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VALUE STREAM MAPPING FOR WASTE IDENTIFICATION IN THE LOW COST HOUSE CONSTRUCTION PROCESS (CASE STUDY: XYZ HOUSING)

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ABSTRACT

XYZ housing is a low cost housing created by developers with low-income individuals in mind. However, a lot of individuals bemoan the state of their houses because of flaws like leaks, peeling paint, and other issues. This is unquestionably connected to the way the contractor handled the construction process. When there are signs of waste, particularly when there are delays and waste inventories, it is possible that there will also be additional sorts of waste throughout implementation. By employing the value stream mapping method, this study seeks to both detect and simultaneously minimize or eliminate waste that happens during the construction of affordable homes. Two key tasks are completed: creating an overview of the current state map, which represents the state of the development process currently, and offering solutions and suggestions for improvement given as a future state map.

Keyword*: Waste, Low Cost Housing, Value Stream Mapping*

1. INTRODUCTION

In Bekasi, West Java, there is a company called XYZ Houses that constructs low-cost housing. The developer assigns the contractor the task of constructing the home in line with the work order that has been made and approved by both parties during implementation. If the contractor receives a project to build 10 dwellings, they will proceed according to the current stages. starting with construction of the foundations, walls, roofing, and deuker, then cleaning. The contractor will first carry out excavation work from the first housing unit to the tenth housing unit as part of the process.

However, there are still a lot of signs that waste happened throughout the construction of this house. Building faults, which occur from work that does not adhere to standards and criteria, are one of the most obvious signs of waste. Leaks, cracked walls, painting streaks, damaged ceilings, hygienic damage, broken wooden door and window frames, and cracked ceramic floors and walls are some of the defects that characterize this flaw. Even up to 2021, reports from Indonesian consumer organizations (YLKI) and Ombudsman foundations indicated that the quality of affordable housing was insufficient and a recurrent issue. The completion of residential building that does not follow work orders is another sign of waste. According to preliminary findings at XYZ House, there is a delay at the start of the housing construction process, which is an activity in which construction workers wait, either for materials or for instructions from the supervisor. For tasks requiring material, primarily the kind of sand and ceramic material that the provider is taking too long to deliver. This makes sense given that the two types of material are imported from sources in the Karawang and Cilegon regions, which are outside the Bekasi area.

Based on the aforementioned information, we require a concept method that can be used broadly. The Lean Manufacturing idea, which derives from the Toyota Production System (TPS), has been applied successfully in the manufacturing sector. Lean Construction is the concept method used in the construction sector (LC). In order to develop changes in the housing construction process, the first step is to identify all waste and the cause of the issue. This can be accomplished by locating waste and raising the contractor's value through the use of LC tools, one of which is value stream mapping (VSM). By assisting in the identification of the stages of value added in a process stream (value stream) and the elimination of the phases of non-value added or waste, VSM is used as a tool to facilitate the lean implementation process (Irawan, 2007). However, in light of the data that has been presented, it is important to consider how Value Stream Mapping and the Lean Construction concept approach might be used to address the issue of waste in the construction of low-cost housing.

2. LITERATURE REVIEW

a. Housing Projects in Indonesia

Individual communities and housing developers work together to complete housing developments in Indonesia. While the bulk of the housing needs are met by Perumnas and real estate developers, the fulfillment of specific community housing needs is accomplished gradually. The forms of housing include the following, as listed by Wulan (2008) and summarized in the opinion of (Suparno, 2006) and SNI 03-1733-2004 Procedures for Urban Housing Environmental Planning: 1. Cheap housing is a category of housing that is typically only available to those with low incomes and little spending power. 2. Middle- and upper-class households are typically the only ones who can afford medium-sized dwellings. Facilities and infrastructure supporting the operation, such as road hardening, are available in this sort of dwelling. 3. Luxury housing is a category of dwelling reserved for affluent individuals. This kind of home is furnished with very extensive operating facilities and infrastructure, including sports facilities, parks and play areas, meeting rooms,

shopping malls, and even recreational facilities. Housing Combination 4 (Simple, Medium and Luxury) Combining affordable, moderately priced, and opulent dwelling in one location is known as combined housing. The 1: 3: 6 concept, which compares one luxury house, three midrange houses, and six simple dwellings, is frequently used to build housing that mixes the three categories of housing.

