Jurnal Sistem Teknik Industri
Journal homepage: https://talenta.usu.ac.id/jsti

Capacity Planning for Assembly Plant Unit PC1250 at Heavy Equipment Manufacturing Company

Anastasia Lidya Maukar*[1], Rahman Ramadhan[1]
[1]*Faculty of Engineering, Industrial Engineering Department, President University, Jl. Ki Hajar Dewantara, Kota Jababeka, Cikarang, Bekasi, 17550, Indonesia*
*Corresponding Author: almaukar@gmail.com

ARTICLE INFO
Article history:
Received 4 March 2026
Revised 1 April 2026
Accepted 17 April 2026
Available online 8 June 2026

E-ISSN: 2527-9408
P-ISSN: 1411-5247

How to cite:
A. L. Maukar and R. Ramadhan, "Capacity planning for assembly plant unit PC1250 at heavy equipment manufacturing company," *J. Sist. Tek. Ind.*, vol. 28, no. 2, pp. 88–105, June 2026.

http://doi.org/10.32734/register.v27i1.idarticle

ABSTRACT
The rapid growth of Indonesia's mining sector has triggered a critical capacity bottleneck on PT Komatsu Indonesia's PC1250 production line. Current output is limited to 4 units per month compared to a projected demand of 7 units, resulting in an extreme overutilization rate of 256%. This study applies an Aggregate Planning strategy by comparing three methods: Transportation, Hybrid, and Excel Spreadsheet GRG, which were validated through the Master Production Schedule (MPS) and Rough-Cut Capacity Planning (RCCP). Analysis results show that the Excel GRG Method is the optimal solution with the lowest cost of IDR 132,649,508, more efficient than the Transportation Method (IDR 135,833,000) and the recruitment-focused Hybrid Method (IDR 403,365,672). Although current facility capacity is limited to approximately 1,461 hours (1,320 regular hours and 141 overtime hours), the optimal strategy bridges this gap by utilizing 1,408 regular hours, 395 overtime hours, and 1,383 subcontracted hours. This approach successfully meets the cumulative demand for 49 units without a backlog, reducing the utilization rate from 256% to a more sustainable 95%, thereby ensuring operational stability and maximum economic efficiency.
Keyword: *Aggregate Planning, Capacity Planning, Hybrid Method, Solver Excel Method, Transportation Method*

ABSTRAK
Pertumbuhan pesat sektor pertambangan Indonesia telah memicu kesenjangan kapasitas kritis pada lini produksi PC1250 PT Komatsu Indonesia. Saat ini terbatas pada 4 unit per bulan dibandingkan dengan permintaan proyeksi 7 unit, sehingga menghasilkan tingkat overutilization ekstrem 256%. Penelitian ini menerapkan strategi Aggregate Planning dengan membanding kan tiga metode: Transportasi, Hibrid, dan Excel Spreadsheet GRG, yang divalidasi melalui Master Production Schedule (MPS) dan Rough-Cut Capacity Planning (RCCP). Hasil analisis menunjukan bahwa Metode Excel GRG merupakan solusi optimal dengan biaya terendah sebesar IDR 132.649.508, lebih efisien dibandingkan Metode Transportasi (IDR 135.833.000) dan Metode Hibrid yang berfokus pada rekrutmen (IDR 403.365.672). Meskipun fasilitas saat ini dibatasi sekitar 1.461 jam (1.320 jam reguler dan 141 jam lembur), strategi optimal menutup kesenjangan ini dengan memanfaatkan 1.408 jam reguler, 395 jam lembur, dan 1.383 jam subkontrak. Pendekatan ini berhasil memenuhi permintaan kumulatif 49 unit tanpa backlog, menurunkan tingkat utilisasi dari 256% menjadi 95% yang lebih berkelanjutan, sehingga memastikan stabilitas operasional dan efisiensi ekonomi maksimum.
Keyword: Aggregate Planning, Perencenaan Kapasitas, Metode Hibrid, Metode Solver Excel, Metode Transportasi

1. Introduction

The growth of the mining equipment industry in Indonesia continues to significantly change production requirements. With increased downstream mining and infrastructure projects, demand for high-capacity excavator machinery has risen significantly over the past few years [18]. In addition, the Global Excavator

Attachment Market stood at USD 632.97 billion in 2024 and is projected to grow from USD 666.21 billion in 2025 to USD 1,003.19 billion in 2033, with a CAGR of 5.25% for 2025–2033 [1]. This changing industry landscape must be supported by a production process capable of managing increasingly variable demand, slow manufacturing cycles, and the intricate components inherent in heavy equipment manufacturing [9].

Within this evolving landscape, PT Komatsu Indonesia operates as a critical manufacturer of high-capacity earth moving equipment, including the PC1250 excavator. The company's assembly plant serves as the final integration point where labor-intensive manual proficiency, rather than automated machine cycles, dictates throughput. Currently, the assembly section for the PC1250 unit operates with a dedicated workforce of 7 operators over a standard 20-day monthly period. Historically, this configuration was sufficient to support a stable demand of 3 to 4 units per month; however, the manufacturing system is now facing a new reality, as the marketing department has set aggressive new targets beginning in August 2025.

Within the production environment assessed in this study, internal observations reveal a clear mismatch between available capacity and market requirements. With a workforce of 7 operators and a standard working period of 20 days, the assembly section can produce only 4 units per month. However, forecasted demand beginning in November 2025 indicates a requirement of seven units per month a capacity shortfall of approximately 75%. This gap significantly increases operational risks, including excessive overtime, reliance on subcontracting, inventory instability, and unmet customer delivery commitments; in high-value manufacturing, such inefficiencies often lead to escalating production costs and reduced service levels, which undermine competitiveness and supply reliability [11].

In addition to time and labour capacity constraints, overlapping work patterns across processes indicate that the current production system is operating near maximum capacity, meaning that, without adjustments to capacity planning, the company has the potential to experience bottlenecks on the main assembly line and delays in completing subsequent units.

Through large-scale mechanical manufacturing processes, previous research shows that boom effects, workforce shortages, bottlenecks, and scheduling inaccuracies are common challenges that often hinder meeting targeted one-month production plans [15]. Heavy machinery products also require multistage fabrication, long processing times, large components, and coordinated assembly of subcomponents, which poses additional planning complexity [10]. Research further highlights that even minor deviations in planning accuracy can lead to significant cost escalations due to the long cycle times and high-value components involved [13].

