

Calculation of Productivity Loss at Batching Plant Due to Production Decline

Fasya Dibyana Prakasita¹, Firman Aditya Putra², Genta Putra Adietama³

^{1,2,3}Student, Civil Engineering, Bandung Institute of Technology

Abstract

The Batching Plant owned by PT Semen Indogreen Sentosa was established in the Binjai-Langsa Section on the Trans Sumatera Toll Road Project specifically to handle the demand for ready-mix concrete in the project. However, several obstacles in the project have caused a decrease in production from the batching plant, necessitating an evaluation of productivity loss due to these issues. The productivity loss calculation was conducted by sampling one of the batching plants over a 1-month working period using three approaches/methods: Zink's Method, Thomas Baseline Technique, and Ibbs Statistical Approach. The calculation results from these three approaches provided a range of minimum daily productivity values, which should be 4.40 w-h/m³ - 2.48 w-h/m³, which can then be used as a reference for evaluation purposes, claims, etc.

Keywords: Productivity loss, ready-mix concrete, labor productivity

1. Introduction

The construction of the Trans Sumatera Toll Road (JTTS) is one of the National Strategic Projects (PSN) with a major target from the government, aimed to be completed by 2024. Various efforts have been made to continue and accelerate the construction of JTTS according to the mandate of the President of the Republic of Indonesia. The government, through the Ministry of State-Owned Enterprises (BUMN), proposed to allocate State Capital Participation (PMN) in the draft state budget for the 2023 fiscal year amounting to IDR 3056 trillion to PT Hutama Karya (Persero) as the owner. Part of the fund allocation will be used to complete the Binjai-Langsa section amounting to IDR 109 trillion. To achieve this construction target, Hutama Karya group is making efforts to accelerate from various aspects, one of which is ensuring that the supply chain process runs smoothly. PT Hutama Karya Infrastruktur, as a subsidiary of PT Hutama Karya (Persero) and the contractor for the JTTS Project Binjai-Langsa Section, is a construction service company that heavily relies on other suppliers/subcontractors for their work, especially for major work items such as rebar, soil fill, precast concrete, and ready-mix concrete.

PT Semen Indogreen Sentosa, affiliated with PT Hutama Karya (Persero), as the main supplier of ready-mix concrete for the JTTS Project Binjai-Langsa Section, is required to ensure the provision of ready-mix concrete runs well. There are 6 batching plants spread along the JTTS Project Binjai-Langsa Section currently being worked on. These batching plants were specifically established to support the performance and speed up construction in this section. Despite having large targets, the work on the JTTS Project Binjai-Langsa Section has encountered several obstacles in the past two months, causing the production of ready-mix concrete to be suboptimal. One of the main factors is high rainfall. Due to the high rainfall, especially in the afternoon and evening, preparations for work and site preparations for pouring concrete

are hampered by access issues due to waterlogging. Work that should start in the morning is delayed as the contractor must dry the access first before it can be used. Additionally, due to high rainfall, the areas to be poured become limited as preparations are hindered by rain, causing delays in the pouring schedule. Another factor hampering progress is the design changes from the contractor, consultant, and owner due to poor soil conditions. As a result, the planned concrete pouring is delayed as construction work cannot proceed.

To address these construction progress delays, the contractor has taken steps to increase progress by focusing on work that is not affected by weather and design, such as procuring soil fill, enlarging, and receiving iron material, etc. However, these steps by the contractor have led to a decrease in production at PT Semen Indogreen Sentosa as the producer of ready-mix concrete because all batching plants owned by PT Semen Indogreen Sentosa were established specifically to produce ready-mix concrete for the JTTS Project Binjai-Langsa Section. When the contractor focuses on procuring materials not affected by weather, the demand for ready-mix concrete decreases. Additionally, delayed preparations result in postponed pouring schedules, causing batching plant workers to work overtime, leading to additional costs for overtime with the same or often lower production plans.