b. Waste in Construction Project

Activities that do not add value (NVA) are referred to as waste in the lean thinking paradigm (Josephson, et al, 2007). Ohno, the creator of the Toyota Production System theory (Hicks et al., 2004), asserted that there are seven different types of waste that can be produced in a number of manufacturing industry production processes, including:

1. Overproduction is the act of generating excess amounts of finished or semi-finished commodities.
2. Waiting on the arrival of content, information, equipment, and equipment that doesn't offer value is referred to as a delay.
3. Excessive transportation, which refers to the movement of goods, information, tools, and tools that don't bring value but incur costs.
4. Inappropriate processing, which is the occurrence of actions that are inconsistent with the technique or process of production operations as a result of the employment of tools that are inconsistent with their intended uses or mistakes in operating systems or procedures.
5. An abundance of finished goods or surplus raw materials in the warehouse, often known as excessive inventory.
6. Unnecessary motion is movement that is not ergonomic due to poor workstation design or ineffective work practices.
7. A defect is a flaw in a product that necessitates rework, a lot of scrap, and customer claim work (repair).

Ohno's suggestion to categorize the aforementioned waste kinds gradually gained traction and was accepted by the construction sector. According to some researchers, the following factors contribute to NVA waste: poor quality (Alwi, et al., 2002); excessive inspection at the project site (Rahman, et al., 2012); waiting for equipment repair (Ralph, et al., 2012; Senaratne, et al., 2008); failing to listen and speak (Macomber, et al., 2004); poor vehicle and truck movements (Emuze, 2013); and Long walking distances (Tersine, 2004), unnecessary and excessive material orders (Arleroth, et al., 2011; Rahman, et al., 2012), excess materials at the project site (Emuze, 2013), excessive material handling (Ralph, et al., 2012; Alwi, et al., 2002), too much information (Macomber, et al., 2004), and too much oversight are all examples of such issues (Senaratne, et al, 2008; Modegh, 2013).

c. Lean Construction (LC)

According to (Gresh, 2011), the LC can be used in place of traditional construction management because, in general, traditional construction management places an emphasis only on conversion activities and pays little attention to the issue of managing systems and design processes into flow activities, whereas LC has at least two (two) focus areas, namely waste reduction and flow management. The production system consists of two aspects: 1) Conversion of materials, information, and other inputs into a product, and 2) Flow, where nonvalue-adding processes like inspection, waiting, and movement are minimized or even completely eliminated.

Applying LC principles can make the implementation of the Lean Construction concept more effective. As stated by (Aziz, 2013), for instance: 1. Specify the Value, which means determining the needs of consumers and the actions that add "value." 2. Value Stream, which entails removing all actions that do not provide "value." 3. Flow, or making sure the information and material flow along the supply chain is efficient. 4. Pull, which makes certain that

supplies are prepared and that materials and information are obtained when needed (prepare). 5. Perfection, which guarantees that the goods arrive in the hands of the customers on schedule and in accordance with their requirements. The residential construction business can only successfully implement the aforementioned lean concepts by concentrating on streamlining the complete process and integrating stakeholders including developers, contractors, and subcontractors. It is anticipated that a home with good quality in accordance with customer expectations will be attained by continual improvement through waste elimination along the flow process. Use of the LC tool known as Value Stream Mapping will enable all LC concepts to be applied more successfully (VSM).

d. Value Stream Mapping (VSM)

VSM is a flow chart that describes and enhances the movement of materials and information using a symbol known as "Lean Language." With the least amount of waste possible, VSM seeks to offer the best value to customers through the value creation processes of: 1. Design (concept for customer), 2. Development (order and delivery), and 3. Sustainable (project life cycle) (Shook, 2009). VSM visualizes the time, processes, and information flow that occur during the construction process. Waste is the term used to describe activities that do not provide "value." Utilizing VSM, the present state map is located and examined, allowing for the identification of any waste that needs to be eradicated. Then comes a map of the future state, which represents the resolution to the problems that now exist.