Academic studies over the past decade have offered a broad range of approaches to address production planning challenges, including transportation models, linear programming, mixed-integer linear programming (MILP), heuristic methods, simulation-based planning, hybrid Rough-Cut Capacity Planning (RCCP) models, genetic algorithms, and Excel Spreadsheet GRG-based optimization [14]. While these approaches have been widely implemented across the FMCG, garment, electronics, and food-processing industries, most research focuses on products with short processing times and relatively simple assembly flows [5]. Only a limited number of studies explicitly examine Aggregate Planning within heavy equipment manufacturing, despite the significantly higher planning complexity and cost implications, highlighting the need for tailored production planning frameworks that reflect the long, resource-intensive, and interconnected processes characteristic of heavy machinery production.

Given these conditions, a more strategic planning approach is needed to adjust production capacity to the set targets. Therefore, this study proposes applying the Aggregate Planning method to determine an optimal capacity adjustment strategy by regulating the number of workers, working hours, and production levels to achieve the production target of 7 PC1250 units per month effectively and efficiently without incurring excessive costs. The aggregate planning proposals are prepared using three alternative methods Transportation Method, Hybrid Method, and Excel Spreadsheet GRG Method to compare production plans from different optimization approaches and identify the most efficient result in terms of cost and utilization of production capacity; within this planning, companies are allowed to adjust regular working hours, overtime, and subcontracting.

To address the research gap, this study contributes by developing a tailored Aggregate Planning framework specifically adapted to the operational constraints of heavy equipment assembly, and by providing a comparative analysis of the Transportation Method, Hybrid Method, and Excel Spreadsheet GRG optimization within a labor-intensive, long cycle manufacturing environment. The primary contribution lies in bridging the disconnect between theoretical cost minimization and operational feasibility by integrating aggregate planning models with Rough-Cut Capacity Planning (RCCP) to validate that the proposed capacity strategies specifically combinations of regular time, overtime, and subcontracting are actionable without disrupting the assembly line flow [16], while also demonstrating how multiple mathematical planning models can reveal strengths and limitations in medium or long term planning environments [17].

2. Literature Review

2.1. Aggregate Planning

Aggregate planning is one method of production planning. If production capacity remains fixed in accordance with long-term planning orders, it is the responsibility of aggregate production planning to establish policies to anticipate demand fluctuations at minimum cost [1]. In other words, aggregate planning is designed to adjust production capacity in the face of uncertain market demand by optimizing the use of available labor and production equipment to minimize total production costs. If orders received are stable over a long period, production planning will not encounter difficulties in setting monthly production plans [2]. However, the reality on the ground is different: demand patterns are often dynamic rather than static, making it difficult to establish monthly production plans. It is where the role of the aggregate planning method comes in to overcome these difficulties.

2.2. Hybrid Strategy

Hybrid strategy in aggregate planning refers to a combination of different approaches to achieve an optimal balance between conflicting objectives in production and operations management. Aggregate planning involves making decisions about production, inventory levels, and workforce utilization over a specified time horizon to meet customer demand while minimizing costs.

The formula for unit per workers per month to calculate it is as shown in Equation (1).

$$\text{Unit per Worker per month} = \frac{(\text{Production Rate x Days})}{7} \tag{1}$$

Equation (2) shows the calculation for unit per workers per hours.

$$\text{Unit per Worker per hour} = \text{Unit per worker per month} \div \text{Days} \times \text{Num. of Working Hour} \tag{2}$$

Equation (3) is used for computing the net demand on the month of January.

$$\text{Net Demand} = \text{Demand} - \text{Beginning Inventory} \tag{3}$$

The formula for Hiring Cost, we can calculate as shown in Equation (4).

$$\text{Hiring Cost} = \text{Worker Hired} \times \text{Hiring Cost} \tag{4}$$

The formula for Layoff Cost, we can calculate as shown in Equation (5).

$$\text{Layoff Cost} = \text{Workers Fired} \times \text{Layoff Cost} \tag{5}$$

Equation (6) is for computing the Overtime Cost.

$$\text{Overtime Cost} = \text{Overtime Hour} \times \text{Overtime Cost} \tag{6}$$

The formula for Total Unit Produces, we can calculate as shown in Equation (7).

$$\text{Total Unit Produces} = \text{Unit Overtime Produces} + \text{Production} \tag{7}$$

The formula for Production Cost, we can calculate as shown in Equation (8).

$$\text{Production Cost} = \text{Total Unit Produced} \times \text{Regular Time Cost} \quad (8)$$

The formula to get the total cost on the month of August which formula as shown in Equation (9).

$$\text{Total Production Cost} = \text{Hiring Cost} + \text{Production Cost} \quad (9)$$

2.3. Transportation Strategy

Transportation strategy in aggregate planning refers to the approach and decisions made regarding the movement of goods and materials within a supply chain during the aggregate planning process [3]. Aggregate planning is a process that involves determining the production, inventory, and workforce levels for a specified time horizon to meet overall demand while minimizing costs [4].

The transportation problem may be expressed mathematically as maximizing the effectiveness function if x_{ij} is the total number of units allocated from the ith to the *j*th. These formula are computed using Equations (2.10)–(2.12).

$$\text{E}=\sum_{\text{i}=1}^{\text{m}} \sum_{\text{i}=1}^{\text{n}} \text{eijxij} \quad (10)$$

Subject to

$$\sum_{\text{i}=1}^{\text{m}} \text{xij=bjj=1,2, ..., n} \quad (11)$$

$$\sum_{\text{i}=1}^{\text{m}} \text{xij=aji=1,2, ..., m} \quad (12)$$

Where

$$\sum_{\text{i}=1}^{\text{m}} \text{ai}= \sum_{\text{j}=1}^{\text{n}} \text{bj}$$

Depending on the effectiveness measure, either minimization or maximization will be necessary for optimization. The allocation matrix, x_{ij} , is under the decision maker's control. The matrix of effectiveness coefficients, e_{ij}, is not directly within his control.

2.4. Excel Spreadsheet GRG Solver

According to Prawer [5], Excel Spreadsheet GRG is one of the most accessible optimization tools because it does not require advanced programming skills and can handle both linear and nonlinear models. The solver supports three main methods: Simplex LP for linear problems, GRG Nonlinear for smooth nonnear problems, and Evolutionary Algorithm for complex models that are difficult to solve using traditional methods [6].

3. Methods

The flowchart of this research's steps can be seen in Figure 1. The initial phase focuses on establishing a comprehensive baseline of the existing production environment. This involves a deep dive audit of current workflows, resource availability, and actual output rates to quantify the existing 256% overutilization. By observing the production floor and identifying specific limitations, this stage provides the necessary realistic outlook required to benchmark subsequent improvements.

