year (GAIKINDO. 2020). As a consequence, firms will find it difficult to sustain in the middle of a slow market during the COVID-19 pandemic, and one method to do so is to adopt efficiency and effectiveness in each of their business. The efficiency of the supply chain process can help the firm operate better (Pattanawasanporn 2014). One of the achivement is to obtain a short and quick process lead time in the supply chain process, that may also serve as an indicator of a productive and effective business process (Abideen and Mohamad 2019), With the ultimate goal of achieving customer satisfaction (Slack, Comtois, and In 2017) .

Lean DMAIC (define, measurement, analyze, and control) is a lean approach way to reduce waste in activities such as packaging specifications, supply logistics, inbound warehouse, warehouse management system, production logistics, and warehouse logistics etc (James W. Martin 2013). Many previous studies have utilized lean and lean six sigma to improve effectiveness and efficiency in warehouse (Papatheodorou and Kontos 2014), distribution (Mishra and Sharma 2014), procurement (Franchetti and Barnala 2013), and logistics (A.Zhang 2016) . But, implementation Lean Six Sigma for internal supply chain still limited, many previous research only focus on one point process from

entire internal supply chain process. Therefore this study focus on all internal supply chain process start from production planning, material ordering, logistics dan warehouse

2. Literature Review

Supply chain is a network of organizations of companies that collaborate and work together to create and deliver products to end consumers. These companies usually consist of suppliers, manufacturers, distributors, store or retailer, as well as supporting the company as a logistics service company or distribution of goods both in the manufacturing sector (Chopra and Meindl 2013). Supply chain itself consists of two activities namely internal supply chain activities in the company's internal and external supply chain whose activities consist of inbound logistics (Supplier) and outbound logistics (Distribution and Customers) (Pattanawasanporn 2014). In **figure 1** classification of supply chain activities state.

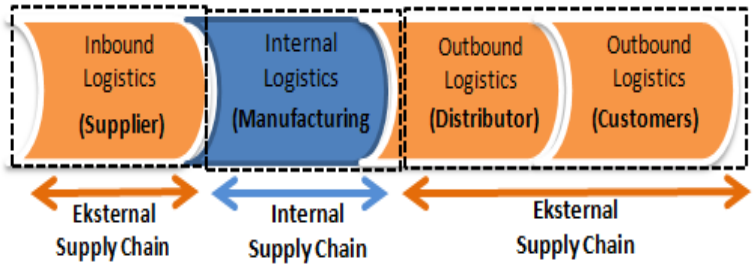

Figure.1 Activity in supply chain process

Lean six sigma is a method that aims to create improvements to a process in achieving efficiency and effectiveness in its operations. With the achievement of a process, it will create a product that is reliable and in accordance with the aspects of customer requirements: low cost and high quality (Alkunsol and Sharabati 2018, Ali et al. 2019 and Madhani 2019). Many advantage for implementation

According to research (Jin, Switzer, and Agirbas 2008), the process of improving the re-layout storage of the results of the lean DMAIC approach was carried out in order to increase the critical to quality (CTQ) parameter by eliminating non-value added activity (NVA), which resulted in: 1. a better warehouse layout, 2. a better workspace, and 3. an increase in the critical to quality (CTQ) parameter. 3. 5S has been improved. This research has an impact on an annual saving of $800,000.

Based on the study's results (Luiz et al. 2019), Six Sigma DMAIC (Define Measure Analyze Improve Control) in combination with the Lean Production strategy is quite effective in identifying process waste and cost reduction. In addition to improving quality performance and minimizing process variability, the oil and gas sector could benefit from good operations management.

The application of lean six sigma DMAIC on thedistribution process in Turkey has an impact on increasing customer satisfaction in the supply chain system and production process by eliminating complaints about the quality of the final product in the automotive manufacturing industry (Erbiyik and Saru 2015).