Given the numerous players and possibilities for abnormalities in the construction process, VSM will be particularly helpful to apply to housing projects. Additionally, VSM will offer comprehensive information that can be used as a guide for making decisions regarding scheduling, unpredictable processes, reorganizing the construction process, and identifying the top priority that needs to be carried out by contrasting the maps of the present and the future states. The findings demonstrate that overall performance has increased, as seen by a steady process flow, consistent activity timing, and quick change responsiveness (Haitao, 2009).

3. THE DEPICTION OF THE CURRENT STATE MAP OF THE PROCESS OF BUILDING HOUSES IN LOW-COST HOUSING

a. Identification of The Housing Construction Process by The Contractor

The foreman plays a crucial part in overseeing the workers and the supply of materials at the project site for all of the work. The foreman must closely monitor the availability of personnel and resources on the job site and give instructions to construction workers at each step of the job. The foreman is required to find a substitute or roll out workers as soon as there are workers who are absent (due to illness or other demands). In order to ensure that there are no "defects" or irregularities in the dwellings the employees have built, the foreman must also oversee and inspect the work performed by the laborers. The foreman must also be able to communicate effectively with the field supervisor on the caliber and advancement of the work.

The work performed by the contractor is to follow the order of work on housing construction as shown in Figure 1 below, which is based on the findings of the interview process with the foreman and field supervisor:

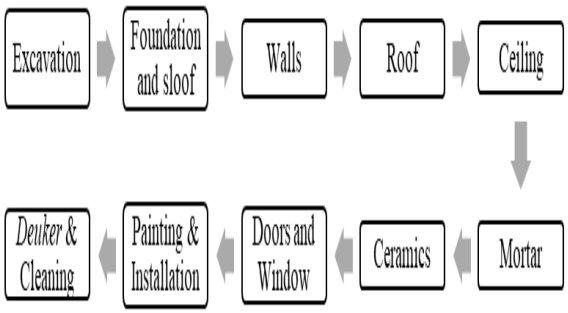

Figure 1. The Sequence of Work on XYZ Housing Construction

Figure 1 depicts the normal workflow of a contractor, from excavation to finishing work. Workers excavating from the first house to the tenth house carry out the operation when a contractor receives a project with ten dwelling units. From the first house to the last house, and so forth, until the last step, workers also complete foundation and roof work (finishing).

b. Daily Cycle Time, Delay and Labor (Mandays).

Based on observations and measurements, 164 low-cost housing units were constructed by XYZ Housing with the help of 6 contractors over the 2018–2019 period. Data collection at this stage takes the form of development process time, which is the cycle time for each work, and data delay, which happens at the start of the process. Based on manual direct measurements taken at the project site, both types of data were collected. Based on the foreman's views and knowledge, labor data are also required.

Additionally, each development step is given a timer, and the results are displayed in Table 1 below.