Following the assessment of the current situation, the research proceeds to identify the critical variables that directly influence production capacity. This stage isolates specific factors such as workforce availability, machine hours, manufacturing lead times, and current demand patterns. Accurately pinpointing these key factors is essential for the precision of the capacity management process, as these variables serve as the primary inputs for the mathematical or logic-based models used in later planning stages.

Aggregate Planning Developments. In this strategic phase, three alternative methods are developed: the Transportation Method, the Hybrid Method, and the Excel Spreadsheet GRG (Generalized Reduced Gradient) Method. The GRG method is integrated to address the non-linear nature of production costs, such as the incremental impact of overtime and subcontracting fees. Crucially, this phase includes a feasibility check to ensure that each proposed aggregate plan can be translated into realistic operational actions without exceeding physical constraints. This stage aims to derive the optimal manufacturing solution by balancing manpower, machine-hour utilization, and production rates against the forecasted demand.

Master Production Schedule (MPS). Once the aggregate plan is established, it is decomposed into a Master Production Schedule (MPS). This stage translates the monthly production targets into a specific, detailed schedule. The MPS serves as the primary data source for capacity verification, ensuring that the aggregate goals are broken down into actionable weekly or unit-based production lots.

Rough-Cut Capacity Planning (RCCP). To ensure feasibility, RCCP is implemented using the Capacity Requirements Planning (CRP) method. This validation step compares the required capacity dictated by the MPS against the available capacity limit (1,320 regular hours and 141 overtime hours). The primary objective of this stage is to guarantee the operational feasibility of the proposed Aggregate Planning (AP) by verifying that the workload is executable within the facility's resource boundaries.The methodology assumes that any demand exceeding this internal capacity ceiling must be managed through subcontracting or strategic adjustments to maintain operational stability.

Plan Comparison & Validation. Upon establishing a feasible RCCP solution, the proposed plans are rigorously compared against each other and the existing production conditions. This comparative analysis evaluates the efficiency of each method in terms of cost-minimization and resource utilization, ensuring the final recommendation is both economically and operationally viable.

Impact Evaluation. The final phase of the framework involves a holistic assessment of the proposed strategy's implications. This evaluation measures the overall effect on capacity alignment, production efficiency, operational costs, and general performance. The research concludes with this step, determining whether the proposed solution serves as an efficient improvement for production planning and providing a set of validated suggestions for implementation.

4. Result and Discussion

4.1. Initial Observation

According to the marketing team, the trend indicates higher demand for PC1250 units; therefore, demand is treated as a fixed input for production planning (no further forecasting). To meet the increased target, production capacity must be adjusted without causing delays, backlogs, or overloading existing facilities, while also controlling costs hence, Aggregate Planning is applied using actual demand data to determine the optimal production, workforce, and inventory strategy for August 2025–March 2026.

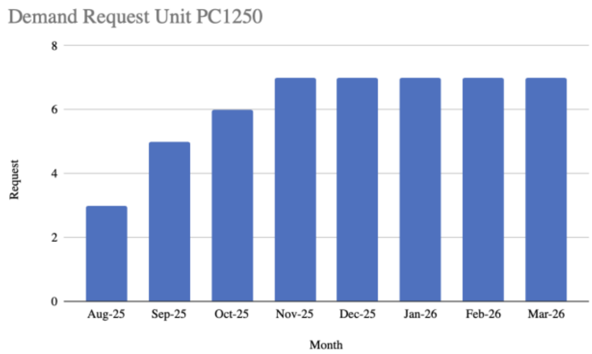

Figure 1. Target Production Chart April 2024-March 2026

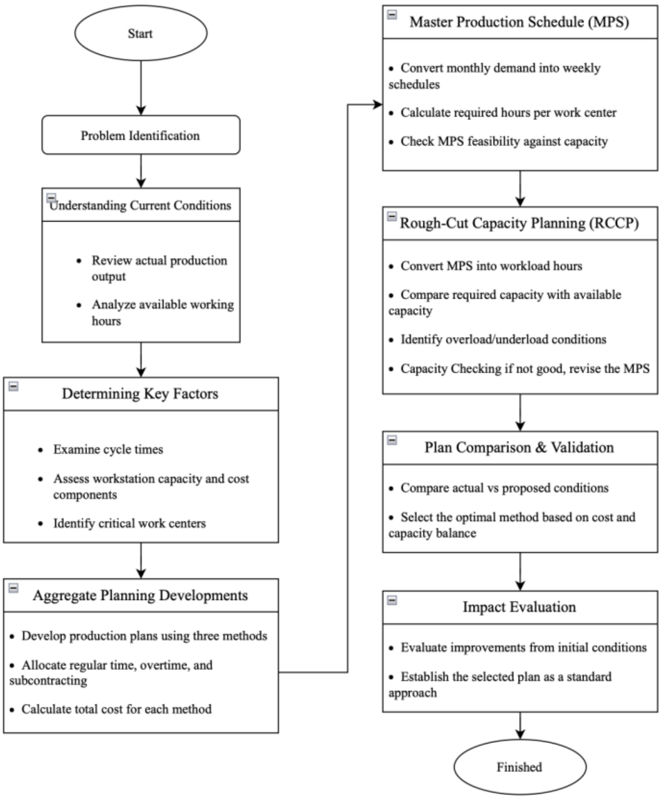

Figure 2. Research Framework Flowchart

4.2. Current Capacity Planning

This section reviews the company's current production capacity and key parameters for aggregate planning, showing that the PC1250 assembly line is labor-intensive and mainly driven by manual skill rather than machine cycles. With 7 workers and 20 effective working days, the company can produce up to 4 units, with sequential and overlapping sub-assemblies (e.g., Main Valve, Engine Hood, Cabin, Radiator), and an average completion time of 8 working days per unit. The data of assembly work station can be seen in Figure 3.

The PC1250 assembly process is sequential and overlapping, as illustrated in Figure 4, and requires an average of eight working days per unit. Given the current capacity of 7 workers and 20 effective working days per month, the maximum achievable output is four PC1250 units per production period.