In the research Madani (2019) , Lean six sigma is a method for enhance the efficiency of Malaysian automotive businesses by increasing operational effectiveness and overall cost efficiency by reducing non-value added activity (NVA) and increasing value added activities (VA). Habidin et al. (2016) Lean six sigma tools has succses improve performance automotive supplier in malaysia through three critical succsess factor culture change, project management skill, andemployee involvement . Baudin (2016) Lean DMAIC can increase performance in automotive component manufacturing company in India by several factors leadership, continuous improvement, quality and customer oriented

All research above concern only in one stage in supply chain process. However , implementation Lean Six Sigma for internal supply chain still limited, many previous research only focus on one point process from entire internal

supply chain process. Therefore, this study focus on all internal supply chain process start from production planning, material ordering, logistics dan warehouse

3. Research Methodology

In this study is both analytical and explanatorical to understanding the potential improvement and implementation Lean six sigma for internal supply chain process in automotive manufacturing located in Indonesia. The aims this research to reduce total lead time process and eliminate waste process entire Internal Supply chain.

Through literature review and state of the art, the DMAIC process in this research consist of Define, Measure, Analyze, Improve and Control aims to reduce total lead time process (Bhat et al. 2019). SIPOC table using to understand stakeholder entire internal supply chain. For measurement stage VSM and CTQ to capture current state internal supply chain and in analyze stage, the main waste factor assessment using ANOVA One Way method to clear improvement will propose to reduce non value added activity.

4. Result and Discussion

In this stage will be explain DMAIC (Define, Measure, Improve and Control) phase from Internal supply chain process, which include production scheduling, material ordering, logistics and warehouse.

4.1 Define Phase (SIPOC Table)

The SIPOC table is a visual tool for capturing business processes in the internal supply chain process from start to finish, also with result of this SIPOC table becoming the identification of items that are appropriate for improvement projects in the Lean Six Sigma DMAIC process (Nicoletti 2013). **Table 1** shown SIPOC table for internal supply chain process.

Table 1. SIPOC (*Supplier, Input, Process, Output and Customer*) Table

Supplier	Inputs	Process	Outputs	Customer
Overseas and Domestic Sales	Sales Order	Forecasting	Order Product	Production Scheduling
Production Scheduling	Order Product	Order Breakdown	Material Requirement Planning and Material Production Schedule	Production Dept, Material Ordering Dept and Logistics Dept
Material Ordering	Material Requirement Planning and Material Production Schedule	Ordering	Purchase Requistion, Purchase Order and Schedule Material	Supplier Company, Logistics and Warehouse
Supplier Company	Purchase Order	Production Process	Raw Material	Customer (Automotive Manufacturer)
Logistic	Purchase Requisiton and Purchase Order	Transportation	Delivery Raw Material	Warehouse Dept
Warehouse	Raw Material	Receiving, Marshaling, Administartion and Supply	Material Handling Raw Material	Production Dept

4.2 Measurement Phase (VSM and CTQ Analysis)

Value Stream Mapping (VSM) and Critical to Quality are two methods used during measurement process (CTQ). The objectives for this stage are to determine the processing time necessary in the internal supply chain, as well as to

identify the activities that contribute to the waste activity (NVA Activity) in order to improve the total lead time (Lee, Tai, and Sheen 2013). CTQ analysis is a tool for identifying customer requirements in the internal supply chain process, which can then be quantified and improved more easily. The researcher then proceeded on to analyze the current state of the internal supply chain process at VSM (Freitas et al. 2019), in order to assess the current status of the process and identify the waste that is causing the long lead time. CTQ and current state VSM internal supply chain are shown in **Figures 2** and **3.**

