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Improvement of Efficiency and Reduction of Waste in the Precast Plate Production Process Using the Lean Construction Method

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Abstract— *PT. X is one of the largest Hollow Core Slab precast concrete industries in Indonesia, where to realize this vision, they continue to develop products and improve productivity performance by trying to improve service quality, production processes, and delivery of products to customers at minimal cost and on time. To achieve this goal, a Lean Construction method is need to eliminate waste and identify activities that can affect product value added. The study began with the identification of waste using a questionnaire, then analyzed by selecting the mapping tool in the Value Flow Analysis Tool and analyzing the root causes of improvement suggestions using the bizagi modeler. The results showed that the most critical wastes that affected productivity were defects (30.67%), improper processing (22.67%), and unnecessary movements (17.33%). The lead time required for the whole process is 1970.06 minutes and after repair is reduced to 1941.36 minutes by combining the printing process to making the hole joint shear connector and column coupling reducing the value added by 28.7 minutes.*

Keywords— *Lean Construction, Bizagi, Value Stream Analysis Tools, Critical Waste, Lead Time, Unification Process*.

I. INTRODUCTION

Science and technology continue to develop along with the times. In the world of construction, advances in science and technology are increasingly demanding construction industry players to continue to strive to innovate. One of the problems that often occurs in the Indonesian construction industry is related to inefficiency and waste in the construction of its construction. Based on data submitted by the Lean Construction Institute, waste in the construction industry is around 57%, while activities that provide value added are only 10% (Abduh, 2005).

The problem that often occurs is the existence of activities that do not provide value added, or called waste (waste). According to Alarcon (1995) and Koskela (1992), waste is defined as all activities that require cost, time, resources, or procurement, both by directly or indirectly, which does not add value to the final product. Waste that occurs will affect the level of productivity.

The decline in productivity is generally caused by five types of unproductive activities, such as waiting, transportation, slow processing, ineffective work, and reworking. In the Hollow Core Slab production process, PT. X there are still Non-value added activities that will be a waste of production time.

This research will be carried out identification and elimination of waste that occurs in the production process of precast Hollow Core Slab concrete slabs. Some things that need to be understood in this study are how the production process flow, what causes wastage, and how the right improvement proposal to minimize or eliminate waste, so that company productivity can be achieved.

II. LITERATURE REVIEW

Talking about increasing productivity, cannot be separated from efforts to save the use of inputs, and efforts to enlarge the output of a production process.

A. Hollow Core Slab

A new breakthrough in the construction of concrete floor slabs for high rise buildings has been present in Indonesia, namely precast prestressed hollow core slab. Technology has been born and developed in Western Europe since 15 years ago and has received a very broad market.

B. Concepts of Lean Construction

According to Gaspersz (2008) lean is a continuous improvement effort to eliminate waste, increase the value added of products (goods and / services). Lean can be defined as a systematic and systematic approach to identifying and eliminating waste or non-value added activities through continuous improvement.

C. Waste

Understanding for each waste itself has a different meaning and is therefore taken from several sources such as the following are seven types of waste that do not add value (Besterfield 2004, Hines 2004):

- Defect can be in the form of product imperfections, lack of labor when the process is running, the rework process (rework) and claims from customers.
- Waiting can be a process of waiting for the arrival of material, information, equipment and supplies. The workers only observe the machine that is running or standing waiting for the next step in the process.
- Unnecessary inventory Can be in the form of inventory storage exceeds the specified warehouse volume, material that is damaged due to being stored too long or

too quickly removed from the storage area, material that has expired.

- Unappropriate processing can be in the form of a mismatch in the process / method of production operation caused by the use of tools that are not in accordance with their functions or errors in operating procedures / systems.
- Unnecessary motion Can be in the form of movements that should be avoided, for example components and controls that are out of reach, double handling, non-standard layouts, operator bends
- Transportation can be a waste of time because the distance of raw material warehouse to the machine away or move material between machines or from the machine to the finished product warehouse.
- Over production can be the production of goods that have not been ordered or products that are produced more than those ordered or sold.

