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An Implementation of Lean Approach to Achieve Working Time Efficiency in Precast Factory

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Abstract

Question: Can the 5S lean approach using *Seiri (Sorting)*, *Seiton (Arranging)*, Seiso (Cleaning), Seiketsu (Standardizing), and Shitsuke (Sustaining) improve the workflow to achieve efficiency in the working time needed to produce Corrugated Concrete Sheet Pile (CCSP)?

Purpose: The aim of this study is to offer modification of work processes by implementing a lean approach using 5S to eliminate waste and improve working time.

Research Method: Data were collected by practitioner interview and in-depth observation to obtain a completed understanding work process of the precast production cycle. Then, Bizagi Modeler 2.0 was used to determine the mapping of the production cycle and the total time duration. Process Activity Mapping is used to determine the problems contained in the cycle, especially activities that are NVA. Then, a modification of work processes used a lean approach with 5S concept to eliminate non-value added (NVA) activities and achieve working time efficiency.

Findings: Based on the research results, it was found that there were two problems in the CCSP concrete production cycle. The first was the strand cutting activity, delayed since it was performed with a lack of workers. The second was the delivery ready mix was categorized as a delay activity that needs to be eliminated. Both of these problems were addressed with 5S. *Seiri* is applied by doing a standard operating procedure completed with the number of workers for each work item. At the same time, *Seiton* concepts are conducted by moving the batching plant. The improvement has resulted in: a decreased execution time of strand cutting from 129.23 minutes down to 64.8 minutes (50%), an elimination of delivery ready-mix as a delay activity (NVA activity) which can save 15.13 minutes

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of production time, and a shortened working time of concrete bucket loading from 10 minutes to 5 minutes (50%). All the working time savings are obtained in the production cycle. Before the improvement it took 33 days to complete 25 production cycle of CCSP. After the improvements the 25 CCSP production cycle took 31.5 days (4.5% efficiency).

Limitations: This study mainly focused on a 5S lean approach with Bizagi Modeler software and Process Activity Mapping method at a precast factory producing CCSP.

Implications: This research will provide guidance for applying the 5S lean approach relative to time efficiency in a construction company and can also inspire further research to develop alternative lean approaches.

Value for Practitioners: This paper presents the impact of applying the 5S lean approach to minimize wastage in the production cycle in order to achieve time efficiency, with an emphasis on construction supply factories wishing to adopt lean.

Keywords: 5S, Bizagi Modeler, Lean Approach, Process Activity mapping, Time Efficiency

Paper type: Case Study

Introduction

Products can be classified based on components such as made-to-stock, assembled-to-order, fabricated-to-order, or engineered-to-order. Precast concrete is an engineered-to-order example (Ballard et al., 2002). Precast concrete can preserve an effective cost in industrialized construction projects (Peng & Pheng, 2011).

Compared to conventional construction, industrialized building systems precast concrete applications may raise labor productivity, accelerate construction, and enhance quality (Ahmad et al., 2018). Implementing lean philosophy in industrialized building systems has represented evidence of better progress in construction projects. Lean Construction principles are implemented to minimize the risk factor effect on time (Issa, 2013). Moreover, a lean implementation can reduce time, cost, material, and effort (Summaya, 2017). It also enhances environmental and economic aspects (Jamil & Fathi, 2016). Furthermore, the efficiency of the work process can be improved by applying lean approaches (Ahmad et al., 2018).

Several studies have revealed that lean application can reduce the work process time. In precast fabrication, Setyastuti et al. (2018) and Daryanto et al. (2020) report results in time reduction of 11 minutes for installing the connection plate and tightening the bolts and 28.7 minutes for the printing process, sizing, plate coding, and making holes for joint shear connectors and co-columns, respectively. In Indonesia, there are also several studies on lean with 5S: *Seiri (Sorting)*, *Seiton (Arranging)*, Seiso (Cleaning), Seiketsu (Standardizing), and Shitsuke (Sustaining). An example study is Kusrini et al. (2020) where Value Stream Mapping (VSM), Single-Minute Exchange of Die (SMED), and 5S were used in the primary business process in Unit Terminal Container (UTC) resulting in productivity efficiency from 60.81% to 70.20%. Other research, mapping using VSM and applying 5S simplified 45 activities to 37, with time savings from

312 to 294 minutes (Dzulkifli et al., 2021). According to (Hilmi, 2017) using VSM and 5S, resulted in 9.02% faster production time, and NVA activities decreased to 0%.

There are several weaknesses of VSM, which is that influence of dynamic factors is not considered, developed future scenarios are neither checked in advance nor evaluated in terms of cost, and there is an inadequate degree of process detail (Lugert et al., 2018). The biggest difference is that value stream mapping is focused on driving process change, while process activity mapping (PAM), mining and discovery are well-suited to making existing processes more efficient (TechTarget, 2019). Benefits and shortcomings of PAM are already confirmed by previous publications, according to (Ridwan et al., 2020) by using PAM and 5S can increase efficiency of dunnage production from 96.85% to 97.75%.

Based on the positive impact of PAM on the business process, in this study applying lean with 5s using PAM assisted by Bizagi Modeler was adopted. Bizagi Modeler is an application for designing, documenting, and developing models for professionals to improve and make decisions on these business processes (Gjoni, 2014).

Methods

In this research, CCSP is selected as the unit of analysis. The precast factory has two types of products which are Corrugated Concrete Sheet Pile (CCSP) and Girder. Based on the observations and interview results, the order quantity of CCSP (442 pieces) is almost 2 times higher than Girders (230 pieces). In addition to the high number of orders, CCSP concrete has more significant waste than girders because in one single CCSP product cycle, the concrete used can produce 18 pieces. In a girder production cycle, the concrete used can only produce 5 pieces. From observation, CCSP production also has another consequence, which is frequent delay problems resulting in overtime to achieve production targets.