Based on the production decline and additional overtime costs, it is necessary to calculate the productivity loss at the batching plant to serve as an evaluation reference for the company and as a basis for calculating claims due to this productivity loss. This study samples production and additional overtime costs at one batching plant and calculates the productivity loss and the steps to be taken based on this evaluation. The productivity loss calculation uses three methods: Zink's Method, Thomas Baseline Technique, and Ibbs Statistical Approach. These three methods will be calculated to later serve as the reference range for minimal productivity and recommendations for determining the basis for claims to the contractor, etc.

2. Study Literature

A. Zink's Method

Zink introduced the concept of the measured mile analysis technique [12][13]. This method differs from others as it allows isolating specific impacts while accounting for inherent inefficiencies in the work performed. It is not based on general industry averages (which may not be appropriate for specific projects) nor assumes that all inefficiencies are caused by the owner as in the total cost method [1].

This technique involves comparing productivity during unaffected periods with productivity during affected periods. Productivity is calculated for both periods, and the difference between them is the productivity loss due to the impact. Ideally, the measured value is the continuous period during the project when labor productivity is unaffected [9].

According to [3], Zink's method should be followed in selecting the measured range of work done during that period. The nature and complexity of the work affected and the composition and skill level of the workers should be comparable. The measured range should also represent a reasonably achievable level of labor productivity.

[12] proposed defining and calculating the measured value using the following three-step procedure:

1. Input the actual working hours spent on a project compared to the percentage of work hours completed (working hours on the ordinate and percentage progress completed and time frame related to the percentage progress completed on the abscissa).
2. Since the first and last 10% progress generally involves "preparation" and "completion" and does not represent the expected ongoing costs or average, data for the first and last 10% progress is ignored,

and only the remaining 80% is calculated.

3. Identify the reasonable linear or nearly linear portion in the progress within the 80% range on the labor curve that shows the segment without obstacles defining the most efficient progress rate. This will be the measured value.

While theoretically, calculating the measured value is straightforward, it has the following practical difficulties:

1. Calculating losses due to specific impacts requires very detailed and reliable information. In other words, good productivity recording is essential for measured mile analysis. It takes a lot of time and effort to record and identify inefficiencies caused by the owner or contractor daily for each specific activity. Many contractors do not maintain this level of detail, especially on projects with many changes.
2. Some argue that the measured value should be "a continuous period when labor productivity is unaffected" [9]. However, in many projects, work disruptions are so widespread that there is no sequential series of unobstructed work and thus no measurable value.
3. The sample size of the measured value should be "reasonable" [12] [3]. But there is no consensus or clear standard on what "reasonable" means. As will be seen later in the presented case study, some current guidelines result in too small a sample size.

B. Thomas Baseline Technique

To address some weaknesses of measured mile analysis, Thomas introduced the baseline concept [9]. The baseline period is the time when the contractor achieves its best productivity. This is not necessarily a continuous, impact-free period. Inefficiencies caused by the owner and contractor may exist throughout. When a continuous, impact-free period is available, the measured mile and baseline period are the same. However, there are many situations where a baseline period can be identified, but no measurable mile is visible. Data presentation later will show the significant difference between measured mile analysis and the baseline method. According to the definition of measured mile analysis [12], the goal of the measured mile calculation is to find periods without impacts caused by the owner. The measured value should be a series of continuous time periods. The baseline method does not require it to be a continuous period but determines the baseline size as 10% of the project duration with the best productivity.

Thomas explains the baseline method mechanism in a series of articles [5][6][7][8][9][10][11]. The calculation steps are:

1. Determine 10% of the total working days.
2. Round this number to the next highest odd number. This number should not be less than 5. This number determines the size of the number of days in the baseline subset.
3. This "n" value is selected as the "n" working days with the highest daily production or output.
4. Calculate the daily productivity for all "n" working days.
5. The baseline productivity is the median of the daily productivity values in the baseline subset. Thomas is inconsistent here. In at least one case, he used the average rather than the median value of the baseline subset [5]. Statistically, the average of a data set is not always the same as the median.

Compared to measured mile analysis, the baseline method has the following advantages:

1. The baseline method does not require calculations with the same level of detail as measured mile analysis. Measured mile analysis requires production periods that are free or nearly free from productivity disruptions. The baseline method, on the other hand, does not require such filtering. Such

filtering typically requires a much more detailed work recording, so the baseline method may not be as burdensome in this regard.