D. Bizagi Modeler

BPMN represents the symbol of business process modeling developed by the Object Management Group. The main aim of BPMN is to provide all business users with easy-to-understand notation, starting with the business analyst who created the initial concept of the process, the technology developer responsible for implementing the existing process, and the management and monitoring process. Therefore BPMN functions as a bridge between business process design and business process implementation (Weske, 2007).

E. Value Stream Analysis Tools (VALSAT)

According to Hines & Rich (1997) Value stream analysis tools are used as a tool to map in detail the value stream that focuses on the value adding process. This detailed mapping can then be used to find the cause of the waste that occurs.

F. Root Cause Analysis/RCA

RCA is used to identify the root cause of the risk. RCA is a structured evaluation method to identify the root cause of an undesired outcome and the steps needed to prevent the return of an undesired outcome.

G. Analysis SWOT

SWOT is an acronym for strengths, weaknesses, opportunities, and threats from the company's external environment. According to Jogiyanto (2005: 46), SWOT is used to assess the strengths and weaknesses of the company's resources and the external opportunities and challenges faced.

III. Method

Describe the research methodology in detail about the material, tools, and stages of research, starting from the initial identification to the conclusion and suggestion stages, and understanding some of the difficulties that arise during conducting research and how to improve the solution.

A. Data Collection & Processing Stage

The data collection and processing stage is carried out by field observations, direct interviews with relevant parties, and questionnaires. The steps are as follows:

- Questionnaires were distributed to identify waste in the production process that was filled by actors who focused on the production of precast floor plates, including the production manager, assistant manager, and coordination of the head of the line. Distribution of questionnaires using the Waste Workshop system, namely activities carried out to obtain data / information related to waste through the distribution of questionnaires as well as interviews with respondents.
- Weighting of seven wastes and VALSAT analysis After the waste data is obtained, then weighting is carried out to determine the most dominant waste occurring throughout the process flow. Then, the dominant mapping tool for the waste analysis with VALSAT is chosen.

B. Analysis and Evaluation Phase

This stage is the stage, where the process of analysis and evaluation of the results of data collection and data processing has been obtained. This stage is the stage of improving the production process after waste is identified. The following stages of the repair process are carried out, i.e:

- Identification and analysis of the root causes of critical wastage with Root Cause Analysis (RCA). After that, an analysis is conducted to find out the cause of critical waste.
- Then, improvement steps are taken to minimize waste in order to achieve improvements that are in accordance with the wishes of using the Bizagi Modeler.
- Use SWOT Analysis for suggestions & input.

C. Conclusion and Suggestion Stage

This stage is a conclusion or summary of the results of the analysis and evaluation that have been studied. This conclusion is the result of answers to the problem formulation and research objectives that have been explained in the initial chapter. Also, suggestions are made by giving input, both the objects involved and further research so that they are taken into consideration.

IV. Results and Discussion

Discuss the results of data collection and processing that have been carried out, as well as the analysis which is then used as material to make corrective steps from the results of research. The final step is to make recommendations for improvement from the analysis.

A. Physical Flow

Physical flow is a process flow that occurs in the production area. In this research, the description of the Hollow Core Slab production process is as follows:

- Giving releasing agent to the mold
- PC wire withdrawal
- Prestressing
- Taking the mixture from the batching plant
- Fill the mixture on the slim bomber machine

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- Concrete molding process along the 150m track
- Sizing
- Making joint shear connector & column holes
- Curing
- Giving a code on the plate
- Cutting with a line cutting machine
- Appointment to the end of the track

B. Waste Identification

The next step is identification of waste (Table I). Waste identification is done by distributing questionnaires to 10 respondents related to Hollow Core Slab production. The results of respondents' answers from each question up to 7 waste indicators are included in the score assessment and a percentage of each waste will be obtained.

TABLE I. 7 waste identification results.