In this research there are 4 steps. First step is observation during a production cycle to determine the production flow, labor needs, and workforce habits. This mapping process will be assisted by Bizagi Modeler 2.0 software which can describe the production flow, display the time requirements for each activity, and critical activities in the production cycle. Second step is Process Activity Mapping (PAM) analysis, used to determine VA, NNVA and NVA activities. The PAM is conducted by the research team, and the results are validated by the production manager for quality control. The output of Process Activity Mapping is getting NVA activities and activities that have problems. The third step is improvement analysis with 5S. This analysis will apply the 5S concept to eliminate NVA activity and fixing problems that occurs in the production cycle. The output of this analysis will produce several improvement actions because of discussions amongst the academic team. The improvement actions are then discussed with the production manager to choose improvements that are deemed feasible for simulation before they will be applied to the factory. The last step is simulation with effectiveness analysis to understand the improvement impact on working time. The research method is outlined in the flow chart in **Figure 1** below.

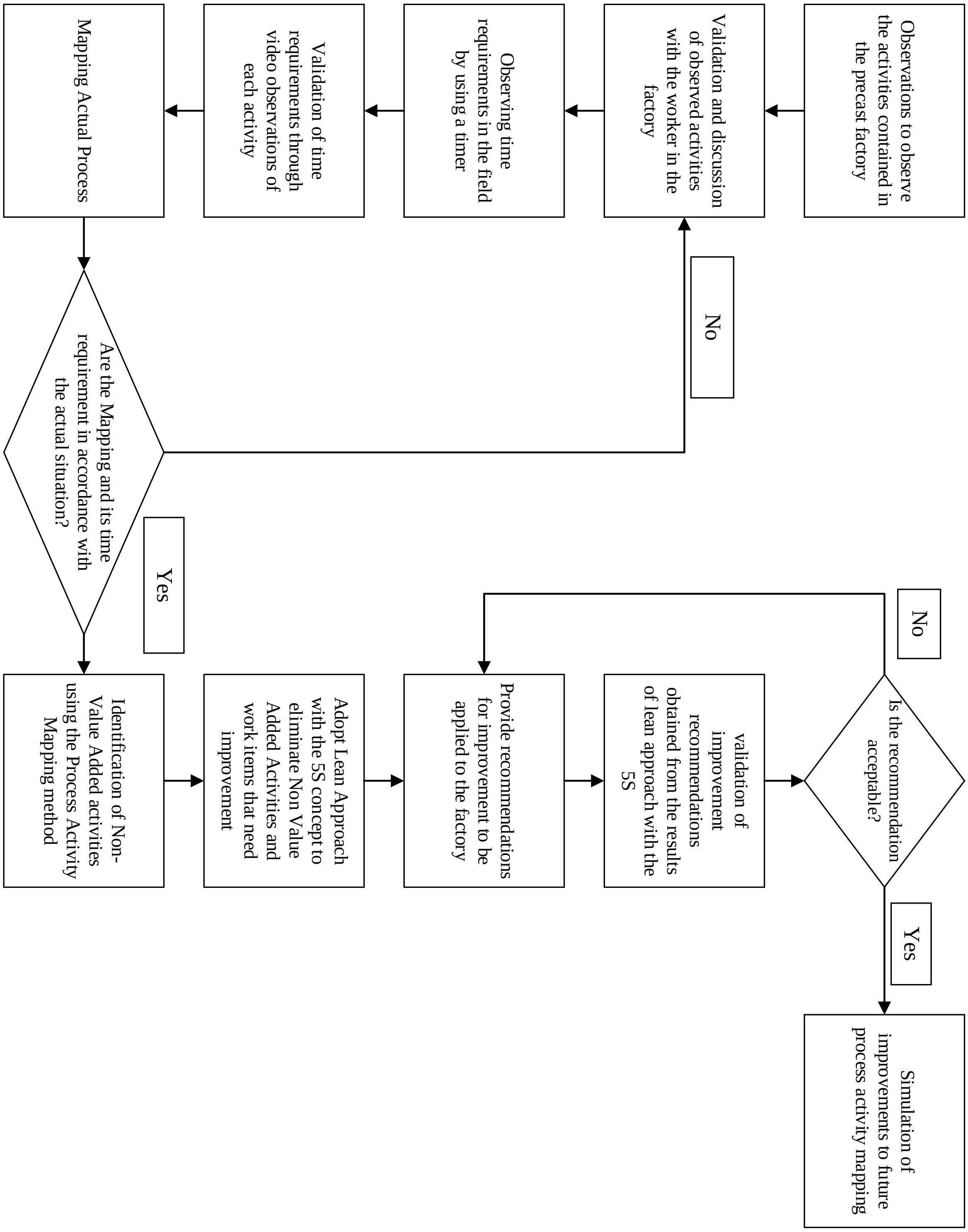

Figure 1: Research Method

Discussion

Production Cycle Modelling

The production cycle obtained from interviews and observations was processed and described using the Bizagi Modeler 2.0 program, complete with mapping and critical activities. The critical activity is an activity that should not have problems because if there is a delay in the activity, it will cause delays in all activities (Eirgash et al., 2017). The critical activities are shown in **Figure 2** with red color boxes.

The detailed steps and durations are determined below:

Cleaning moulding is an activity to remove the remnants of material left behind due to the previous production process to avoid defects in the final CCSP. The activity used a workforce of two people with brush and hammer cleaning tools. It took 1 minute 12 seconds for each mould.

Moulding lubrication provides releasing agent in formwork console oil to the mould. It facilitates releasing concrete from the mould to prevent damage to the concrete surface due to sticking to the mould. One person performed the activity with a sprayer. It took 58 seconds for each mould.

Strand setting is an activity to insert 12.7 diameter strand cable into the CCSP mould, consisting of 20 holes, that needs time 1 hour 48 minutes. The activity starts with the stressing tool, then inserts it into the mould hole, continued inserting into the locking device, and finally cuts the rest of the connection. The activity was performed by four to five people with the paired method.