2. In cases where no measurable mile is visible or available, the baseline productivity level can still be determined and used to measure changes.

Disadvantages of the baseline method include:

1. Highly subjective. There is no evidence that 10% of all daily productivity is a reasonable or widely accepted percentage to represent the contractor's best achievable performance. Every project is different. Although 10% of the project duration may be a suitable reference period for some projects, it is impractical to assume it is a universally applicable number for all projects. Furthermore, this 10% sample may be 10% of the time similar work is performed, not 10% of the total project, which may consist of a series of very different work categories. However, Thomas is unclear about this.
2. This procedure selects the content of the baseline subset "as n working days with the highest daily production or output." Daily output may be maximized based on workforce size. Therefore, certain days may be selected as the baseline that does not truly represent the achieved productivity.

C. Ibbs's Statistical Clustering Method

This method, discovered by William Ibbs and Min Liu, aims to correct the shortcomings of previous methods. The basic principle of its productivity loss calculation is to compare unit productivity during an unobstructed period with that achieved during an obstructed period and then cluster them. The main idea of this statistical clustering method is to separate data into different groups. The basis for division in this method is the similarity of data points. In other words, all data divided into the same cluster group should have comparable productivity values.

The statistical clustering method is relevant to this type of data analysis problem and can be divided into 1) hierarchical clustering techniques and 2) non-hierarchical clustering techniques [2]. Hierarchical techniques arrange data into a tree-like graph based on similarity. All data points start as individual clusters, and at each clustering step, the two closest clusters are merged until only one cluster remains. For example, there will be 10 clusters at the first level if there are a total of 10 data points. At the next level, the cluster of the two closest data points is merged; say, the sixth and eighth data points are merged because the distance between these two points is the smallest among all pairwise combinations of the 10 data points. Then, at the third level, a new object joins the cluster containing the two previous data points, or another two-object cluster is formed with the decision based on some assignment criteria. This assignment criterion might reach a point where the incremental increase in analysis becomes "very small" at each progressive analysis step.

The process continues similarly until finally, a single cluster comprising all objects is formed. In the hierarchical method, once two data points are merged into a single cluster, those points will cluster with other data points individually.

Alternatively, non-hierarchical clustering techniques form clusters by optimizing certain clustering criteria. The K-means clustering algorithm is a specific form of non-hierarchical clustering. The K-means algorithm starts by dividing all data points into K groups with the cluster centers distributed as widely as possible. Then, data points are moved between clusters based on the distance between the data points and the K cluster centers. After the first iteration is complete, new clusters are formed, and the cluster centers are updated. This process repeats until no further changes in the cluster means occur, or the maximum number of iterations is reached.

The calculation process for the K-means method for identifying baseline productivity involves three basic steps:

1. Select the initial cluster centers. The first step is to select the maximum and minimum productivity values and use them as the initial cluster centers for all existing data.
2. Update the initial cluster centers. After selecting the initial cluster centers, the next step is to calculate the data starting from the first data to be combined with the nearest value to form a new cluster. Then, each step, in turn, is combined with the nearest cluster, and the cluster mean is updated accordingly. In the K-means algorithm, the distance between data points and the cluster center is calculated as the Euclidean distance defined by Dillon (1984).
3. Assign points to the nearest cluster. Repeat step 2 until no further changes in cluster means occur, or the maximum number of iterations is reached, and all data is divided into 2 cluster groups, and the smaller cluster value is taken.

Implementing the K-means clustering method for calculating baseline productivity can be programmed in Microsoft Excel or directly used in commercial software packages such as SPSS [4]. The advantages of K-means clustering are:

1. Objective. In the statistical clustering method, all daily productivity is divided into two groups according to their values. Impacted daily productivity and unaffected daily productivity are divided into two different groups.
2. No 10% rule applies to all for baseline productivity calculation. All baseline productivity is calculated based on the actual performance and characteristics of the project.
3. It is a simple and fast calculation method. The calculation process can be programmed in Microsoft Excel or statistical software like SPSS.