No	Waste	Score Respondent										Total Score	Percentage	Ranking
		1	2	3	4	5	6	7	8	9	10			
1	Over Production	0	1	0	1	0	1	0	1	0	1	5	6,67	6
2	Transportation	0	0	1	0	2	0	0	1	0	2	6	8,00	5
3	Unnecessary motion	1	1	2	1	1	2	2	1	1	1	13	17,33	3
4	Unappropriate Processing	2	1	2	2	1	3	2	2	1	1	17	22,67	2
5	Unnecessary inventory	0	1	0	2	0	0	1	1	1	1	7	9,33	4
6	Waiting	0	0	1	0	0	2	0	0	1	0	4	5,33	7
7	Defect	2	2	3	2	2	3	3	3	2	1	23	30,67	1
	Total											75	100,00	

C. Value Stream Analysis Tools (VALSAT)

After getting a score from each waste, the next is plotting the percentage value into the VALSAT table (Table II). This concept is used in the selection of effective tools for detailed waste analysis by multiplying the average score of each waste based on the analysis of questionnaire data with the VALSAT matrix.

TABLE II. Ranking VALSAT Results.

No	Mapping tools	Total	Percentage	Ranking
1	Process Activity Mapping	545,33	40,54	1
2	Supply Chain Response Matrix	169,33	12,59	3
3	Production Variety Funnel	101,33	7,53	5
4	Quality Filter Mapping	305,33	22,70	2
5	Demand Amplification	120	8,92	4
6	Decision Point Analysis	86,67	6,44	6
7	Physical Structure	17,33	1,29	7
Total		1345	100,00	

Based on the ranking in the table above, then the top 3 (three) VALSAT ratings were chosen for the analysis of waste that occurred, namely Process Activity Mapping (40.54%), Quality Filter Mapping (22.70%), Supply Chain Response Matrix (12.59 %).

D. Process Activity Mapping / PAM

Process Activity Mapping (PAM) is a tool that has a function to record all activities of a system, as well as reduce activities that do not provide value added, then simplify it in order to reduce waste that occurs. There are several stages in making PAM, i.e.

- Record all activities contained in the physical flow, namely the equipment used, the distance traveled, the time required for each activity, and the number of workers
- Classify these activities into 5 types of categories namely operation, transportation, inspection, storage, and waiting, with an explanation Operations and inspections are value-added activities. Transportation and storage are important but not value-added activities. Waiting is a type of activity with no value added.
- Analyzing the proportion of each activity that adds value (VA), does not add value (NVA), and does not add value but is needed (NNVA).

There are five stages that need to be done to do PAM, namely studying the process flow, identifying waste, considering rearranging the sequence of processes to be more efficient, considering improving the flow pattern, and considering eliminating heavy work (Hines & Rich, 1997). Broadly speaking, PAM maps activities such as time, number of operators, and 5 activities (operation (O), transportation (T), inspection (I), storage (S), and delay (D)). Based on the activities that exist in the company, the data obtained is the number of activities and activity categories. VA (value added) indicates activities that provide value added, NVA (not value added) shows activities that do not provide value added, and NNVA (necessary but not value added) indicates activities that must be carried out, but do not provide value added. For example, giving a releasing agent to a mold, the activity of moving the cleaning machine to the line is included in the transportation because the machine is not on the track and must be moved from the storage area of the machine to the production line but this activity is not of value added.

Based on PAM mapping, the total number of activities is known (Table III), so that valuable and non- valuable added activities are obtained (Table IV).

TABLE III. Summary of Calculation of Amount and Time of Each Activity.

Activity	Amount	Time (minute)
Operation	17	1945,05
Transportation	6	17,20
Inspection	0	0
Storage	0	0
Delay	3	7,82
Total	26	1970,06

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TABLE IV. Summary of Calculation of Amount and Time of Each Classification.

Classification	Amount	Time (minute)
VA	12	1918,94
NVA	3	7,82
NNVA	11	43,31
Total	26	1970,06
Value Ratio		0,97

Ratio value is the value of the time ratio between activities that add value to the total number of activities. Based on the table above, the ratio value for the Hollow Core Slab production process is 0.97 or 97%. from the summary calculation of the amount and time of activity from the two tables above then analyzed as below (Table V)

The Hollow Core Slab production process consists of 26 sequential work steps (Fig. 1).