Strand stressing is an activity to give pre-tensioning force to 20 PC strands with a diameter of 12.7. This activity is installed with gradual tensile strength starting from 1000 psi, 2000 psi, 3000 psi, 4000 psi, 5000 psi, and 5541 psi by using a hydraulic prestressing jack machine and operating by one operator and one assistant. The activity took 1 hour and 30 minutes.

Reinforcement cutting is an activity of cutting reinforcement with a diameter of 8 and a diameter of 13 following the working drawings before the reinforcement is formed. The activity was performed by two people using an iron cutting machine. The activity took 11 minutes 23 seconds to cover the needs of all 18 moulds.

Forming reinforcement is an activity to form reinforcement with diameters 8 and 13, which have been cut and then shaped according to the working drawings before the reinforcement is installed. The activity was performed by two people using a bar bender. It took 15 minutes for all the needs of 18 moulds.

Reinforcement assembly is an activity to assemble reinforcement, fulfilling the working drawings before closing the moulding. The activity could be performed after the strand has been pre-tensioned. Two people performed it for each zone to speed up the assembly process. The activity took 20 minutes and 39 seconds for each mould.
Reinforcement control is an activity to ensure that the installed reinforcement is the requirement of the working drawings to prevent errors that can cause product defects. One quality control person performed the activity and took 1 minute 17 seconds for each mould.

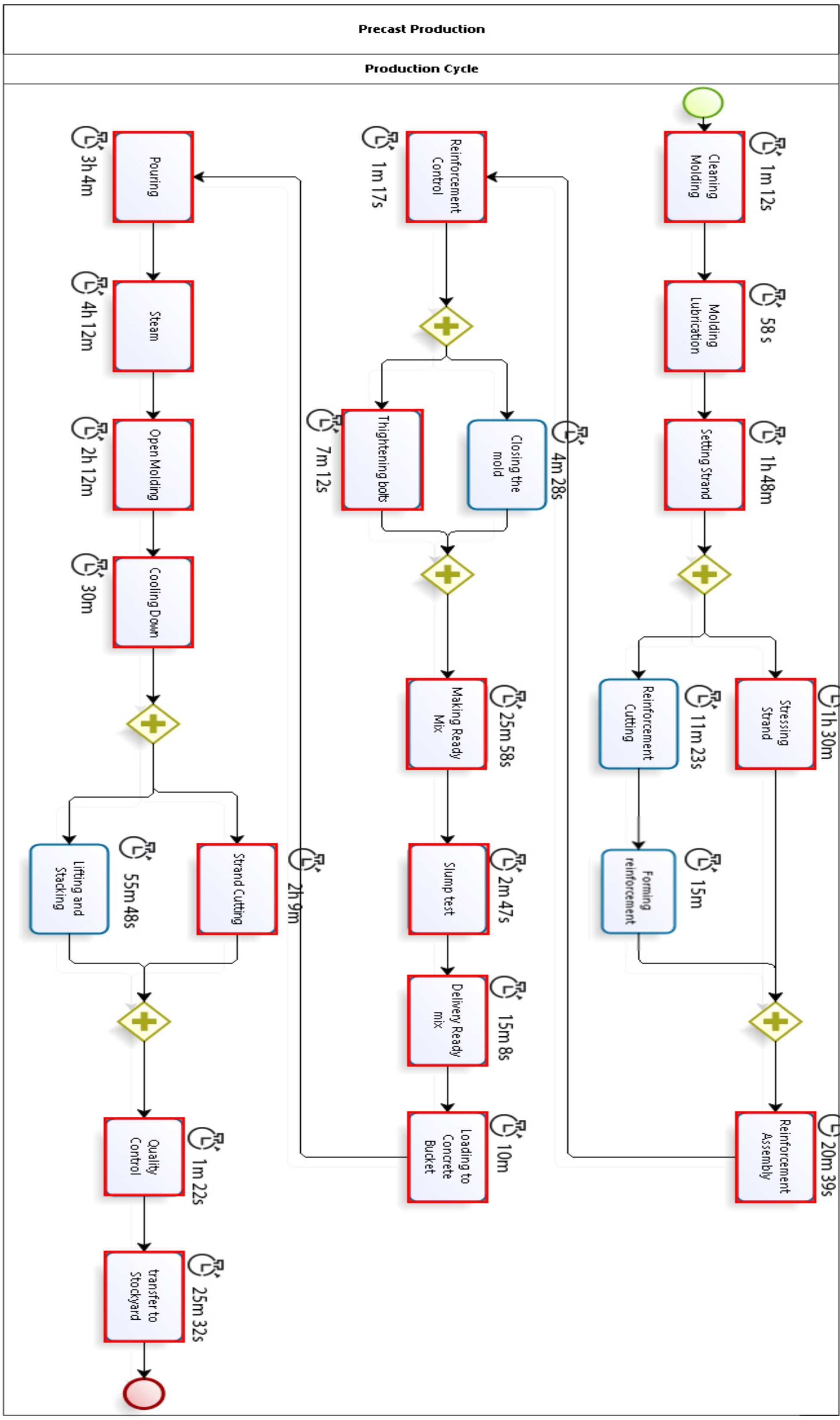

Figure 2: Production Cycle

Closing the moulding is an activity after the reinforcement has passed the reinforcement control stage and has been approved to continue. Two people performed this activity (i.e., one person operated the hoist crane, and one person attached the sling to the moulding cover). The activity took 4 minutes and 28 seconds. The moulding was closed before the casting process was performed.

Tightening the bolts is critical to prevent bleeding in the ready mix, which can cause defects due to not meeting the concrete. The activity was performed by four people divided by two for each zone, and it took 7 minutes 12 seconds for each mould.