Tabel 1. Average Cycle Time, Delay, and Labor Per Unit of Homes in XYZ Housing

No	Work order	*Cycle Time* (CT)/ number of housing units	*Delay*/ number of housing units	CT+*Delay* / number of housing units	CTx(CT+Delay) / number of housing units	Labor (mandays)
1	Excavation	40/164 = 0,24	7/164 = 0,04	47/164= 0,29	40x47/164= 11,46	47x17/164= 4,87~ 5
2	Foundation and sloof	114/164 = 0,7	11/164 = 0,07	125/164=0,76	114x125/164= 86,89	125x24/164= 18,29~ 18
3	Walls	150/164 = 0,91	23/164 = 0,14	173/164=1,05	150x173/164= 158,23	173x24/164= 25,32~25
4	Roofs	67/164 = 0,41	28/164 = 0,17	95/164=0,58	67x95/164= 38,81	95x14/164 = 8,11~ 8
5	Ceiling	46/164 = 0,28	19/164 = 0,12	65/164=0,4	46x65/164= 18,23	65x16/164= 6,34~ 6
6	Mortar	153/164 = 0,93	19/164 = 0,12	172/164=1,05	153x172/164= 160,46	172x16/164= 16,78~ 17
7	Ceramics	56/164 = 0,34	22/164 = 0,13	78/164=0,48	56x78/164= 26,63	78x13/164= 6,18~ 6
8	Doors and windows	56/164 = 0,34	26/164 = 0,16	82/164=0,5	56x82/164= 28	82x12/164= 6
9	Paint and installation	50/164 = 0,3	19/164 = 0,12	69/164=0,42	50x69/164= 21,04	69x13/164= 5,47~ 6

Tabel 1. Average Cycle Time, Delay, and Labor Per Unit of Homes in XYZ Housing (Continuation)

No	Work order	*Cycle Time* (CT)/ number of housing units	*Delay*/ number of housing units	CT+*Delay* / number of housing units	CTx(CT+Delay) / number of housing units	Labor (mandays)
10	*Deuker* & cleaning	38/164 = 0,23	8/164= 0,05	46/164=0,28	38x46/164= 10,66	46x12/164= 3,37~ 3
	Total	4,7 days	1,11 days	5,8 days	560,42 days	100 mandays

The contractor then processes all the data (cycle time, delay, and labor) using the I-Graf software to describe the current activities of the housing construction process (current state map). The following time hypotheses were used:

1. A 9-hour workday (from 8:00 to 17:00), with a 1-hour lunch break (12.00 - 13.00).
2. There is only one shift of work and no overtime.
3. There are six workdays in a week.
4. A month has four weeks.

Figure 2 below shows the outcomes of designing the current state map using the IGraf program.