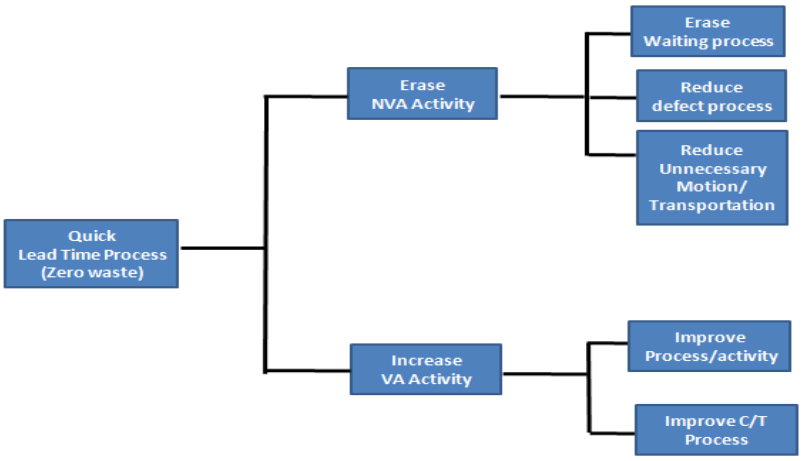

Figure 2. Critical to Quality (CTQ) analysis

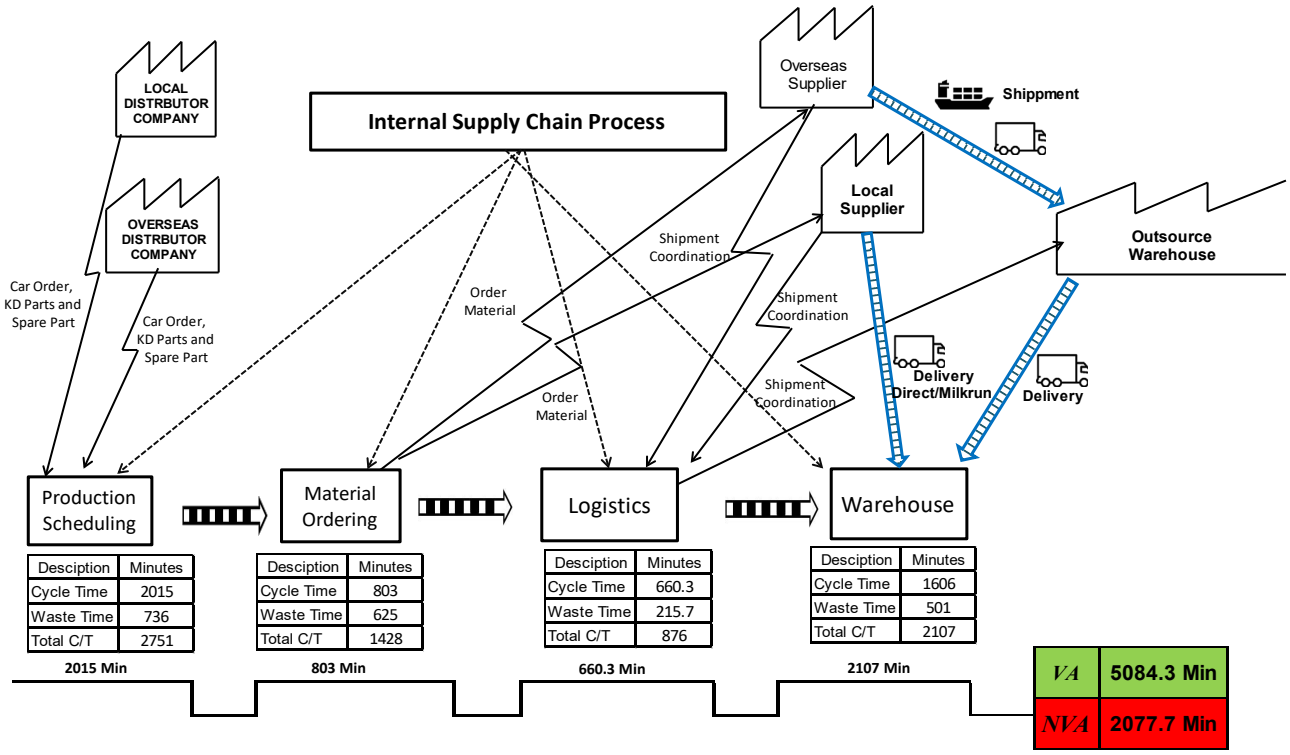

Figure 3. Current state Value Stream Mapping (CVSM)

In the current state of the internal supply chain process, the total processing time is 14 days and 404 minutes, with detail value added activity (VA) of 5085.3 minutes and non value added activity (NVA) of 2077.7 minutes. **Table 2** shows the waste that exists in the internal supply chain process based on the results of the Value Stream Mapping analysis, which reveals that there are three primary wastes i.e: waiting time, administration time and transportation/ motion.