Making ready mix is an activity to make a ready mix for CCSP W400B concrete, requiring concrete with a quality of fc' 62 MPa. Later the mix ratio will be adjusted according to the design. The activity took 25 minutes 58 seconds, including sand and split delivery using an excavator to fill the ramp.

The slump test is an activity to ensure that the ready mixture that has been made has met the value of the planned quality to prevent defects in the final concrete result, such as not achieving the compressive strength of concrete which causes re-production to be performed. The activity was performed before the fresh concrete was delivered to the work area. The activity took 2 minutes and 47 seconds.

Delivery ready mix is an activity after the slump test value related to the quality plan. The ready mix can be brought to the pouring area for the casting process using a concrete mixer truck. The activity took 15 minutes 8 seconds and is an activity that includes delays or can cause delays.

Loading into a concrete bucket is filling fresh concrete into a concrete bucket to reach areas the truck cannot reach for direct filling. One person performed the activity to keep the filling from being excessive, taking 10 minutes.

Pouring is an activity of pouring the ready-mix into moulding using one concrete bucket that cannot be reached by truck and one concrete mixer truck for an accessible area. The activity took 3 hours and 4 minutes.

Steam is an activity in the form of fresh heating concrete with high-pressure steam with coal as fuel to accelerate the evaporation of water in the concrete to get the planned strength without having to wait 28 days for the concrete to reach that strength. Two people performed the activity to control the temperature so that it is not too high or low to avoid defects in the product, such as changes in the volume of the concrete. The activity took 4 hours and 12 minutes.

Cooling down is an activity to lower the temperature of the concrete after the steam process to reduce the heat in the concrete so as not to cause the concrete to be damaged during the moulding process. One person performed the activity to ensure the temperature of the concrete was safe for lifting. It took 30 minutes to make sure the moulding was ready to open.

Open moulding is an activity to open the moulding cover, which three people perform (i.e., two people remove the locking bolts, and one person operates the hoist crane). The activity took 2 hours and 12 minutes.

Strand cutting is an activity of cutting strands that are still connected using an oxy-acetylene welding tool performed by two people. The activity took 2 hours and 9 minutes. However, it was found that the activity was only performed by one person, causing an increase in execution time.

Lifting and stacking CCSP is an activity after the strand has been cut, which will then be lifted and stacked before being checked by the quality control officer. The activity was performed by two hoist crane operators on both sides. This activity took 55 minutes and 48 seconds.

Quality control is the last stage before the CCSP concrete is transferred to the stockyard. This stage checks all substantial parts for physical defects that can cause substantial damage. In this study, a repair would be performed if it was still within reasonable limits. On the other hand, if severe, the rebuild process would be performed instead. The activity was performed by one person who served as quality control, and it took 1 minute 22 seconds.

After the CCSP concrete has passed the quality control stage, the concrete will be transferred to the stockyard before the delivery process. The concrete does not accumulate in the work area, disrupting the production cycle. Three people performed the activity (i.e., one person operated the hoist crane, and two other people managed the arrangement of the concrete stacking on the haul truck). The activity took 25 minutes and 32 seconds.

Production Working Time

From the analysis results with the Bizagi Modeler, the total cycle time from the average total duration obtained from the observation results is four times, as shown in Table 1 below.

Table 1: Working Time Analysis

Work Items	Duration Day 1 (minutes)	Duration Day 2 (minutes)	Duration Day 3 (minutes)	Duration Day 4 (minutes)	Mean Duration	Standard Deviation
Reinforcement assembly	379.30	377.80	378.20	380.30	378.90	1.13
Pouring	302.80	303.50	305.20	304.50	304.00	1.06
Steam	251.80	252.00	251.40	252.80	252.00	0.59
Open the moulding	131.20	132.22	130.90	133.40	131.93	1.13
Tightening bolts	130.00	130.20	129.00	129.20	129.60	0.59
Strand cutting	129.00	128.72	129.00	130.20	129.23	0.66
Strand setting	109.00	107.00	109.00	107.00	108.00	1.15
Strand stressing	98.00	99.00	100.00	99.00	99.00	0.82
Closing the moulding	81.00	82.00	79.48	79.40	80.47	1.26
Lifting and stacking	56.30	55.40	55.60	55.90	55.80	0.39

Cooling down	30.00	29.80	30.20	30.00	30.00	0.16
Making ready mix	25.98	26.30	25.80	25.80	25.97	0.24
Transfer to stockyard	25.50	25.40	25.80	25.38	25.52	0.19
Cleaning the moulding	21.10	21.60	22.00	21.70	21.60	0.37
Moulding lubrication	17.20	17.50	17.20	17.70	17.40	0.24
Delivery ready mix	15.20	15.30	15.48	14.54	15.13	0.41
Forming reinforcement	15.00	15.00	15.00	15.00	15.00	0.00
Reinforcement cutting	12.00	11.45	11.20	10.87	11.38	0.48
Loading to the concrete bucket	10.00	10.00	10.00	10.00	10.00	0.00
Slump test	3.00	2.70	2.80	2.62	2.78	0.16
Reinforcement control	1.20	1.30	1.28	1.34	1.28	0.06
Quality control	1.22	1.20	1.30	1.16	1.22	0.06
Total Time of Production Cycle					1846.21	

Process Activity Mapping (PAM)

PAM is a tool to record all activities in a cycle to identify workflow and NVA activities (Pude et al., 2012). This tool eliminates waste to make the work easy, quick, and inexpensive (Hines & Rich, 1997). It can also find out the total number of activities so that value-added activities (VA), necessary non-value-added (NNVA) activities, and non-value-added (NVA) activities are obtained and to find out the time needed for each activity. In the analysis with PAM, brainstorming with the experts and field observations were also carried out to determine the work items that were having problems.