TABLE V. Number of Activities of Each Activity Type.

Activity Type	O	T	I	S	D
Number of Activities	17	6	0	0	3
Percentage	65,38	23,08	0,00	0,00	11,54
information					
O = Operation	T = Tranportation		I = Inspection		
S = Storage	D = Delay				

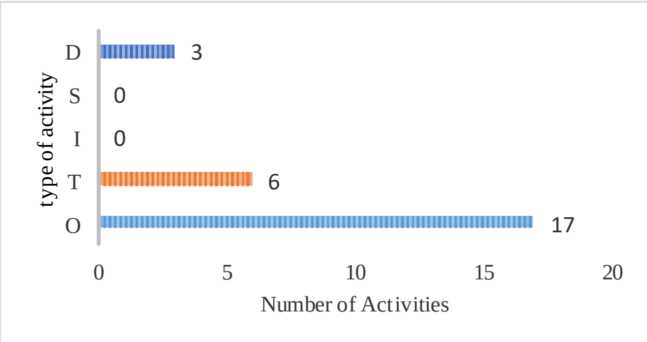

Fig. 1. Example of a figure caption.

Based on tables and Fig. and the number of value-added activities as much as 12, while activities that are not value-added but needed and activities that are not value-added as much as 14. That is, activities that do not add value must be minimized. The following (Fig. 2) shows the percentage of the number of activities.

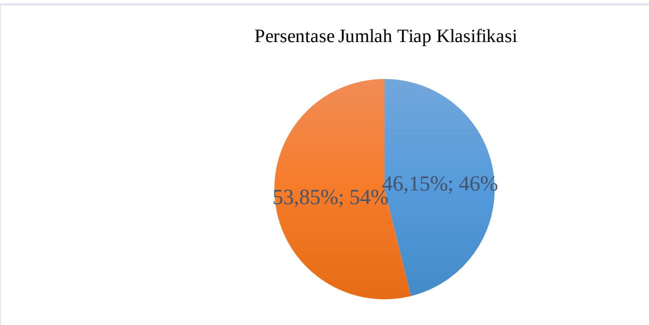

Fig. 2. Percentage of Number of Activities.

E. Quality Filter Mapping / QFM

Quality Filter Mapping (QFM) is a tool used to identify quality defect problems that occur along the supply chain. In this study, the defects studied were only product quality defects found during the inspection process after the finished product. Repair defect data (Table VI), (Fig. 3).

TABLE VI. Hollow Core Slab repair defective product.

No	Month	Product		
		Repair Defect	Number of cumulative defects	Percentage of Defect Repair
1	January	8	8	13,11
2	February	5	13	8,20
3	March	6	19	9,84
4	April	4	23	6,56
5	May	5	28	8,20
6	June	4	32	6,56
7	July	5	37	8,20
8	August	6	43	9,84
9	September	12	55	19,67
10	October	6	61	9,84
	Total	61		100,00

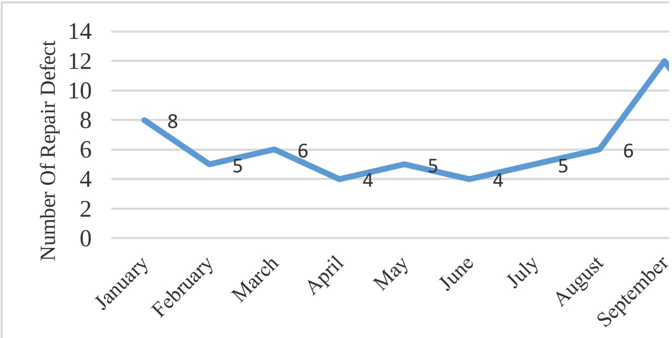

Fig. 3. QFM chart of Hollow Core Slab repair defect products.

Based on tables and fig. it can be seen that the biggest waste of product defects is September with a percentage of 19.67%. The cause of product defects on average occurs due to the lack of equal distribution of concrete mortar, causing porous products.