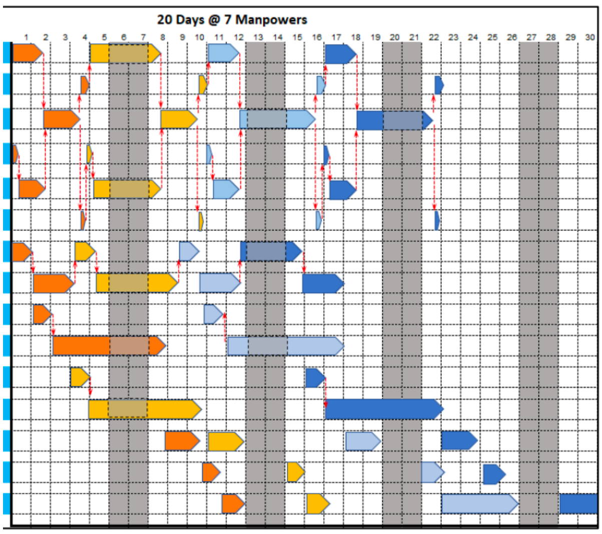

Figure 3. Data of Assembly Works Stations

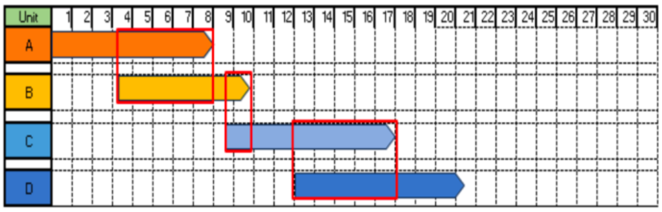

Figure 4. Breakdown Production in 20 Work Days

Table 1. Completion Time

Unit	Finished Time	Total Time
1	1 - 8 Days	8 Days
2	4 - 10 Days	7 Days
3	9 - 17 Days	8 Days
4	13 - 21 Days	8 Days

With the current resources (7 workers and 20 effective working days per month), the company can produce only four PC1250 units per period, leaving a gap of three units against the new target of seven units per month (a 75% required increase). Because the system is already near maximum capacity and work processes overlap, the main assembly line risks bottlenecks and delays unless capacity is adjusted. Therefore, this study applies Aggregate Planning to determine the most cost-effective way to meet the target by optimizing workforce, working hours, and production levels, using collected data on demand, working hours, working days, manpower, and costs.

Table 2. Regular, Overtime, and Subcontract Time

	Work Hours	Break Time	Operational Time	Workdays
Reguler	7.30 – 16.30	12.00 – 13.00	8 Hours	Monday – Friday
Overtime	17.00 – 19.00	-	2 Hours	Monday – Friday
Subcont	7.30 – 16.30	12.00 – 13.00	8 Hours	Monday – Friday

Regular work runs Monday–Friday from 7:30 a.m.–4:30 p.m. with a 1-hour break, totaling 8 effective hours/day; weekday overtime is 5:00–7:00 p.m. for 2 additional hours, and subcontractors follow the same regular schedule.

Table 3 summarizes effective working days from August 2025 to March 2026 by subtracting holidays and weekends from total calendar days; for example, August 2025 has 31 days with 10 holidays, resulting in 21 working days. Across the period, working days range from 20–23, with October 2025 highest at 23 and December 2025, February 2026, and March 2026 lowest at 20.

Table 3. Data Total of Working Days

Month	Aug-25	Sep-25	Oct-25	Nov-25	Dec-25	Jan-26	Feb-26	Mar-26
Total Days	31	30	31	30	31	31	28	31
Off Days	10	9	8	9	11	9	8	11
Working Days	21	21	23	21	20	22	20	20

Table 4 summarizes the aggregate planning inputs: 8 hours/day regular work, overtime limited to 25% of regular hours, subcontracting capped at 50%, initial inventory (P1) of 0, and 7 workers. Costs are IDR 29,000/hour (regular), IDR 40,000/hour (overtime), IDR 55,000/hour (subcontract), with hiring and layoff costs of IDR 4,900,000 and IDR 7,000,000 per worker; holding cost is 3% of the annual selling price (IDR 24,500,000,000), totaling IDR 735,000,000 for 49 units ending stock. Performance data show an actual cycle time of 58.85 hours versus a 65-hour standard, with 49 units produced over 243 working days (about 4 units per period).

Table 4. Cost and Other Data

Description	Data
Number of Working Hours	8 hours/day
Max Overtime	25% of regular time capacity
Max Subcontract	50% of overtime capacity
Beginning Inventory P1	0 units
Num of Current Worker	7
Regular Time Cost	IDR 29,000/hr
Overtime Cost	IDR 55,000/hr
Subcontract Cost	IDR 40,000/hr
Hiring Cost	IDR 4,900,000/worker
Layoff Cost	IDR 7,000,000/worker
Annual Holding Cost	3% of selling price per unit
Selling Price of P1	IDR24,500,000,000
Total Selling Price	IDR24,500,000,000
Holding Cost	IDR735,000,000
Ending Inventory P1	0
Cycle Time	58,85 hours
Standard time (Man-hour) of P1	65
Total Unit Production	49
Total worker days	243
Production Rate	4

4.3. *Data Processing*

Figure 5 shows the demand rising from 3 units (Aug 2025) to 5 (Sep) and 6 (Oct), then stabilizing at ~7 units/month from Nov 2025 to Mar 2026, making it the key input for monthly aggregate planning. Because Unit 7 assembly is labor-intensive and not constrained by equipment, the demand is measured in man-hours, using a standard of 65 hours per unit to match labor capacity.

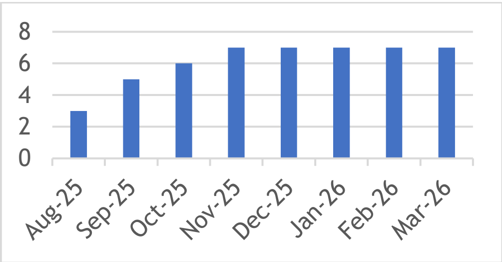

Figure 5. Total Demand August 2025-March 2026

At this stage, an optimal production plan is developed using aggregate planning through three alternatives: Transportation, Hybrid, and Excel Spreadsheet GRG so their results can be compared to identify the most cost-efficient and capacity-effective approach, with flexibility to adjust regular hours, overtime, and subcontracting.

In this method, the main assumptions are that maximum overtime is limited to 25% of regular capacity and subcontracting is capped at 50% of overtime capacity. Based on these constraints, Table 5 presents the resulting unit cost.

Table 5. Cost per Unit in IDR

Type	Cost/unit
Regular time (RT)	29,000
Over time (OT)	40,000
Subcontract (SC)	55,000

Next, the regular time, overtime, and subcontract were calculated per month from August 2025 to March 2026 based on working days. It is shown in Table 6.