Table 2. Waste process in internal supply chain

Process	Waste	Problem Description
Production Scheduling	Waiting process	CBU FG Confirmation process too long causes by office layout too far
		CBU Shipment and Control process earn waiting cause PIC not always in possition
Material Ordering	Administration	Checking order from MRP still do twice and need re-confirmation to PS team
		Set up BOM still need waiting and confirmation from Manufacturing, Warehouse and PS team to fill it
Warehouse	Waiting process	There waiting process in receiving process in warehouse stage due too TIME WINDOWS schedule still not proper
		Waiting confirmation for unpacking schedule too long process
	Administration	Before Input material to ERP system still do twice check and input first to manual form
		Inventory stock count report should be report first to staff after to SPV and it's need time for waiting
	Transportation/ motion	Several Warehouse layout too far from station supply and need re-layout activity
		Unpacking station too far from warehouse and loading dock KD parts
Logistics	Transportation/ motion	For several packaging quantity still not fully utilize and impact to Delivery cycle
		Routing for milkrun delivery need re-arragement to achive shortest distance
	Waiting	Waiting process for truck parking in supplier and company

4.3 Analyze Phase (ANOVA)

According the results of the VSM analysis, there are three wastes in the internal supply chain process. Furthermore, using an ANOVA analysis in overall internal supply chain process (Production Scheduling, Material Ordering, Logistics and Warehouse) to determine the degree of significance and whether or not there is a correlation between the causes of the lead time process failure (Selim Ahmed et.al.2018, Meryem Uluskan and Ezgi Pınar Oda 2019).

Hypotesis : **Ho : *P* value > *ά (Ftable > Fobservation*** **(1)**

H1 : *P* value < *ά (Ftable < Fobservation)* **(2)**

Signification test : signification degree (*ά) = 0,05 atau 5%* **(3)**

If the P value is more than or equal to ***ά***, then there is a relationship between the waste process with internal supply chain lead time, implying that waste causes long lead times. Meanwhile, if the values of P value less than ***ά***, there is no relationship between the two, therefore waste is not the primary cause of the process's long lead time. In **table 3** shown result ANOVA in all internal supply chain process.

Table 3. ANOVA result

No	Type of Waste	*F critical*	*F calculated*	Analyze (Result)	Decision
1	Waiting time	2.911	2.627	*Ftable > Fobservation*	Ho (accepted)
2	Administration	2.901	2.491	*Ftable > Fobservation*	Ho (accepted)
3	Transportation /Motion	2.891	2.065	*Ftable > Fobservation*	Ho (accepted)

4.4 Improvement

Improvement is a part of removing waste and problems from the a process that will be improved to achieve a research goal [28]. Several actions are known to cause waste, according the results of the Value Stream Mapping current state analysis. Based on the analysis of current state mapping using value stream mapping (VSM), it is found that the type of waste that has a long cycle time is the waiting process. Therefore, a re-design process and re-layout were carried out with the aim of eliminating the waste that mentioned previously. Several points of improvement in the internal supply chain process i.e:

4.4.1 Production Scheduling

The CBU office's re-layout inspection section in the assembly factory near the final shipping line. The purpose of this re-layout is to shorten the time waiting in the CBU FG confirmation sub-process. In **figure 4** is a re-layout of the office checking area.