As for the failed / defective product and QFM graphics presented in the (table VII) and (fig. 4)

TABLE VII. Hollow Core Slab reject defective product.

No	Month	Product		
		Reject Defect	Number Of Comulative Defect	Percentage Of Reject Defect
1	January	2	2	13,33
2	February	1	3	6,67
3	March	2	5	13,33
4	April	0	5	0,00
5	May	1	6	6,67
6	June	0	6	0,00
7	July	0	6	0,00
8	August	1	7	6,67
9	September	6	13	40,00
10	October	2	15	13,33
	Total	15		100,00

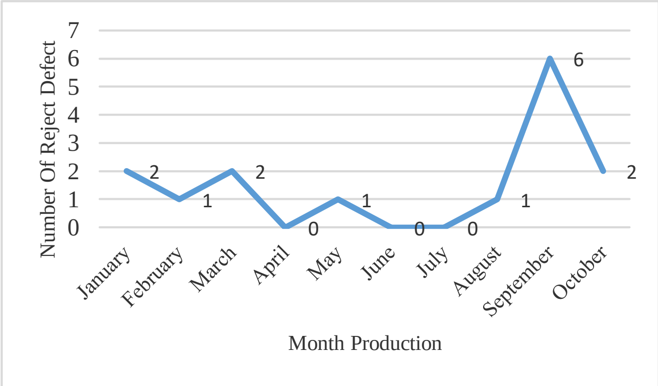

Fig. 4. QFM chart of Hollow Core Slab reject defect products.

Based on tables and graphs, it can be seen that the largest waste of reject product rejections was in September with a total of 6 sheets, a percentage of 40%. The cause of product defects is due to high slump lost, ineffective operation of the tool and errors when cutting, resulting in porous, cracked, and PC-Wire products being sucked into the concrete.

F. Supply Chain Response Matrix / SCRM

The supply chain matrix (SCRM) is a mapping tool used to identify and evaluate the amount of inventory needed and the time requirements available. There are 3 (three) areas in SCRM namely material warehouse area, production process area and finished product area. The data used in the manufacture of SCRM are arrival data and material requirements for raw materials per day, data on finished product output per day and data on product shipments per day. In this study, data taken are from these three areas during the period January - October 2019.

The following tabulation (Table VIII) is the calculation of lead time and inventory and SCRM graphs.

TABLE VIII. Tabulation of Hollow Core Slab SCRM calculations.

No	Item	Cumulative Lead Time	Cumulative Days Physical Stock
1	Material Storage Area	0,08	1,039
2	Production Process Area	0,41	1,114
3	Finished Product Storage Area	0,49	2,079
	Total	0,98	4,232

Based on the table above, the cumulative amount of time needed is 0.98 days with cumulative inventory of 4.232 days, so that the total time in the supply chain is 5.212 days. Days physical stock (dps) is the average value per day of the duration of the material in the order system. The greater the value of dps, the accumulation of inventory fulfillment along the supply chain will be longer (Daonil, 2012).

G. Root Causes Analysis / RCA

Root cause analysis (RCA) analysis is a working tool that functions to find the root causes of problems that occur. In this study, the method used is a fishbone diagram. The basic function of this method is to identify possible causes, which then separate the root causes. In this study, the fishbone diagram method is used to identify the main problems of the biggest critical waste, namely defect, unappropriate processing, unnecessary motion.

Fishbone diagram for wasteful defects (Fig. 5)

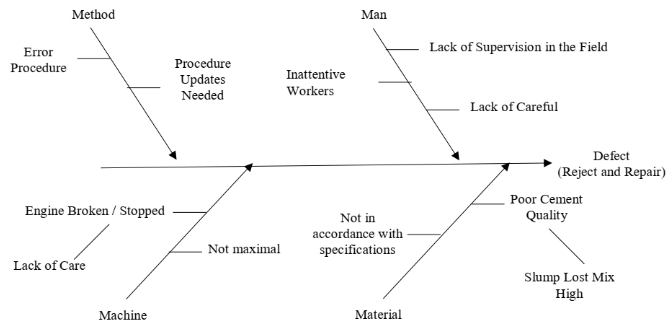

Fig. 5. Wasteful defects.