3. Method

This research was conducted by collecting data from one of the batching plants. The data collected include production data and the total work hours per day over a 1-month production cut-off period (26 October – 25 November 2022). Work hours are counted from 08.00 WIB until the end of the workday according to the contractor's request (overtime for standby or production). These work hours are also calculated from the morning, assuming that even if there is no concrete pouring at the batching plant, the fixed labor costs for paying permanent employees are still counted (according to the daily distribution of monthly salaries). If on one or more working days, production plans fail due to some obstacles, the work hours will be carried over to the next day. After that, productivity loss is calculated using three methods: Zink's Method, Thomas Baseline Technique, and Ibbs Statistical Approach. As a reference based on the target daily productivity of the batching plant according to the cost of goods sold (COGS) or the production cost, the ideal target is 10 work hours with 25 employees and a minimum production of 140m³/day, resulting in a target daily productivity value of $10 \times 25 / 140 = 1.78$ w-h/m³.

4. Data Analysis

After collecting production data and total work hours over a 1-month period, it was found that there were 31 working days with a total production of 2408 m³. Workdays without production were carried over to the next day. For example, on the 3rd production day on 28 October 2022, there was no production, but there were still work hours due to heavy rain, which caused workers who were already on standby at the batching plant to be paid for standby without production income that day. Therefore,

the work hours of the employees were carried over to 29 October 2022, assuming the production plan on 28 October 2022 was postponed to 29 October 2022. Based on the data, there were 5 working days without production, so the work hours on those days were carried over to the next day, and the 31 days' data changed to 26 days as shown in Table 1. After adjusting the production workdays, the next step was to calculate productivity loss using Zink's Method, Thomas Baseline Technique, and Ibbs Statistical Approach, as presented in Table 2.

Work Day	Production Date	Work Hours (w-h)	Cumulative work hours (w-h)	Total Output (m ³)
1	26 Okt 22	180	180	35.5
2	27 Okt 22	275	455	74
3	28 Okt 22	250	705	0
4	29 Okt 22	375	1080	204.5
5	30 Okt 22	646	1726	143
6	31 Okt 22	475	2201	293.5
7	1 Nov 22	350	2551	127.5
8	2 Nov 22	325	2876	97
9	3 Nov 22	250	3126	47
10	4 Nov 22	264	3390	22
11	5 Nov 22	250	3640	0
12	6 Nov 22	350	3990	0
13	7 Nov 22	336	4326	80.5
14	8 Nov 22	230	4556	41.5
15	9 Nov 22	336	4892	97
16	10 Nov 22	400	5292	129
17	11 Nov 22	375	5667	109
18	12 Nov 22	350	6017	69
19	13 Nov 22	144	6161	0
20	14 Nov 22	288	6449	55
21	15 Nov 22	322	6771	92.5
22	16 Nov 22	308	7079	86
23	17 Nov 22	300	7379	69.5
24	18 Nov 22	375	7754	104
25	19 Nov 22	400	8154	96
26	20 Nov 22	150	8304	0
27	21 Nov 22	336	8640	70.5
28	22 Nov 22	360	9000	83.5
29	23 Nov 22	300	9300	69.5
30	24 Nov 22	275	9575	22
31	25 Nov 22	375	9950	89.5
TOTAL		9950	9950	2408

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1	26 Okt 22	180	180	35.5
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5	31 Okt 22	475	2201	293.5
6	1 Nov 22	350	2551	127.5
7	2 Nov 22	325	2876	97
8	3 Nov 22	250	3126	47
9	4 Nov 22	264	3390	22
10	7 Nov 22	936	4326	80.5
11	8 Nov 22	230	4556	41.5
12	9 Nov 22	336	4892	97
13	10 Nov 22	400	5292	129
14	11 Nov 22	375	5667	109
15	12 Nov 22	350	6017	69
16	14 Nov 22	432	6449	55
17	15 Nov 22	322	6771	92.5
18	16 Nov 22	308	7079	86
19	17 Nov 22	300	7379	69.5
20	18 Nov 22	375	7754	104
21	19 Nov 22	400	8154	96
22	21 Nov 22	486	8640	70.5
23	22 Nov 22	360	9000	83.5
24	23 Nov 22	300	9300	69.5
25	24 Nov 22	275	9575	22
26	25 Nov 22	375	9950	89.5
TOTAL		9950	9950	2408