VA is an activity that can provide added value such as quality, time, and other values to a production cycle or other related activities. Value Added activities are activities that do not have defect and problems as much as possible because they will affect the production cycle and the product results (Perdana et al., 2019). For example, in cleaning the moulding activities, if the cleaning is not finished excellently, it will cause the previous materials to stick to the product, which can affect the shape and even the quality of the product. In this research, a few activities included in Value Added such as reinforcement assembly, pouring, steam, tightening bolts, strand cutting, strand setting, strand stressing, closing the moulding, making a ready mix, cleaning the moulding, moulding lubrication, forming reinforcement, slump test, reinforcement control, and quality control.

NNVA is an activity that does not directly affect the quality, time, and other values, but this activity must exist (Shou et al., 2020). In addition, this activity can be carried out outside the production cycle so that it has flexible time to do it, but still must mind the production cycle afterwards, so there are no problems. If this activity is omitted, it will affect the production cycle and the condition of the work area. As an example, “transfer to stockyard” is a NNVA and if this activity is eliminated, what happens is that the product will accumulate in the work area, which can narrow the layout of the work area so that it has an impact on the mobility and security level of the work area. In this research, NNVA activities include opening the moulding, strand cutting, lifting and stacking, cooling down, transferring to the stockyard, reinforcement cutting, and loading a concrete bucket.

Non-Value Added is an activity that does not provide any value to the production cycle or product results, but consumes cost, time, and resource. It needs to be eliminated as much as possible to make production system effectively and efficiently (Wu et al., 2013). In this production cycle, waiting times due to the filling time from the batching plant to the concrete truck, filling from the concrete truck to the concrete bucket, and waiting time for parked concrete trucks are caused by Non-Value Added activity, delivery of ready mix. The current process activity mapping of CCSP production is shown in **Table 2**.

Table 2: Current Process Activity Mapping

Work Items	Type of Activity	Classification	Duration (minutes)	Number of workers (plan)	Number of workers (actual)
Reinforcement assembly	Operation	VA	378.90	4	4
Pouring	Operation	VA	304.00	7	7
Steam	Operation	VA	252.00	2	2
Open the moulding	Operation	NNVA	131.93	3	3
Tightening bolts	Operation	VA	129.60	4	4
Strand cutting	Operation	NNVA	129.23	**2**	**1**
Strand setting	Operation	VA	108.00	4	4
Strand stressing	Operation	VA	99.00	2	2
Closing the moulding	Operation	VA	80.47	2	2
Lifting and stacking	Transportation	NNVA	55.80	2	2
Cooling down	Operation	NNVA	30.00	1	1
Making ready mix	Operation	VA	25.97	1	1
Transfer to stockyard	Storage	NNVA	25.52	3	3
Cleaning the moulding	Operation	VA	21.60	2	2
Moulding lubrication	Operation	VA	17.40	1	1

Delivery ready mix	**Delay**	NVA	15.13	1	1
Forming reinforcement	Operation	VA	15.00	2	2
Reinforcement cutting	Operation	NNVA	11.38	2	2
Loading to the concrete bucket	Operation	NNVA	10.00	1	1
Slump test	Inspection	VA	2.78	1	1
Reinforcement control	Inspection	VA	1.28	1	1
Quality control	Inspection	VA	1.22	1	1
Total Time of Production Cycle			1846.21		

A summary of the PAM analysis can be seen in Table 3. From PAM identification, 11 operation activities classified as VA activities with duration time of 1431.94 minutes, 5 operation activity categorized as NNVA activity with a time of 312.54 minutes, 3 inspection activities indicated VA activities with a time of 5.28 minutes, 1 storage activity as NNVA activity with a time of 25.52 minutes, 1 transportation activity as NNVA activity with a time of 55.8 minutes and 1 activity delay which includes NVA activity with a time of 15.13 minutes. Hence, it appears that 2 activities need to be improved namely the lack of workers on strand cutting work and delivery of ready mix as a delay activity or NVA activity. In consequence, loading to concrete bucket will get impacted due to ready mix delivery activity. These activities are recognized in the critical path, that means crucial to make improvements to avoid the impact of the following process.

Table 3: Summary of Process Activity Mapping Results

Activities	**Amount**	**Time (minute)**	**Percentage (%)**
Value Added	14	1,437.22	77.85
Necessary Non-Value Added	7	393.86	21.33
Non-Value Added	1	15,13	0.29
Total	22	1,846.21	100

Improvements with the 5S Concept

A 5S concept is a tool that improves the work area by eliminating unwanted parts, tools, and debris, streamlining, cleaning, and setting new standards. A 5S concept is adjusting the location to produce enhancements in the work area (Ogunbiyi et al., 2013). In this study, the 5S is used as an improved alternative. The improvement alternatives result from discussions with factory staff to validate feasibility of the alternatives and assist in the selection process. The *Seiri (Sorting)* concept has been planned by making standard operating procedures that direct the worker's needs. A standard operating procedure can ensure field work has been fulfilled. The condition before and after strand cutting work improvement is shown in **Figure 3** and **Figure 4**.

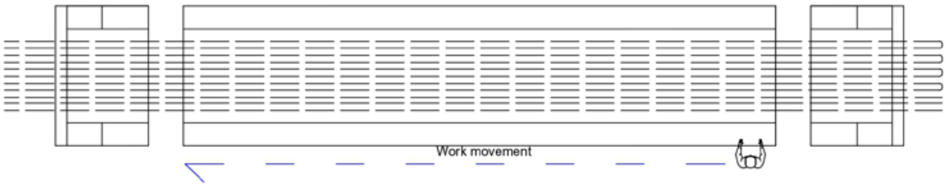

Figure 3: Strand Cutting Work Before Improvement

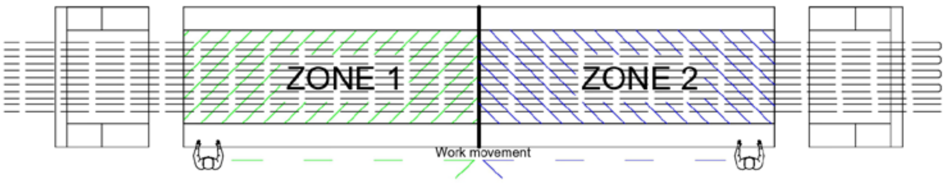

Figure 4: Zoning for Strand Cutting Work

This improvement will accelerate the strand cutting process time by zoning implementation and worker addition. The improvements of strand cutting work that was previously only performed by one person become two people in each, can accelerate work time from 129.23 minutes down to 64.8 minutes (50%).