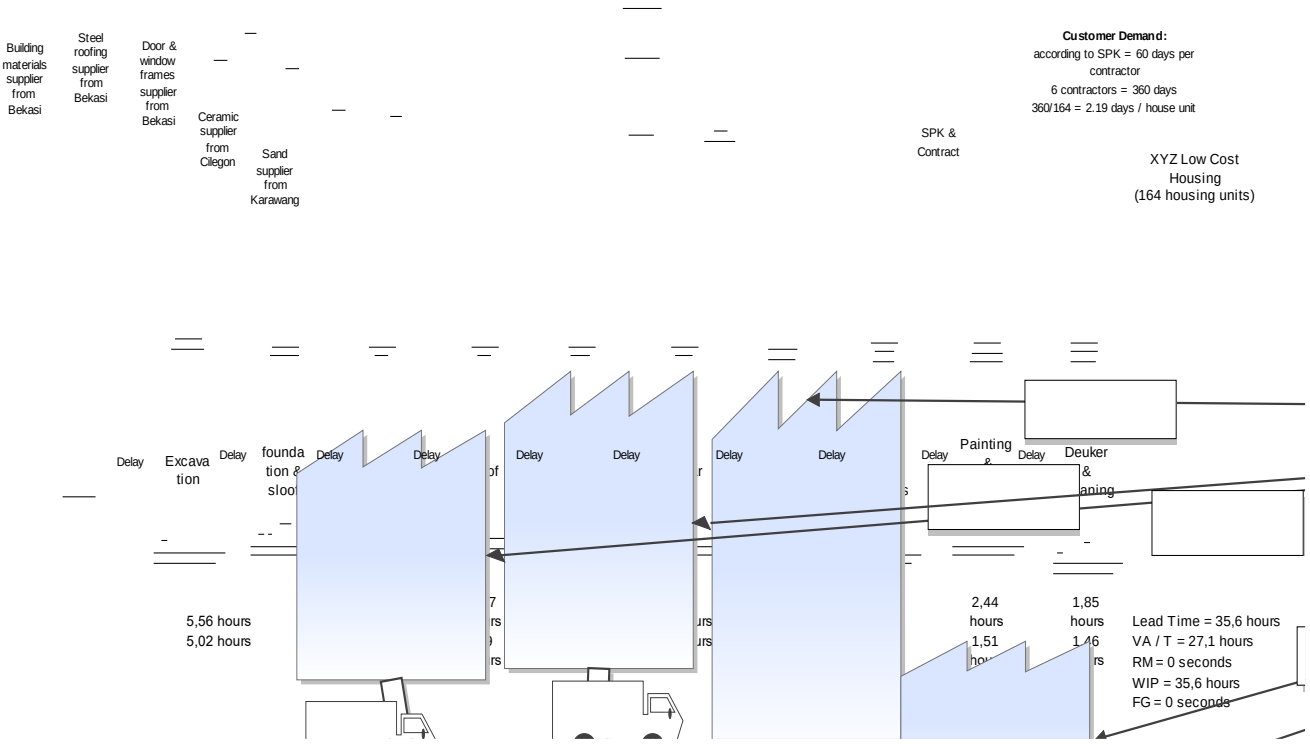

Figure 2. Current State Map of The Process of Low-cost Housing in XYZ Housing

Figure 2 shows that the typical contractor needs 35,6 hours to complete one housing unit (35.6 / 9 hours = 3.96 days), which is also the total amount of work still being done (WIP). When compared to NVA (non-value added) time, which is 3.96 - 3.01 = 0.95 days, VA (value added) time is 27.1 hours (27.1 / 9 hours = 3.01 days). Even though the VA time is longer than the NVA time, this still does not match the developer's customer demand (SPK) of 2.19 days per housing unit, necessitating an evaluation of how well house building has been implemented in each of the processes undertaken.

c. Identification of waste in the process of building houses in XYZ housing

According to Figure 2, it appears that delay and inventory are the two main wastes that occur in XYZ housing. During the construction process, workers engage in the waiting activity of delay. While inventory is a collection of building materials that have accumulated in a storage facility owing to a poor material handling system and is managed by personnel who have specialized in handling material (logistics). These two waste categories will be covered in detail in the paragraphs that follow.

1). Delay

Waiting to begin the task at the beginning of the procedure is the activity known as delay. Both waiting for supplies to arrive from the storage facility and waiting for the start of work because the preceding step wasn't finished properly.

The activities of waiting for materials include waiting for materials from storage warehouses to be used in housing units, as well as waiting for materials from suppliers, primarily for sand material coming from suppliers in Karawang and ceramic materials coming from suppliers in Cilegon, according to information obtained from the foreman and field supervisor as well as direct observations. Given that the two supplier locations are somewhat far from the project location, a lengthier delivery time is expected, which is understandable. Activities generally wait for work to start since the prior step took longer than expected to finish. Other wastes include waste overproduction, defect, motion, transportation, and processing that happen at each stage of the process are to blame for this.

The act of manufacturing items in excess is known as overproduction. When it comes to the construction of affordable housing, this is characterized by employees producing too much cement and iron poles for columns, sloofs, and ringbalks. Overproduction is a wasteful work activity that raises unneeded expenses. A defect is something that happens during the building process that was not anticipated, such as damaged walls, leaking roofs, peeling paint, etc. This occurs as a result of the materials and production processes not meeting the standards and criteria.

Work in progress (WIP) for each job may be affected as a result of workers having to repair and rework. Construction employees who wander around unnecessarily, such as to talk on the phone or play games on their phones, may neglect their work. As a result, there is a delay and the amount of work in progress increases. While transit is the act of moving goods from warehouses with inadequate storage. This occurs due to a lack of laborers and carts to move goods, as well as poor road conditions (muddy roads) near the project site. Finally, processing is the act of processing work that does not adhere to specifications, such as improperly mixing cement and sand, installing ceramic tiles that have not been pre-soaked, excavating too deeply, etc.