Table 4.1 Change of Work Days from 31 Days to 26 Days

Using Zink's Method (Graph 1a), the initial calculation was done by calculating daily productivity by dividing cumulative daily work hours by daily production (hours/m³). For example, on the first day, it was found that in 507 work hours, 1m³ of ready-mix concrete was produced. On the second day, 372 work hours produced 1m³ of ready-mix concrete, and so on. Then, a comparison between cumulative progress

percentage (horizontal) and cumulative work hours (vertical) was made. According to Zink's rule in 1986, the first and last 10% of data are excluded from the analysis, focusing on the remaining 80% progress. However, the author chose to ignore this step as the period taken was already in the middle of the production progress, so all data had the same influence (batching plant production is repetitive, so no adjustment is needed). The next step identified production from the 17th to the 21st day, where productivity was most stable. Then, the average daily productivity was calculated as $348 + 358 + 4.32 + 3.61 + 4.17 / 5 = 3.83$ w-h/m³.

Table 4.2 Calculation of Productivity Loss

Work Day	Production Date	Work Hours (w-h)	Cumulative work hours (w-h)	Total Output (m ³)	Percent Output	Cumulative Percent Output	Daily Productivity Zink (w-h/m ³)	Daily Productivity Thomas (w-h/m ³)	Daily Productivity K-means (w-h/m ³)
1	26 Okt 22	180	180	35.5	1.47%	1.47%	5.07	5.07	5.07
2	27 Okt 22	275	455	74	3.07%	4.55%	3.72	3.72	3.72
3	29 Okt 22	625	1080	204.5	8.49%	13.04%	3.06	3.06	3.06
4	30 Okt 22	646	1726	143	5.94%	18.98%	4.52	4.52	4.52
5	31 Okt 22	475	2201	293.5	12.19%	31.17%	1.62	1.62	1.62
6	1 Nov 22	350	2551	127.5	5.29%	36.46%	2.75	2.75	2.75
7	2 Nov 22	325	2876	97	4.03%	40.49%	3.35	3.35	3.35
8	3 Nov 22	250	3126	47	1.95%	42.44%	5.32	5.32	5.32
9	4 Nov 22	264	3390	22	0.91%	43.36%	12.00	12.00	12.00
10	7 Nov 22	936	4326	80.5	3.34%	46.70%	11.63	11.63	11.63
11	8 Nov 22	230	4556	41.5	1.72%	48.42%	5.54	5.54	5.54
12	9 Nov 22	336	4892	97	4.03%	52.45%	3.46	3.46	3.46
13	10 Nov 22	400	5292	129	5.36%	57.81%	3.10	3.10	3.10
14	11 Nov 22	375	5667	109	4.53%	62.33%	3.44	3.44	3.44
15	12 Nov 22	350	6017	69	2.87%	65.20%	5.07	5.07	5.07
16	14 Nov 22	432	6449	55	2.28%	67.48%	7.85	7.85	7.85
17	15 Nov 22	322	6771	92.5	3.84%	71.32%	3.48	3.48	3.48
18	16 Nov 22	308	7079	86	3.57%	74.90%	3.58	3.58	3.58
19	17 Nov 22	300	7379	69.5	2.89%	77.78%	4.32	4.32	4.32
20	18 Nov 22	375	7754	104	4.32%	82.10%	3.61	3.61	3.61
21	19 Nov 22	400	8154	96	3.99%	86.09%	4.17	4.17	4.17
22	21 Nov 22	486	8640	70.5	2.93%	89.02%	6.89	6.89	6.89
23	22 Nov 22	360	9000	83.5	3.47%	92.48%	4.31	4.31	4.31
24	23 Nov 22	300	9300	69.5	2.89%	95.37%	4.32	4.32	4.32
25	24 Nov 22	275	9575	22	0.91%	96.28%	12.50	12.50	12.50
26	25 Nov 22	375	9950	89.5	3.72%	100.00%	4.19	4.19	4.19
TOTAL			9950	2408	100.00%	MEAN	5.11	5.11	5.11

Zink's method data and Thomas method data are pictured in the next graph.