Table 6. RT, OT, SC, per Month August 2025-March 2026

Period	Working days	Regular time	Overtime	Subcontract
1	21	168	42	21
2	21	168	42	21
3	23	184	46	23
4	20	160	40	20
5	21	168	42	21
6	20	160	40	20
7	19	152	38	19
8	20	160	40	20

Table 7 summarizes key six-month metrics, monthly and cumulative days, demand, and cumulative demand, and shows rising product demand alongside an increasing workforce. These inputs are then used to generate the aggregate plan with the transportation algorithm to determine the best production allocation across periods.

Table 7. Monthly Demand August 2025-March 2026

	Aug-25	Sep-25	Oct-25	Nov-25	Dec-25	Jan-26	Feb-26	Mar-26
Total Days	31	30	31	30	31	31	28	31
Sum of days	31	61	92	122	153	184	212	243
Demand	3	5	6	7	7	7	7	7
Sum of demand	3	8	14	21	28	35	42	49

The transportation algorithm minimizes cost by allocating demand across Regular Time (RT), Overtime (OT), and Subcontracting (SC), prioritizing RT first, then OT, and using SC when internal capacity is insufficient. Period 1 demand (195 man-hours) is met entirely by RT, but rising demand in Periods 2–4 (325, 390, 455) forces increasing use of OT and especially SC (e.g., Period 2: 168 RT/42 OT/115 SC; Period 4: 160 RT/40 OT/255 SC) to avoid backlog. From Periods 5–8, demand remains at 455, and the capacity mix stabilizes (around 160 RT, 40 OT, and 245–265 SC), indicating a consistent, efficient reliance on subcontracting to sustain high demand while limiting overtime.

Table 8. Total Regular Time, Overtime, Subcontract Time

Production planning		
RT	OT	SC
195	0	0
168	42	115
184	46	160
160	40	255
168	42	245
160	40	255
152	38	265
160	40	255
1347	448	1390

Table 9 shows that over eight periods the company used 1,347 man-hours of Regular Time (RT), 288 man-hours of Overtime (OT), and 1,550 man-hours of Subcontracting (SC) to meet the demand. Ending inventory is 0 in every period, meaning that all output is used immediately to satisfy demand. Planned production rose from 195 units in Period 1 to 455 units in Period 4 and remained aligned with the demand thereafter, resulting in a cumulative total of 49.20 units produced across the planning horizon.

Table 9. Total Inventory, Production and Unit

Ending inventory	Total production	Total unit
0	195	3,01
0	325	5,02
0	390	6,02
0	455	7,03
0	455	7,03
0	455	7,03
0	455	7,03
0	455	7,03
0		49,20

Table 10 shows the transportation-based aggregate plan allocates capacity efficiently across periods to meet demand with total usage of 1,347 RT, 288 OT, and 1,550 SC man-hours. At IDR 29,000 (RT), IDR 40,000 (OT), and IDR 55,000 (SC) per man-hour, the costs are IDR 39,063,000, IDR 11,520,000, and IDR 85,250,000, with no holding or hiring costs due to zero ending inventory and no recruitment. The total production cost is IDR 135,833,000, indicating an optimal capacity mix that minimizes costs while meeting demand.

Table 10. Total Cost of Aggregate Planning Transportation Method

No	Cost type	Unit	Price/unit (IDR)	Total (IDR)
1	Regular time	1347	29,000	39,063,000
2	Overtime	288	40,000	11,520,000
3	Subcontract	1550	55,000	85,250,000
4	Holding cost	0	735,000,000	0
5	Hiring cost	0	4,900,000	0
Total				135,833,000

Figure 6 displays the cost comparison. The Transportation and Excel Spreadsheet GRG methods are prioritized because their total costs are closest, while the Hybrid method is far more expensive. The Transportation method costs IDR 135,833,000 using a fixed workforce with RT/OT/SC, the Excel Spreadsheet GRG method is lowest at IDR 132,649,508 through optimization of OT and SC, and the Hybrid method is highest at IDR 403,365,672 due to costly workforce changes, making GRG the best option with ~IDR 3.1 million savings over Transportation.

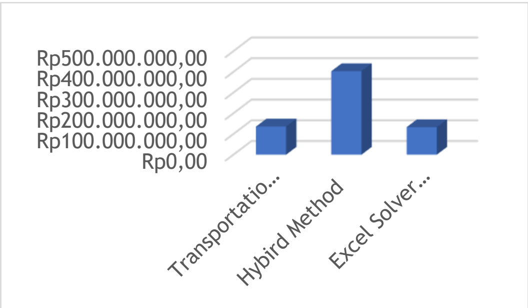

Figure 6. Cost Comparison Chart

Feasibility is validated by converting monthly production hours into daily workload using operational limits (8 RT hours/day, max 2 OT hours/day with 3 hours/day tolerated in peak periods, 1 team of 7 people). The Excel Spreadsheet GRG method is feasible because its peak OT in March 2026 is 52.5/20 = 2.65 hours/day, which is still below the 3-hour tolerance, and it yields the lowest cost (IDR 132,649,508). The Transportation method keeps internal OT at 2 hours/day but relies heavily on subcontracting (12.75 line-hours/day), making it slightly more expensive (IDR 135,833,000). The Hybrid method raises the workforce from 7 to 17 with guaranteed OT, but is operationally complex and very costly (IDR 403,365,672).

Table 11. Monthly Demand August 2025-March 2026

Month	Demand	Working Days
Aug-25	194	21
Sep-25	324	21
Oct-25	388	23
Nov-25	453	20
Dec-25	453	21
Jan-26	453	20
Feb-26	453	19
Mar-26	453	20

Table 11 shows the total production requirement (in man-hours/work units) to be completed, while working days are used to spread this workload evenly across the month to avoid end-of-month accumulation. For example, August 2025 has a total demand of 194.205 man-hours and 21 working days, thus production per day (man-hours) can be computed as follows:

$$\text{Production per day} = \frac{\text{Total Demand}}{\text{Working Days}} = \frac{194.205}{21} = 9.25 \text{ man-hours/day}$$

The production per day in units can be calculated as follows:

$$\text{Units/day} = \frac{\text{Man-}\frac{\text{hours}}{\text{day}} \times \text{Proportion}}{\text{Standard Time}} = \frac{9.25 \times 100\%}{64} = 0.145 \text{ units/day}$$

The same calculation approach is applied for other months (e.g., September: 324 demand over 21 days; October: 388 demand over 23 days) to allocate daily production loads consistently.