Based on the picture above, the next is to analyze the root causes of the most dominant problems in the diagram results that have been made:

- Slump lost stirred concrete is high, due to the poor quality of the used cement silo, so that when the slump value is low, fresh concrete easily dries quickly and when the slump value is high, fresh concrete dries for a long time.
- Hollow Core Slab production process each only available 1 machine / tool so that when used continuously & due to lack of maintenance, the machine / tool often freezes / stops, thus affecting the production process, less than maximum machine performance will also cause some defective products
- The occurrence of defects both rejected and repair defects, can also occur based on employee performance. Defects caused by lack of supervision in the field, workers are less thorough in doing their jobs.

Fish bone diagram for waste of unappropriate processing (Fig. 6)

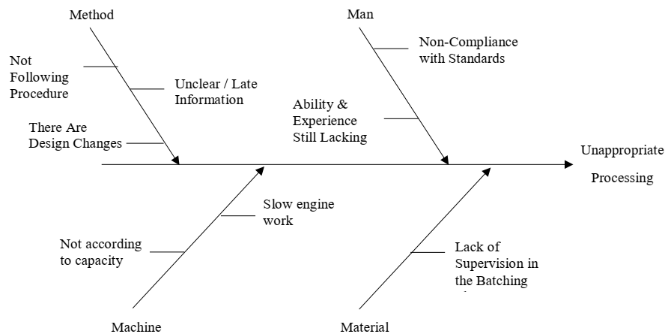

Fig. 6. Unappropriate processing.

Based on the picture above, the next is to analyze the root causes of the most dominant problems in the diagram results that have been made:

- Design changes occur because of sudden changes in demand from customers or initial planning of meeting customer needs is not met. Design is an important thing to fulfill customer needs, so at the beginning of planning, the design must be able to meet all customer needs in

detail. This design change will have a fatal impact on the production process, especially on the performance of time and cost.
- In addition, there are also a number of production processes that should be maximized or done at the same time, so there is a need for updating procedures.
- The number of production machines each is only available one unit, this greatly affects the effectiveness of production, because there is also often a machine jam during the production process.

Fish bone diagram for waste unnecessary motion (Fig. 7)

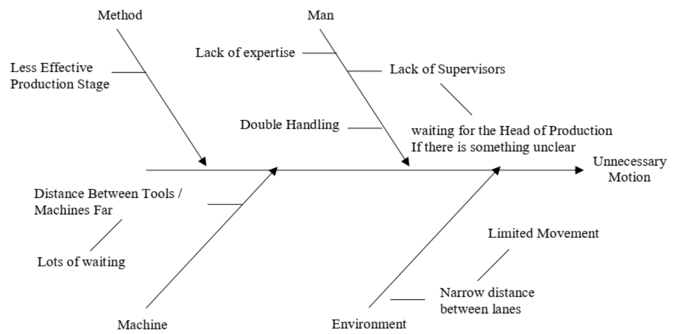

Fig. 7. Unnecessary motion.

Based on the picture above, the next is to analyze the root causes of the most dominant problems in the diagram results that have been made:
- The lack of production department supervisors causes some unnecessary movements including having to wait for the process to proceed if there is an unclear design or size and if there are obstacles that occur.
- The considerable distance between machines also makes many builders wait and only see until the process is complete, the narrow distance between lines also complicates the movement of workers for example during the process of sizing and making coakan.
- Ineffective production stage also causes many craftsmen to just wait, until the process is completed that there should be some work that can be done simultaneously.