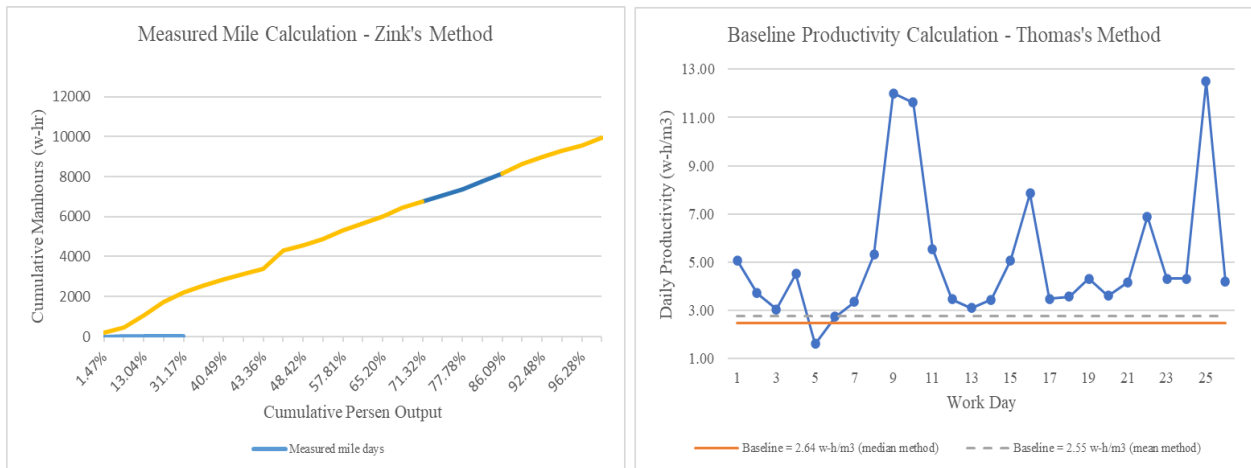


Figure 4.1 Zink's Method (a) and Thomas Method (b)

Using the Thomas Baseline Technique (Figure 1b), this procedure takes 10% of the 26 workdays and rounds the 2.6 figure to the next highest odd number, not less than 5, thus selecting "n" as 5 production days. The 5 workdays were chosen based on the highest daily productivity values and identified. The median and average of the five data were then calculated. From the data above, the highest productivity values were 3.06, 1.62, 2.75, 3.35, and 3.10 w-h/m³. The next step is to calculate the median and average of these five data, resulting in a median of 2.48 and an average of 2.77 w-h/m³.

Figure 4.2 K-Means Method Step 1 (a) and K-means Method Step 2 (b)