2) Inventory

Inventory is the accumulation of products in a storage facility as a result of unorganized material goods. Due to poor storage systems and storage circumstances, this may result in material damage or decreased material quality. Therefore, if the low-quality material is still used, it will have an effect on the building flaw, necessitating repair and rework labor.

Inventory happens because no logistical personnel are in charge of the available stock. For instance, regulating the quantity and condition of materials arriving from suppliers, organizing the contents in the storage warehouse, hiring more staff to transfer materials out of the storage warehouse, and providing carts for material transportation. Additionally, the logistics officer must closely communicate the material's availability to the contractor so that the order may be instantly revised if the material runs out and the work can be completed right away.

4. CREATE A FUTURE STATE MAP OF THE HOMEBUILDING PROCESS IN XYZ HOUSING.

The current state map previously defined the conditions of the house construction process, and the future state map represents the condition of changes to those conditions. The delay and inventory wastes, which have been identified as the two main wastes in the current state map, have each been provided solutions and recommendations. The future state map displayed in Figure 3 below is summarized in the paragraphs that follow.

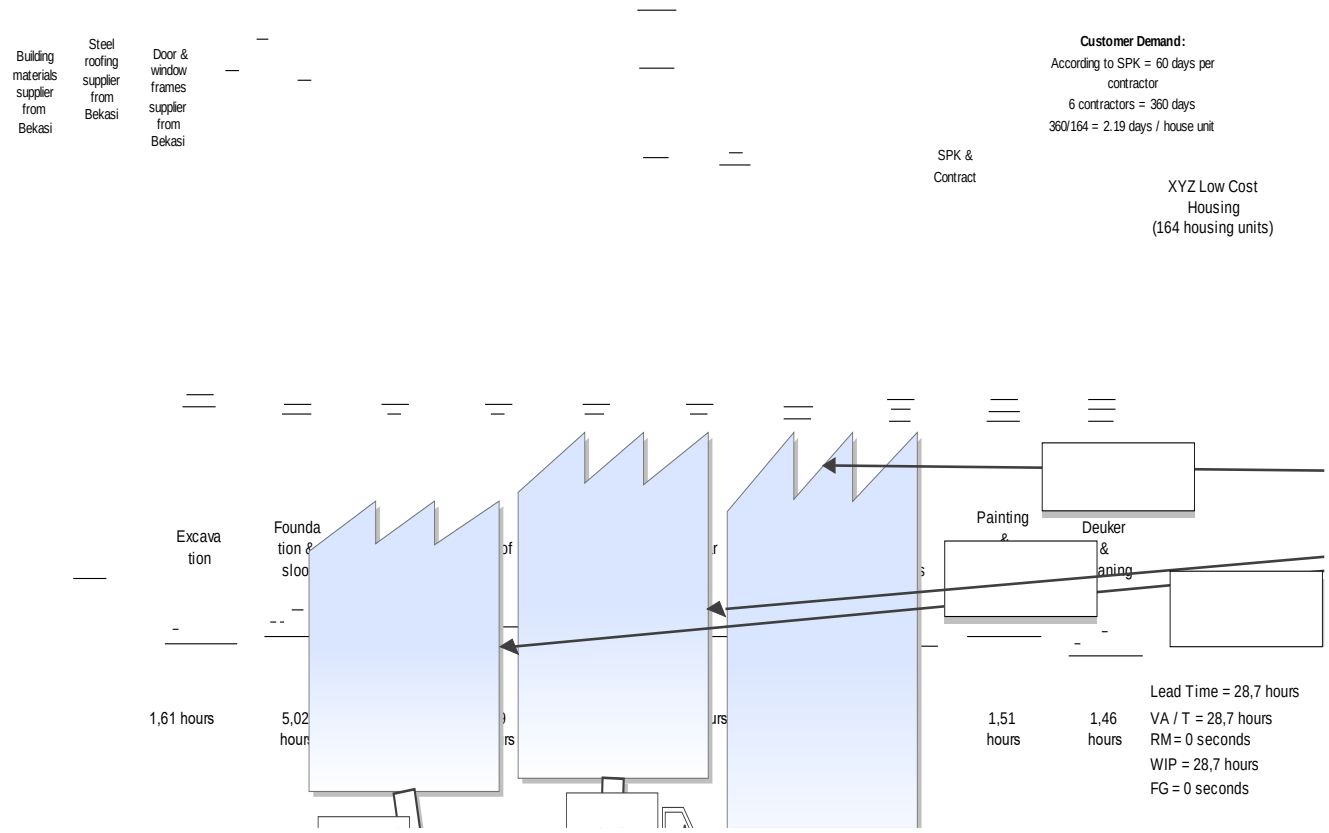

Figure 3. Future State Map in XYZ Housing

According to Figure 3, it appears that the delay at the beginning of the process has been minimized or removed, changing the lead time from the initial 35.6 hours (35.6 / 9 = 3.96 days) to 28.7 hours (28.7 / 9 = 2.8 days). It is suggested that the sand supplier from Karawang and the ceramic supplier from Cilegon be replaced with suppliers in the Bekasi region and close to XYZ housing in addition to time efficiency.

As a consequence of interviews and brainstorming, 4 foremen and a field supervisor who had a deeper understanding of the XYZ dwelling construction process were given answers and recommendations. Reducing or

eliminating waiting activities that take place is the suggested solution and action for waste delay. Finding the cause of the waiting activity must come first if it is caused by materials that are late in arriving at the project site. For instance, the lack of sufficient laborers and material transportation (carts) is the basis of the issue, so the foreman must immediately plan on collaborating with the logistics officer. Therefore, the foreman must prepare to collaborate with the logistics officer right once. If the supplier's delayed delivery of the material was the cause of the issue, the foreman and the logistics team will work with the supplier to plan an order and set a delivery date for the supply.