The second improvement with *Seiton (Arranging)* concept, was suggested by moving the batching plant for CCSP products and the girder next to the batching plant area for spun pile products. At the bottom of the mixer, there is a flexible hose concrete tool to make it easier to take the ready mix, which will be poured into the concrete bucket. After relocating, the batching plant eliminates the accumulation on the transportation lines for ready mix delivery, material delivery, and finished precast concrete delivery. Not only will it eliminate accumulation on the shipping line, but it will also reduce the need for concrete mixer trucks further reducing operational costs. Layout changes can be seen in **Figure 5** and **Figure 6**.

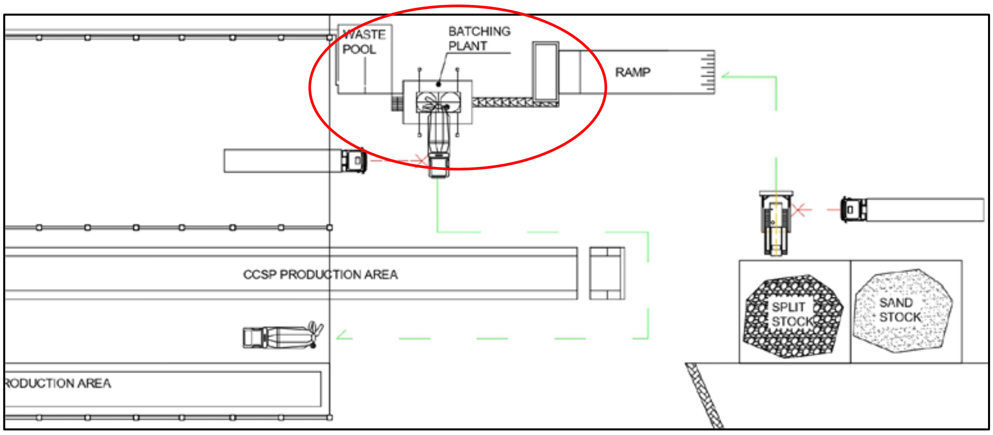

Figure 5: Layout Condition Before Improvement

In the layout condition before the improvement, there is still an accumulation of traffic between the traffic activities of ready-mix delivery and material delivery from the stockyard to the delivery truck, which is shown as a red line (**Figure 5**). The occurrence of intersections is constrained by the long distance for the concrete mixer truck to reach the work area, and not all CCSP production moulding areas can be reached by the concrete mixer truck.

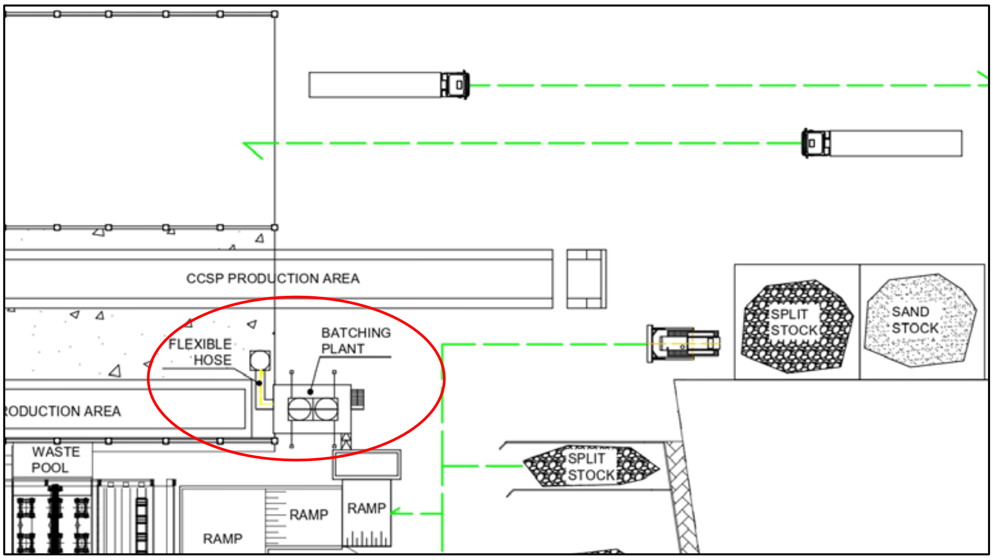

Figure 6: Layout Condition After Improvement

The improvement of moving the batching plant could omit ready mix delivery activities, which means doing away with a concrete mixer truck. As a replacement, a tool such as a flexible hose must be installed to accelerate the pouring process on the concrete bucket from 10 minutes to 5 minutes (50%). The decreased time occurred due to the loss of the concrete mixer truck parking process before pouring concrete into the concrete bucket. As a result, a time savings was observed of 15.13 minutes with eliminating delivery ready mix and 5 minutes for accelerating the loading process to the concrete bucket.

The third improvement with *Seiso* (Cleaning) concept was suggested by purchasing a waste material cart to transport the remaining material in the work area to be collected at the final disposal site. A clean work area will later be able to facilitate activities in the production cycle so that it is safe, conducive, effective, and efficient.