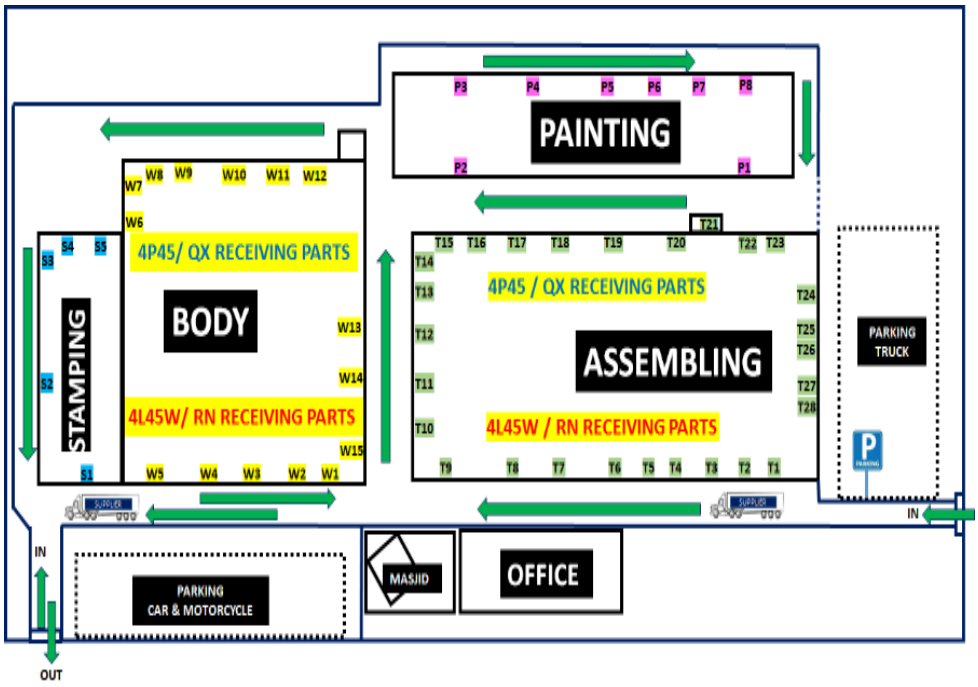

Figure 4. Facility Re-layout activity in production scheduling proces

Next, redesign process in the inspection process, which was previously apart of the CBU shipment and control sub-process, was already relocated to the CBU FG confirmation process. This is also related to the re-layout of the temporary office checking area to allow for a more thorough final inspection, that will reduce time of waiting and motion throughout the production scheduling process.

4.4.2 Material Ordeing

Improvements in the material ordering process that will be made with a redesign process approach to eliminate waste (NVA) in the material ordering process, i.e.

- Changing the *due date of* the warehouse stock (inventory) update process, where previously there was a waiting time for the material ordering team. *The Due date* previous on the third day of the current week, was changed the *due date* the inventory data one day before posting process must be submitted by the warehouse team. In the process of this change, it is hoped that waste in the sub-processes *Calendar shipment* and *Bill of Material Management* can be eliminated.

- Next, is the *redesign process* to eliminate waste in thesub-process *Manufacturing performance registration*. Where in this sub-process waste administration occurs, this is because the stages of the process are very long and repetitive. In this case, the researcher proposes a simplification of the process.

4.4.3 Logistics

From the results of the analysis of current state mapping using VSM at the measurement stage. Researchers got data on non value added activity (NVA) and value added activity (VA) for 600.3 minutes for VA and 215.7 minutes for NVA, respectively. The improvement approach that will be carried out is to make improvements using the re-layout, re-design and kaizen approaches. The explanation regarding the two approaches is explained as follows:

- **Relayout**
  In adding to being closer and as needed, re-layout receiving truck docking with the objective of reducing truck waiting time, it also strives to level in-out traffic (dweling process) from inside of the plant.
- **Redesign**
  The aim of the re-design phase in the logistics stage is to making the receiving process as easy as possible at both the factory and the supplier. The goal of this redesign is to eliminate non-value added (NVA) in the receiving process, especially milk run, direct delivery, and outsourcing warehouse processes.
- **Kaizen**
  Improvements with the kaizen approach here focus on utilizing trucks and packaging to increase the TFR (Truck Filling Ratio) and PFR values (Packaging Filling Ratio). **Figure 5** is one form of improvement in order to increase the value of PFR in **Figure 6**.