Table 12. Demand Proportion

Month	Demand / Total Demand	Total Demand	Production Per Day (Man Hours)	Production Per Day in Units
Aug-25	0.061224	194,205	9,24	0,143
Sep-25	0.102041	323,675	15,41	0,238
Oct-25	0.122449	388,41	18,4929	0,286
Nov-25	0.142857	453,145	21,5733	0,333
Dec-25	0.142857	453,145	21,5733	0,333
Jan-26	0.142857	453,145	21,5733	0,333
Feb-26	0.142857	453,145	21,5733	0,333
Mar-26	0.142857	453,145	21,57	0,333

The Master Production Schedule (MPS) breaks monthly production targets into weekly quantities proportional to each week's working days, smoothing workload, preventing end-month backlogs, and supporting capacity checks (e.g., RCCP). Using this method, monthly totals (e.g., 3 units in August, 5 in September, 6 in October, and 7 units per month from November 2025–March 2026) are distributed across weeks based on available working days so weekly outputs vary but always sum to the required monthly demand.

Table 13. Master Production Planning August 2025-March 2026

Month	Week	Working Days	Product P1
Aug	1	1	0,143
	2	5	0,714
	3	5	0,714
	4	5	0,714
	5	5	0,714
	Total Production		3
Sept	1	4	0,952
	2	5	1,190
	3	5	1,190
	4	5	1,190
	5	2	0,476
	Total Production		5
Oct	1	3	0,857
	2	5	1,429
	3	5	1,429
	4	5	1,429
	5	4	1,143
	Total Production		6
Nov	1	0	0,000
	2	5	1,667
	3	5	1,667
	4	5	1,667
	5	5	1,667
	Total Production		7
Dec	1	5	1,667
	2	5	1,667
	3	5	1,667
	4	3	1,000
	5	3	1,000
	Total Production		7
Jan	1	1	0,333
	2	5	1,667
	3	4	1,333
	4	5	1,667
	5	5	1,667
	Total Production		7
Feb	1	5	1,667
	2	5	1,667
	3	5	1,667
	4	5	1,667
	Total Production		7

Month	Week	Working Days	Product P1
March	1	5	1,667
	2	5	1,667
	3	4	1,333
	4	5	1,667
	5	2	0,667
	Total Production		7

4.4. Rough-Cut Capacity Planning (RCCP)

Rough-Cut Capacity Planning (RCCP) is performed to verify whether the available production capacity can support the production schedule proposed in the Master Production Schedule (MPS). At this stage, the planned monthly production volume is compared with the capacity of critical work centers by calculating the processing time required (run time + setup time) for each unit.

The MPS represents the short-term production plan, which determines how many finished units should be produced each month. This data shows a month-to-month increase in production, particularly from August 2025 (3 units) to a plateau in November 2025–March 1016 (7 units).

Table 14. MPS Demand Augustus 2025-March 2026

Master Production Schedule								
Month	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Unit	3	5	6	7	7	7	7	7

Table 15. Current RCCP Period August 2025 – March 2025

Work Center	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
WC 1	64.51	107.52	129.02	150.52	150.52	150.52	150.52	150.52
WC 2	112.35	187.25	224.70	262.15	262.15	262.15	262.15	262.15
WC 3	7.98	13.30	15.96	18.62	18.62	18.62	18.62	18.62
Capacity Requirements	184.84	308.07	369.68	431.29	431.29	431.29	431.29	431.29
Working Days	21	21	23	20	21	20	19	20
Capacity Reguler	168	168	184	160	168	160	152	160
Overtime	18	18	19.7143	17.143	18	17.1429	16.28571	17.1429
Total Time	186	186	203.714	177.14	186	177.143	168.2857	177.143
Utilization	99%	166%	181%	243%	232%	243%	256%	243%
Status	Under	Over	Over	Over	Over	Over	Over	Over

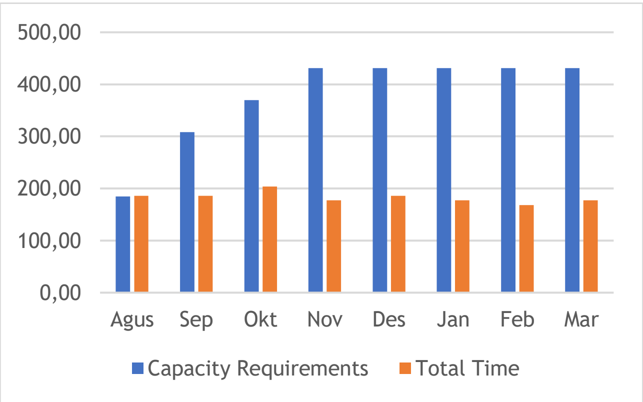

Figure 7. Available Capacity vs. Required Capacity using Current RCCP August 2025-March 2026

In August 2025, the plan is still feasible with 99% utilization, but from September onward the system becomes overloaded as utilization rises to 147% and continues to worsen (161% in October and peaking above 200% from November 2025 through March 2026) (see Figure 7). This persistent overutilization indicates a structural capacity shortage, driven mainly by long setup times, especially at Work Center 2, which becomes the bottleneck, so even regular time plus overtime and subcontracting cannot meet the required workload. Overall, the RCCP confirms the MPS is misaligned with available capacity, requiring actions such as adding shifts, increasing subcontracting, leveling demand across periods, or revising the MPS to avoid delays and operational strain.

Table 16. RCCP Aggregate Period August 2025-March 2026

Work Center	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
WC 1	65	108	129	151	151	151	151	151
WC 2	112	187	225	262	262	262	262	262
WC 3	8	13	16	19	19	19	19	19
Capacity Requirements	185	308	370	431	431	431	431	431
Working Days	21	21	23	20	21	20	19	20
Capacity Reguler	176	176	192	176	168	184	168	168
Capacity Reguler +Ovt	10	55	60	55	53	58	53	53
Capacity Reguler + Ovt + Subkon	10	94	138	224	235	214	235	235
Available Capacity	195	325	390	455	455	455	455	455
Utilization	95%	95%	95%	95%	95%	95%	95%	95%
Status	Under	Under	Under	Under	Under	Under	Under	Under

Fig 8 displays the result after applying time adjustment from aggregate planning.