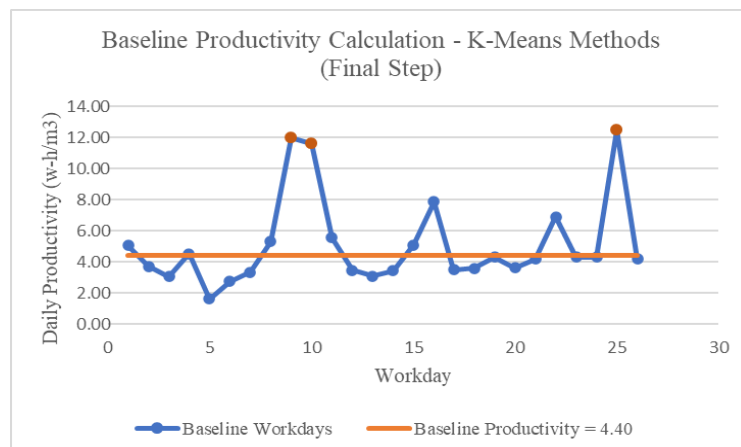
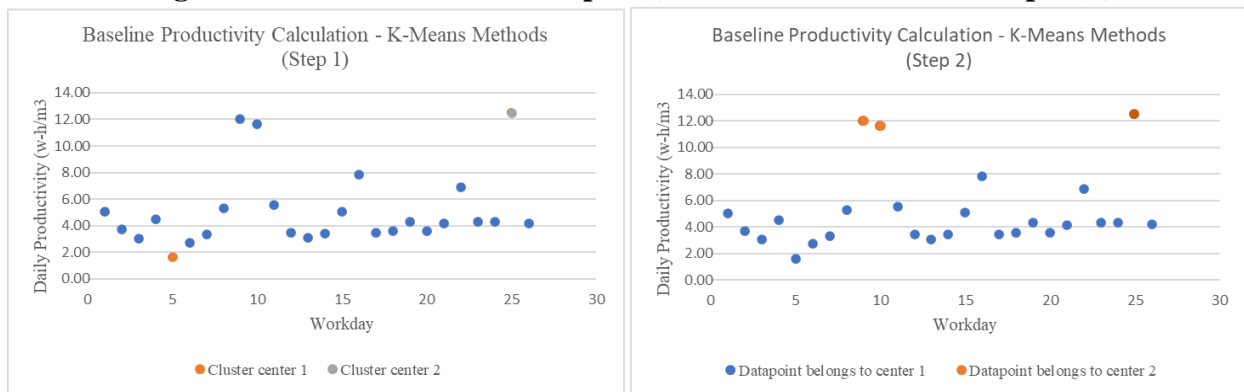


Figure 4.3 K-Means Method Final Step

Using the Ibbs Statistical Approach (Figure 1a), the first step is to identify $K=2$ and select the maximum and minimum values to use as initial clusters. The maximum value = 12.5 and the minimum value = 1.62 divide the variable values into two most distant clusters. The next step is to calculate from the first day's productivity of 5.07 assigned to its nearest center, which is 1.62. Each subsequent number is assigned alternately to its nearest cluster, and the cluster mean is updated accordingly. For example, after assigning the value 5.07 to the center of cluster 1.62, the new cluster mean is $5.07 + 1.62 / 2 = 3.34$ w-h/m³. Then, the second day's productivity of 3.72 is assigned to its nearest center, which is 3.34. The new median is $3.72 + 3.34 / 2 = 3.53$ w-h/m³. This process continues until the final day's productivity of 4.19 is assigned to the nearest center (Graph 2b). Based on the calculation, 23 days are in the first cluster and 3 days in the second cluster. At the end of this step, the new median is min = 4.40 and max = 12.22. The calculation results can be seen in Graph 3.

From the calculations of the three methods, the analysis results using these three methods were 3.83 w-h/m³ (Zink's Method), 2.48 w-h/m³ and 2.77 w-h/m³ (Thomas Baseline Technique), and 4.40 w-h/m³ (Ibbs Statistical Approach). From these data, it can be established that the minimum productivity range should be 4.40 w-h/m³ - 2.48 w-h/m³. This productivity value is considered fairer compared to calculating the average productivity over the 1-month production period. However, compared to the company's target daily productivity value, the productivity range for this period is still far below the expected value of 1.78 w-h/m³. The calculated productivity range can be used as a reference for future evaluations, claims, etc.

5. Conclusions

The Batching Plant owned by PT Semen Indogreen Sentosa was established along the JTTS Binjai-Langsa Section specifically to handle the demand for ready-mix concrete in the project. Several obstacles in the project caused a decrease in production from the batching plant, necessitating an evaluation of productivity loss due to these issues. The productivity loss calculation was conducted by sampling one of the batching plants over a 1-month working period using three approaches/methods: Zink's Method, Thomas Baseline Technique, and Ibbs Statistical Approach. Based on the calculation of the target daily productivity of the batching plant according to the cost of goods sold (COGS) or the production cost, the ideal target is 10 work hours with 25 employees and a minimum production of 140m³/day, resulting in a target daily productivity value of $10 \times 25 / 140 = 1.78$ w-h/m³. After calculating the three approaches, the minimum daily productivity range should be 4.40 w-h/m³ - 2.48 w-h/m³, which can then be used as a reference for evaluation purposes, claims, etc.

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