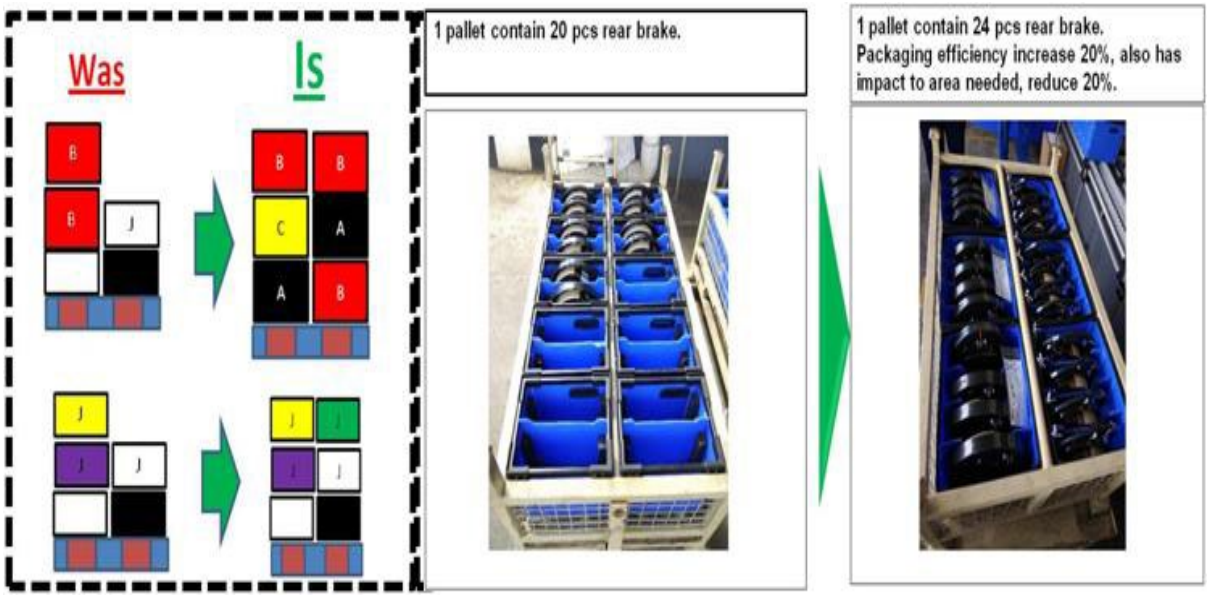

Figure 5. Kaizen aktivity (left) order lot palletize (right) Quantity up for packaging