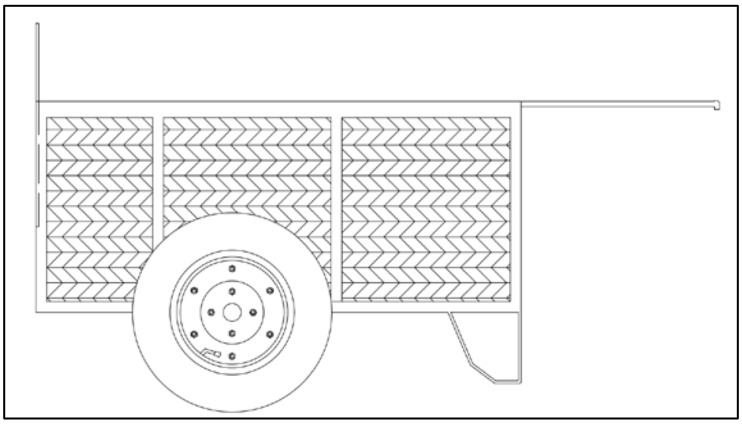

Figure 7: Waste Material Cart

The fourth improvement with Seiketsu (Standardizing) concept was suggested by making a poster about 5S in the work area so that workers can always apply 5S values in all their activities to achieve the goal of implementing lean, namely, an effective and efficient production system.

Figure 8: 5S poster

The fifth improvement with Shitsuke (Sustaining) concept was suggested by installing CCTV cameras in the production area to ensure that workers have implemented the overall 5S values in the work area. CCTV installation will be installed in several sectors which can be seen in **Figure 9** with red dots.

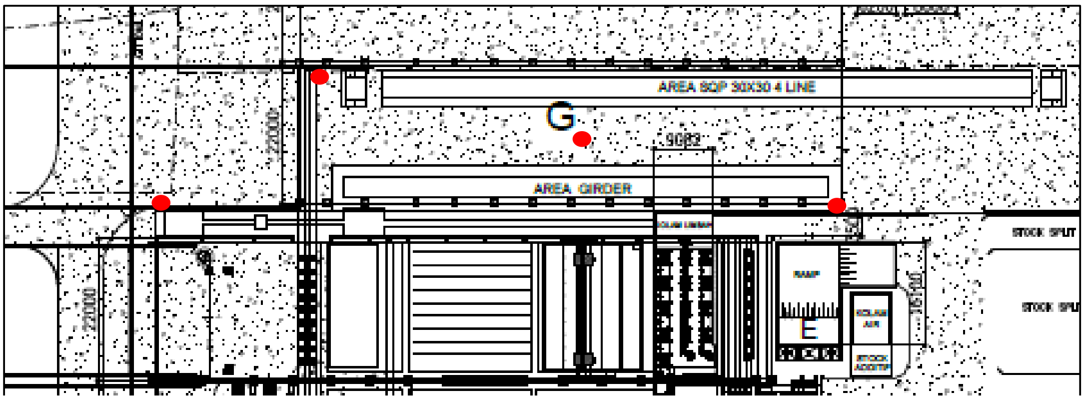

Figure 9: CCTV Installation Layout

Improvement Impact

The following is a summary of the impact on the CCSP precast production cycle with 5S, which can be seen in **Table 4**.

Table 4: Summary of Repair Impacts

Concept	Improvement	Impact
Seiri	Doing standard operating procedure that was to be completed by the number of workers of each work item in it	Shortened execution time of strand cutting from 129.23 minutes become 64.8 minutes. The shortages in labour causing work delays could be avoided.
Seiton	Moving the batching plant (change layout)	Eliminate delay in delivery of ready-mix (NVA activity) – reducing time of travel. Shorten time execution of concrete bucket loading from 10 minutes to 5 minutes.
Seiso	Purchase waste material cart	Ensure that the work area is protected from material residues so that activities can run safely, effectively, and efficiently.
Seiketsu	Installation of 5S reminders or posters in the factory area	Remind workers to apply 5S values so the production system can run effectively and efficiently.
Shitsuke	Installation of CCTV cameras in the factory area	Ensuring workers apply 5S values to production activities.

From the above improvements, *Seiri* and *Seiton* directly impact time, so the implementation of both is expected to provide optimal time-saving results. The merging of these improvements will shorten the execution time of strand cutting and eliminate the delivery-ready mix work items that cause changes in the production cycle. Below is the new production cycle, shown in **Figure 8**.