H. Analysis SWOT

Strength is the company's internal factors that are positive that contribute to the company's ability to achieve the mission, ideals and goals of the company's organization. These factors must be known to the company so that it is not wrong in designing strategies to achieve company goals. As for the strengths in the Hollow Core Slab production industry, among others:
- PT. X always prioritizes quality
- PT. X provide satisfying service
- Family management
- The company's reputation is in the eyes of both buyers and suppliers

Weaknesses are negative internal company factors that play a role in achieving company goals. Weaknesses in a company should be minimized, because if weaknesses are more dominant then the company will not be able to compete. As for the strengths in the Hollow Core Slab production industry, among others:
- The absence of marketing and promotional media
- Limitations of the tools owned
- The flow of the production process is still less effective
- Lack of production supervisors
- There are still many product defects

Opportunities are positive external factors that can be utilized by the company in achieving the company's mission and goals. A business can develop by utilizing existing opportunities. Therefore the opportunities of the Hollow Core Slab production industry at PT. X is:
- Many projects have begun to use Hollow Core Slab.
- Expand marketing reach

Threats are external forces that are negative that can affect the company's development in achieving the company's mission and goals. Threats in a business cannot be eliminated but can be minimized by the strength of the company. Therefore the threat from the Hollow Core Slab production industry at PT. X is:
- The emergence of new competitors with the same product
- Loss of buyers due to competing products
- Competitor product prices are cheaper

To clearly illustrate how the opportunities and threats faced by the company are adjusted to the weaknesses and strengths of the company, we need a tool called the SWOT matrix (Table IX). This SWOT matrix can produce four possible alternative strategies that are appropriate for the company.

TABLE IX. 7 Waste Identification Results.

	Strengths	Weakness
Threats	Maintain and improve service quality for consumers	Establish good relations with distributors and customers to remain loyal
	Maintain and improve product quality	Monitor the development of competing products & the existence of a special division for marketing
Opportunities	Maintain & continue to improve quality	Increase promotion by maximizing technology such as social media.
	Improve service quality	Increase the number of tools / machines if product demand continues to increase and improve the production process flow to make it more efficient

V. Recommendations

In this research, making recommendations for improvement based on critical wastage from the identification of waste PAM, SCRM, QFM, and RCA. The following are detailed recommendations for improvement.

A. Combining the Process of Concrete Molding Process along the 150m Track, Sizing, Making Joint Shear Connector & Column Holes, Giving a Code on the Plate

Based on the PAM analysis, it was found that waste is in the form of inaccurate processes, namely the existence of activities waiting for the process of making joint shear connectors and column columns, as well as providing plate codes so that it wastes more time and makes workers more waiting until the process is finished & goes to the next process. This merging process was carried out because there were still workers left and could be used to make the process of making joint shear connectors & column columns, as well as coding on Hollow Core Slab plates. By making changes to this process flow, it is hoped that time efficiency can be obtained in the process flow and maximizing the number of remaining paths, because the curing process is also quite long, so that a lot of time is left, can be used to carry out the next production process on paths 2 and 3. For the coding of the plates, it is also necessary to have an update that is using printed paper containing Hollow Core Slab plate information.

Flow of the production process after the improvements presented using Bizagi Modeler (Fig. 8).