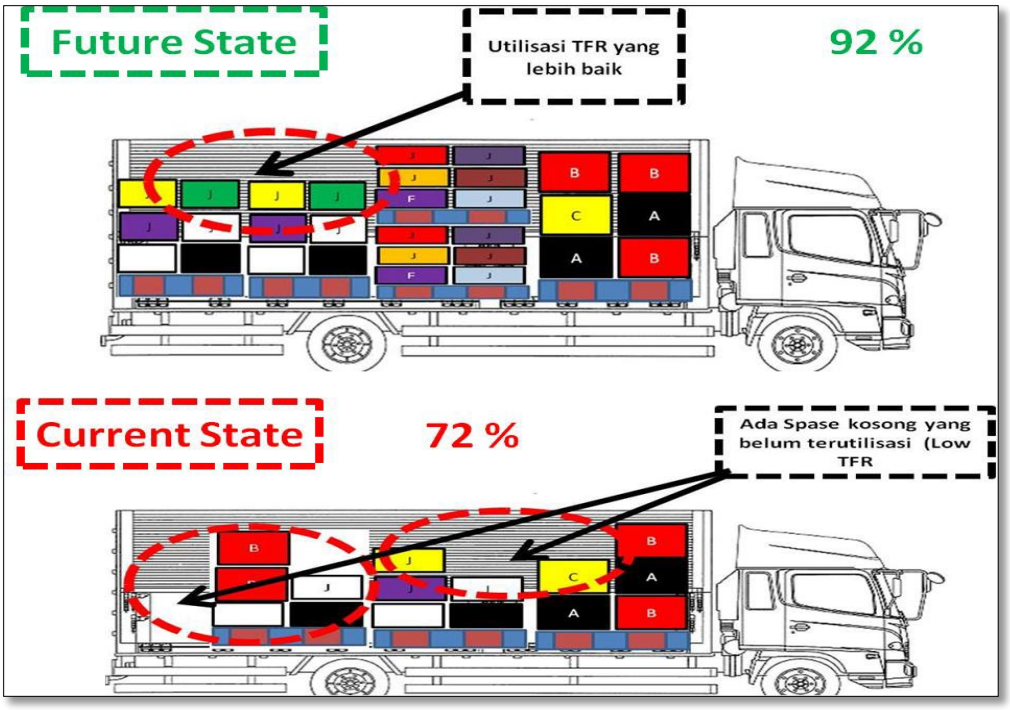

Figure 6. Kaizen aktivity (left) order lot palletize (right) Quantity up for packaging

4.4.4 Warehouse

Re-layout in the warehouse, which has an important part to play in reducing waste in terms of waiting, and transportation/motion, which contributes significantly to create waste (NVA) in the warehouse process (Oey and Nofrimurti 2018). As a conclusion, several re-layouts were carried out in this study to eliminate waste (NVA) in the warehouse process i.e:

- Yamazumi chart (Job Leveling)

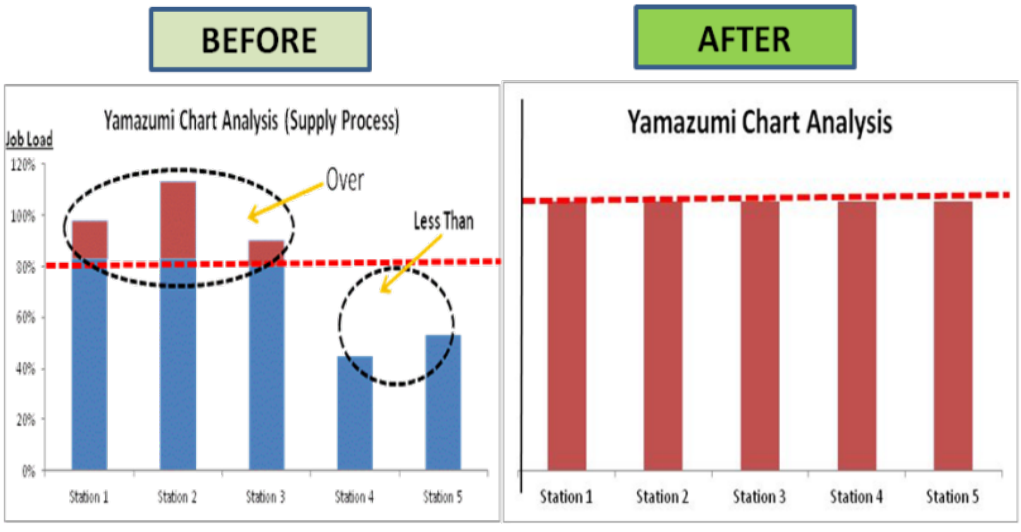

Figure 7. Before and after leveling using Yamazumi chart

- **Relayout warehouse**
  - The KD parts warehouse is moved closer to the sequence supply for special KD parts.
  - KD parts posting to ERP System is done near the unpacking process. By moving the layout of the laptop and scanner to the unpacking area.
  - Re-layout warehouse milkrun parts from gate 01 to near gate 02 area. This aims to eliminate searching time from the supply process.
  - Re-layout the shutter rack specifically for child parts from the "central warehouse child part" to near the line feeding area. It aims to eliminate transportation or repetitive motion of the man power supply.
  - Merge of KD's unpacking child part areato the KD big part unpacking area
  - Re-layout local warehouse part 1, from all to the central shuuter area KD parts to be separated according to the line supply area. It aims to eliminate waiting time
- **Redesign Process**
  - Change SOP and *flow process requests for KD Parts* to the outsource warehouse.
  - Simplify the process of receiving and posting to ERP System for KD Logistics parts
  - Making changes to the *flow process stock control process*
- **Kaizen Activity**
  - Make changes to the *shutter feeding* in the production line.
  - Change the ID text part, especially for the *unique part* with the name of fruits or plants. It aims to reduce *time* and *searchingmissupply parts* to the production line by warehouse operators.