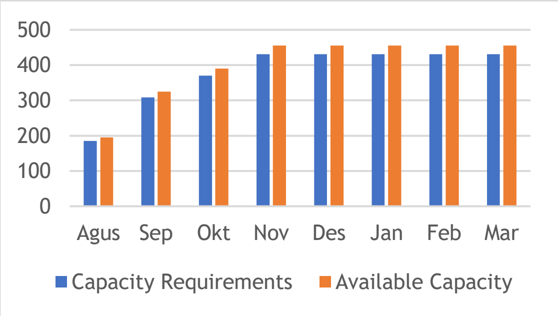

Figure 8. Comparison Between Required Capacity and Available Capacity August 2025-March 2026

After applying the proposed time adjustments from aggregate planning, the revised RCCP shows a far more stable condition: all months shift from frequent overutilization to consistent underutilization, meaning capacity is now sufficient and controllable. In August 2024, 195 available hours exceed 184.84 required hours (95% utilization), and this same 95% utilization is maintained across September (325 vs 308.07), October (390 vs 369.68), and November (455 vs 431.29). The pattern continues through December to March, where required capacity remains 431.29 hours and available capacity stays at 455 hours, keeping utilization steady at 95%. Overall, the plan balances demand and capacity with a built-in buffer, reducing bottlenecks and providing flexibility while still using resources efficiently and avoiding overload or delays.

4.5. Production Planning Proposals and Comparison with Actual Conditions

Figure 9 compares current production capacity with marketing demand and shows the company follows a level-production strategy, maintaining a steady 3–4 units per month from August 2025 to March 2026 despite fluctuating demand. This creates a small surplus in August (4 produced vs 3 demanded) but quickly turns into shortages as demand rises to 5 units in September and 6 in October, then stabilizes at 7 units per month from November onward leaving a persistent 3-unit monthly deficit when production stays at 4. The PC1250 assembly line is already at its practical maximum under current constraints (only seven workers, limited regular hours, overlapping work, and about eight days per unit), so output cannot be increased without changing capacity. To close the gap, aggregate planning was evaluated using Transportation, Hybrid, and Excel GRG approaches: the Hybrid option meets demand but requires costly aggressive hiring, while the Excel GRG option does not meet demand and is therefore inefficient.

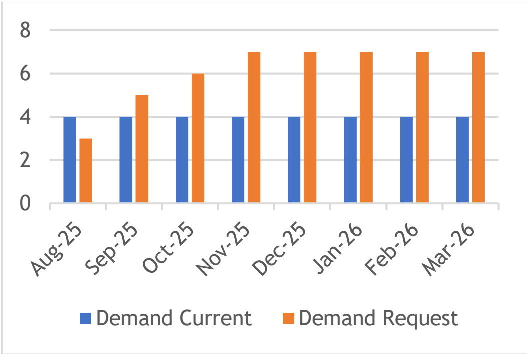

Figure 9. Current Production Capacity vs Demand August 2025-March 2026 in Units

Referring to Figure 10, the Solver GRG results show that planned production matches the projected demand exactly rising from 3 units (August) to 5 (September) and 6 (October), then holding at 7 units per month from November to March. This perfect alignment ensures the full cumulative demand of 49 units is met within the planning horizon without backlog. The plan achieves this through an optimized mix of resources 1,408 regular hours, 395 overtime hours, and 1,383 subcontracting hours while also delivering the lowest total cost of IDR 132,649,508.

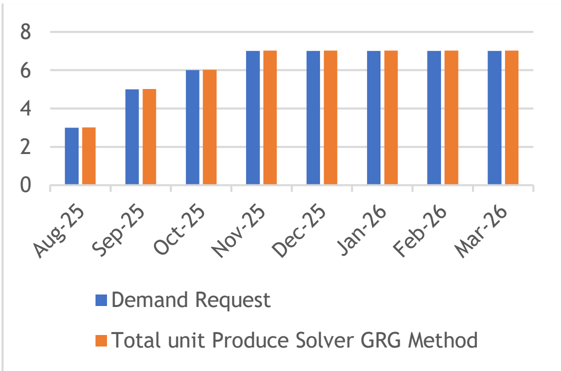

Figure 10. Demand Request vs Total Units Produced using Transportation Method August 2025-March 2026

The best solution is aggregate planning using the Solver GRG method with regular time, overtime, and subcontracting, which increases capacity from 4 to 7 units per month without hiring, avoids excess inventory, reduces costs, and can be implemented immediately for August 2025–March 2026.

Table 17. Combination of RT, OT, SC

Month	1	2	3	4	5	6	7	8	Total
Regular Time	176	176	192	176	168	184	168	168	1408
Overtime	9,5	55,0	60,0	55,0	52,5	57,5	52,5	52,5	395
Subcontract	9,5	94,0	138,0	224,0	234,5	213,5	234,5	234,5	1383

Figure 11 shows the cost comparison among methods. There are stark differences in cost efficiency among the various aggregate planning methods evaluated. The Hybrid approach proved to be the least efficient, totaling IDR 403,365,672. This high cost is primarily driven by the significant expenses associated with workforce fluctuations, such as hiring and firing.

In contrast, the Transportation method (IDR 135,833,000) and the Excel Solver GRG method (IDR 132,649,508) demonstrated much higher efficiency. The GRG method emerged as the most economical solution, saving IDR 3,183,492 compared to the Transportation method. Its superiority stems from its ability to mathematically optimize the specific mix of regular time, overtime, and subcontracting to meet demand at the lowest possible cost.

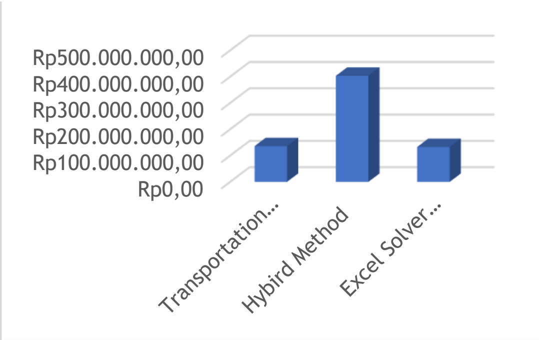

Figure 11. Comparison Costs

Figure 12 shows that current capacity is low and fluctuates between 168.2 and 203.7 man-hours, while aggregate planning raises capacity sharply and more consistently from 222 man-hours in period 1 to 325 in period 2, then 390–455 in later periods, stabilizing at 455 man-hours from periods 4 to 8. This demonstrates that aggregate planning effectively closes the gap between existing capacity and required demand, reducing the risk of backlogs and improving readiness to meet higher demand.