In contrast, the time wasted waiting for the results of earlier activity to be completed is caused by other waste, such as excess production, flaws, motion, transportation, and processing. It is advised that foremen and field supervisors give employees who are carrying out the development process close work supervision. This oversight is done on a regular basis to ensure that the job is completed in line with the standards and specifications.
While for waste inventory, suggestions and solutions are made to improve the number of employees who are knowledgeable about construction material issues (logistics). To prevent goods from being damaged, the employee must know how to properly store and arrange it in a warehouse. Additionally, to ensure that there is never a material shortage and construction workers are left waiting, logistics staff members must constantly coordinate with contractors and foremen regarding the availability of material.

5. DISCUSSION

Dwelling projects are development initiatives that result in a lot of housing units being developed all at once. Housing developments are a sign of waste in the construction process, just like other construction projects are. While house construction projects are being implemented, there are still issues with the way the work is being done, which causes project completion to be delayed. It was determined that delay was a significant obstacle to effective project management. According to Wa'el et al. (2007), delays are a prevalent concern in most projects, while their severity varies greatly from one project to the next and one industry to the next. Project delays are situations that extend the project's timeline for completion of the entire or a portion of it (Chan, et al, 2002). Delays not only impair project completion but can also result in cost overruns, relationship and management issues, and other causes of inefficiency (Sambasivan, et al 2007). Delays are significant occurrences that can make project managers uneasy (Carden, 2007), and they can have negative effects on a project's economic viability, productivity, costs, and possibilities (Long et al., 2004).
VSM is an effective lean tool used to find out in detail the construction process carried out by contractors. VSM will identify the waste that occurs in each process, so that it will be able to know the right solutions and recommendations to handle it. As Sawhney (2011) argues that VSM allows a systematic view of the process, identifies activities that bring value (Value Adding / VA) and does not bring value (non-value added / NVA) in the process flow, so that elimination of waste can be carried out and provide improvement according to lean principles.

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