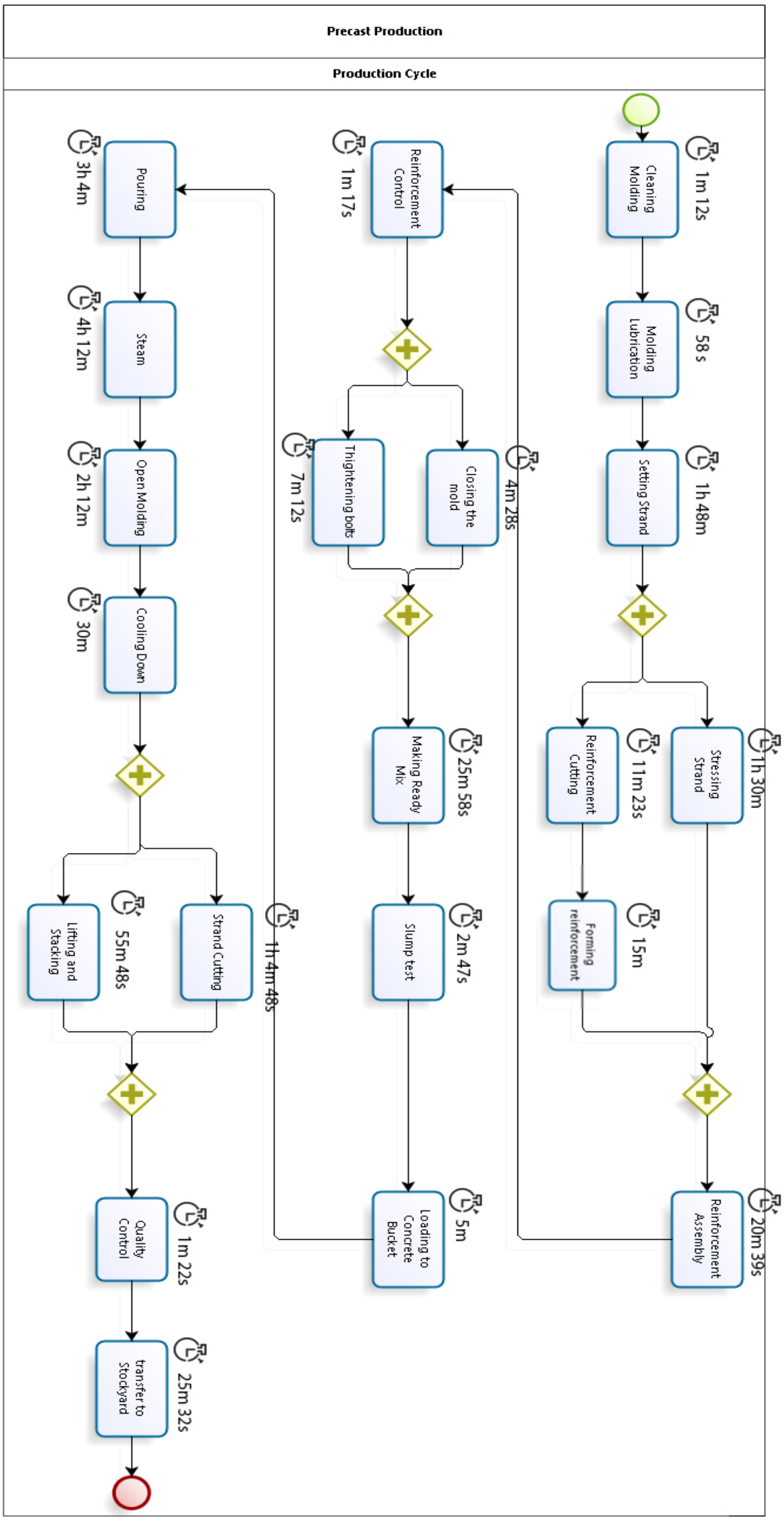

Figure 8: New Production Cycle After Improvement Using 5S Concept

After obtaining a new production cycle, a future process activity mapping analysis was carried out by the research team to determine the affected activities through the simulation results, which the factory manager validate afterwards.

Table 5: Future Process Activity Mapping

Work Items	Type of Activity	Classification	Duration (minutes)	Number of workers (plan)	Number of workers (Future)
Reinforcement Assembly	Operation	VA	378.90	4	4
Pouring	Operation	VA	304.00	7	7
Steam	Operation	VA	252.00	2	2
Open moulding	Operation	VA	131.93	3	3
Tightening bolts	Operation	VA	129.60	4	4
Setting strand	Operation	VA	108.00	4	4
Stressing strand	Operation	VA	99.00	2	2
Closing the mould	Operation	VA	80.47	2	2
Strand cutting	Operation	VA	64.80	2	2
Cooling down	Operation	VA	30.00	1	1
Making ready mix	Operation	VA	25.97	1	1
Transfer to stockyard	Storage	NNVA	25.52	3	3
Cleaning moulding	Operation	VA	21.60	2	2
Moulding lubrication	Operation	VA	17.40	1	1
Forming reinforcement	Operation	VA	15.00	2	2
Reinforcement cutting	Operation	VA	11.38	2	2
Loading to a concrete bucket	Operation	VA	5.00	1	1
Slump test	Inspection	NNVA	2.78	1	1
Reinforcement control	Inspection	NNVA	1.28	1	1
Quality control	Inspection	NNVA	1.22	1	1
Total Time of New Production Cycle			1,761.65		

Comparing Table 2 and Table 5 shows that the total new cycle time is 1,761.65 minutes, and the total cycle time before the improvement was 1,846.21 minutes. The saving in time is 84.56 minutes (4.5%) for a single production cycle of CCSP (**Table 5**). As stated earlier, the precast factory could produce 18 pieces in a single production cycle of CCSP. For example, during the research period, the precast factory accepted an order of 442 pieces of CCSP. It took around 25 cycles to fulfill the order. By implementing a new production cycle, the total time that could be saves is 2,113.85 minutes or 35.23 hours (1.47 days).

Table 6: Effectiveness Analysis - one production cycle producing 18 CCSP pieces

Concept	Before (minutes)	After (minutes)	Difference (minutes)	Efficiency (%)
Seiri* and *Seiton	1,846.21	1,761.65	84.56	4.58%

Conclusion

Based on the research results, two problems were discovered in the CCSP concrete production cycle, which are strand cutting activity was delayed since it was performed with a lack of workers and the delivery ready mix was categorized as a delay activity that needs to be eliminated. Both problems were addressed with 5S – specifically, *Seiri (Sorting)* and *Seiton (Arranging)* which have a direct impact on working time. The three other concepts, namely, *Seiso (Cleaning), Seiketsu (Standardizing), and Shitsuke (Sustaining)* have an indirect impact on production time through improvement in habits and work area layout. *Seiri* was applied through a standard operating procedure including the number of workers for each work item. At the same time, *Seiton* concepts were conducted by moving the batching plant.

The improvement has decreased execution time of strand cutting from 129.23 minutes become 64.8 minutes (50%), elimination of delivery ready-mix as a delay activity (NVA activity) which can save 15.13 minutes of production time, and a shortened working time of concrete bucket loading from 10 minutes become 5 minutes (50%). These working time savings are obtained on one production cycle where 18 CCSP pieces are produced. Before improvements, it took 33 days to complete 25 production cycle of CCSP. After the improvement, the time to complete 25 cycles took 31.5 days (4.5% efficiency).

With this improvement in time, operational costs and energy use will be impacted. Other impacted aspects directly to the factory were not explored in this research and are future research topics. With further research, it will be possible to satisfy the factory desire to integrate Lean Construction in its production system. Future research should also conduct a cost/benefit analysis for moving the batching plant.

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