After making improvements to the internal supply chain process that results in the removal of NVA activity and a reduction in processing time, as in the transportation milk run. This causes the overall process time in the internal supply chain to accelerate and enhance its effectiveness after the improvement with Lean Six Sigma DMAIC, compared to before the impelementation. The future state after Lean Six Sigma DMAIC improvement is represented in **Figure 8.** The total lead time in the internal supply chain after Lean Six Sigma implementation is 10 days and 196.3 minutes, which is better than the 14 days and 404 minutes before the implementation.

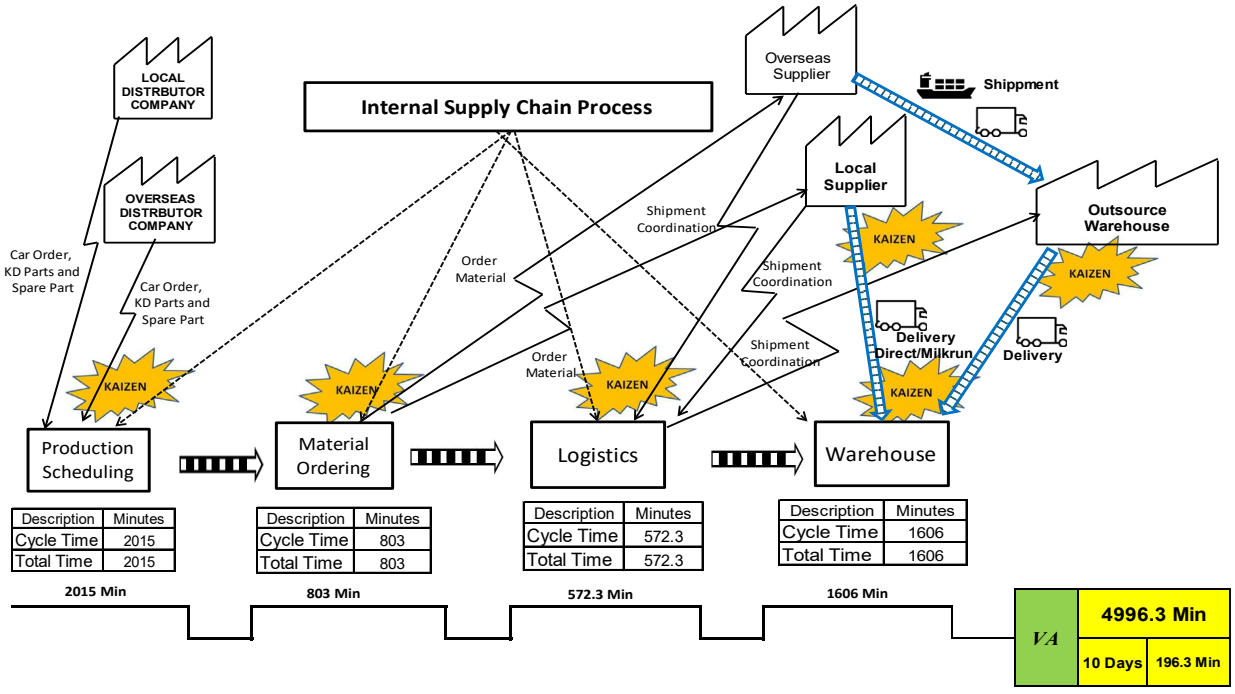

Figure 8. Future state Value Stream Mapping internal supply chain process

5. Conclusion

The main concern, as stated in the study's objectives, is to reduce total lead time process by eliminating waste (NVA) in the internal supply chain process. And the finding of the study shows that using Lean six sigma in a company's internal supply chain can reduce process lead times even while improving effectiveness and efficiency. Based on a comparison of total time between current and future states in the Value Stream Mapping, which has successfully mapped non-value added activity (NVA) and value added activity, we can determine what kind of improvement is required to eliminate waste in the form of non-value added activity (NVA).

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