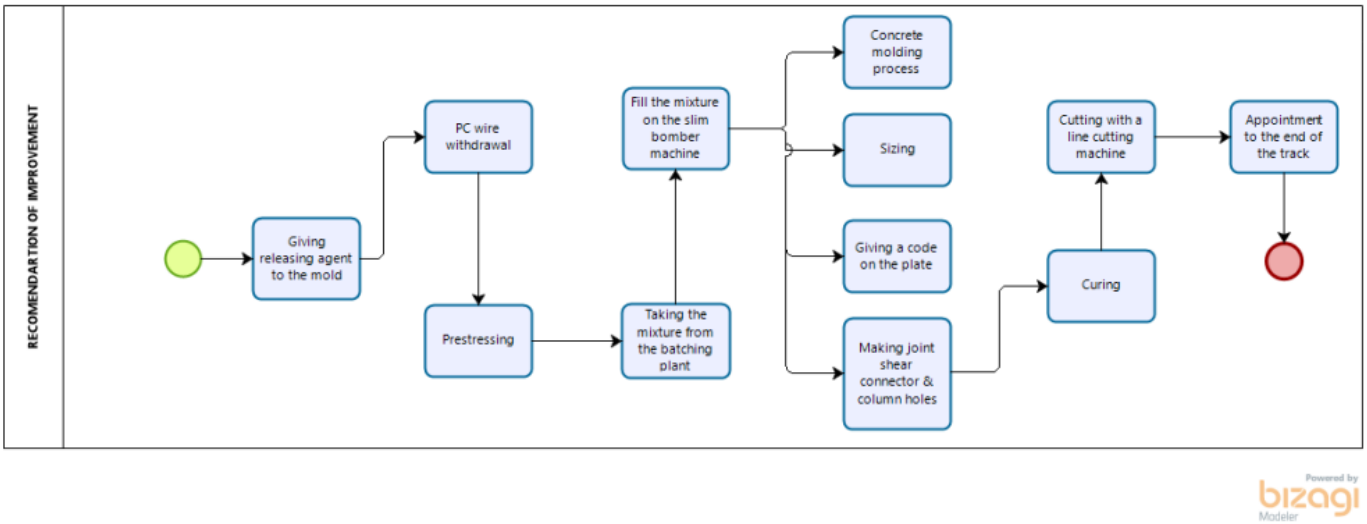

Fig. 8. Recommendation using bizagi

B. Proposed Improvement Recommendations Based on Critical Waste

Based on the results of the analysis of the root causes of the problem of critical waste by using root cause analysis, the following suggestions can be given to minimize waste:

1. To minimize or eliminate the occurrence of Hollow Core Slab defects, the thing that needs to be done is to conduct a direct inspection to find out how the work process in the field, whether it is according to procedure or not and need to add a production supervisor, because there is only 1 supervisor who must oversee all production from various type of product produced
2. Supervision must be made when making concrete mix in the batching plant, so that the resulting slump lost is not high.
3. There is a need to update the procedure more effectively, because there are several processes that should be done together as recommended in the drawing of the merging process of printing, sizing, encoding the plate, making the hole joint shear connector & column coupling can save time around 28.7 minutes by using 3 lanes.
4. Design changes can be minimized by designs made outside the production cycle, so it does not affect the course of the initial design production. According to Koskela (1997), design changes can be reduced by increasing the value of the results in accordance with customer needs, reducing variations that are not in accordance with existing procedures / provisions, and carried out more intensive supervision throughout the entire process, including the design process.
5. The need for production is greatly influenced by the availability of tools such as hoists, sprayers, cleaning machines, wire drawing machines, wire cutting, slim bombers, iron knives, cutting machines, lifter machines. The function of the whole tool is very important, because the activities of the production process use these tools, but the addition of tools is not the right solution because given the conditions of customer demand is still small and can be completed with existing equipment so that what needs to be done is to improve management 5R (Abridged, Rawat, Neat, Clean, and Diligent).

VI. Conclusions And Recommendations

A. Conclusions

Based on the results of research on increasing productivity in the Hollow Core Slab production process by applying lean construction methods to minimize waste, the following conclusions can be concluded:

1. Dominant activities that do not provide value added that can affect productivity increases are defects (30.67%), unappropriate processing (22.67%), unnecessasy motion (17.33%).
2. How to improve to reduce the waste that occurs is renewing the procedure is more effective, because there are several processes that should be done together.

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B. Suggestion

Based on the results of research, suggestions that can be submitted by researchers include:

1. Improve management of 5R (Concise, Careful, Neat, Clean, and Diligent) so that the production process cycle runs smoothly. If product demand continues to increase, it is necessary to add tools and utilize 5 channels to make it faster and more effective.
2. Design planning needs to be done by involving all stakeholders involved in the production process so as to produce a final design that is in accordance with customer needs, easy to do, easy to apply, and waste minimization.
3. There needs to be supervision in every step of the process, because each step affects the quality of the production output, In determining improvements for reducing waste and increasing efficiency of processing time, it is necessary to consider the impact and risk, so it is known how much influence the improvement.
4. It is expected that for further research activities, it is necessary to evaluate the improvements after making the proposed improvements.
5. The aim is to test whether the proposal is successful or needs to be improved again. As well as the need for deeper research until transportation to the product storage area. As well as adding calculations about the cost of losses in the event of an rejected product defect.

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