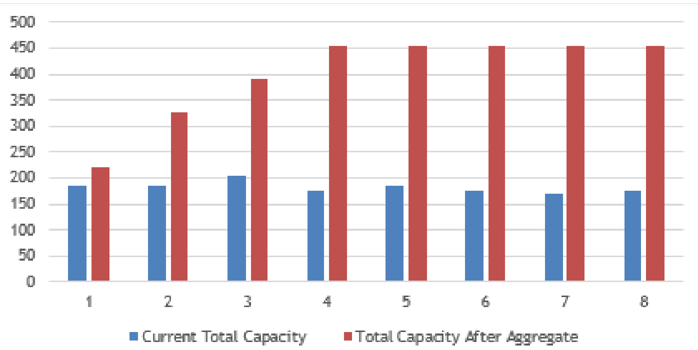

Figure 12. Current Capacity vs Capacity After Aggregate Planning using Proposed Method Period August 2025-March 2026

Figure 13 shows a major improvement in capacity use after aggregate planning. Under current conditions, utzization starts at 99% but quickly exceeds capacity, 166% in period 2, 181% in period 3, and peaks around 243–256% in periods 4–7 indicating the company cannot meet requirements without excessive overtime, which risks fatigue, quality issues, and scheduling problems. After aggregate planning, utilization stabilizes at about 95% across periods 1–8, remaining below 100% and indicating that planned capacity realistically matches demand, reduces reliance on overtime, and balances the workload more efficiently.

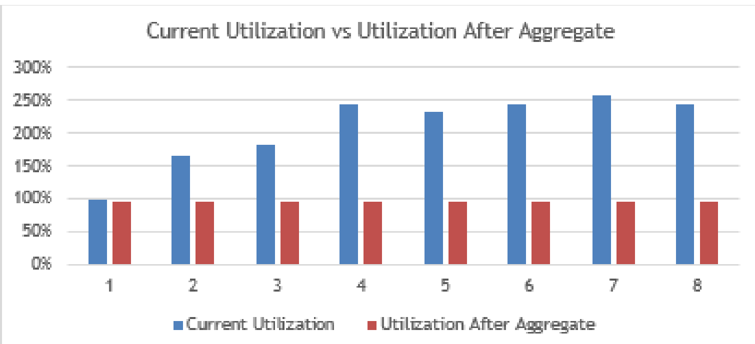

Figure 13. Current Utilization vs Utilization after Aggregate in August 2025-March 2026

4.6. Implications

The analysis implies that the current production system faces a structural capacity gap: with existing resources, the line can sustain only 3–4 units per month, while market demand is rising to 7 units. This mismatch creates severe overutilization, peaking at 256%, which triggers systemic risks such as workforce fatigue, potential quality defects, and schedule unreliability. After applying aggregate planning specifically the Solver GRG approach capacity is stabilized, and utilization is brought down to a sustainable 95%. This 95% threshold represents an operational "safety zone" for heavy equipment manufacturing, providing enough throughput to meet demand while leaving a 5% buffer to manage the high technical variability and specialized rework common in large-scale assembly. The validation through RCCP confirms that this proposed aggregate plan is fully feasible, as the resulting workload fits precisely within the calibrated limits of regular time, maximum allowable overtime, and external subcontracting capacity.

Managerially, the study identifies an optimized resource mix (1,408 regular hours, 395 overtime hours, and 1,383 subcontract hours) as the most cost-effective strategy. Beyond the immediate scope of PT Komatsu, these findings offer a scalable framework for other heavy machinery sectors such as maritime construction, locomotive assembly, or aerospace that share "high-value, long-cycle" production characteristics.

5. Conclusion

Based on the results of this study, it can be concluded that the PC1250 assembly line currently faces a significant capacity gap, producing only 3–4 units per month against a rising market demand of 7 units. This mismatch leads to overutilization exceeding 100%, rendering the existing plan infeasible and increasing risks related to production delays, worker fatigue, and quality degradation.

To address these challenges, the most economical and feasible solution identified is Aggregate Planning using the Excel Solver GRG method. By optimizing a combination of 1,408 regular hours, 395 overtime hours, and 1,383 subcontracting hours, this approach successfully meets demand without requiring additional hires or incurring backlogs. This strategy results in a total cost of IDR 132,649,508 and stabilizes post-planning utilization at approximately 95%, ensuring a controllable and sustainable production flow.

Despite these positive results, this study acknowledges several critical limitations. First, the planning model assumes a deterministic environment where supply chain lead times and subcontractor quality are constant and ideal; in reality, heavy equipment manufacturing is highly susceptible to global logistics disruptions and material variability. Second, the model does not fully account for the "learning curve" effect or the potential drop in labor productivity during extended overtime periods, which could slightly alter the predicted output in a real-world setting. Lastly, the cost parameters used are static, whereas inflation and fluctuating energy prices can impact the long-term feasibility of the proposed budget.

Future research should consider integrating stochastic variables or Monte Carlo simulations to account for demand and supply uncertainty. Additionally, incorporating a human factor analysis regarding the long-term impact of the 395-hour overtime allocation on operator health and precision would provide a more holistic view of operational sustainability in heavy industries.

References

[1] Y. Akanksha, “Laporan analisis ukuran, pangsa pasar, dan tren perlengkapan ekskavator berdasarkan jenis, industri, saluran penjualan dan wilayah prakiraan, 2022–2030,” 2024.
[2] E. H. Aghezzaf and A. Artiba, “Aggregate planning in hybrid flowshops,” *Int. J. Prod. Res.*, vol. 36, no. 9, pp. 2463–2477, Sep. 1998, doi: 10.1080/002075498192634.
[3] E.-A. Attia, A. Megahed, A. AlArjani, A. Elbetar, and P. Duquenne, “Aggregate production planning considering organizational learning with case-based analysis,” *Ain Shams Eng. J.*, vol. 13, no. 2, p. 101575, 2022, doi: 10.1016/j.asej.2021.09.002.
[4] G. Buxey, “Aggregate planning for seasonal demand: Reconciling theory with practice,” *Int. J. Oper. Prod. Manag.*, vol. 25, no. 11, pp. 1083–1100, 2005, doi: 10.1108/01443570510626907.
[5] R. D. Chatare and V. D. Joshi, “Use of Excel spreadsheet GRG for minimizing the total transportation cost at a recently opened clothing boutique,” *Splint Int. J. Prof.*, vol. 9, no. 2, pp. 124–129, 2022, doi: 10.5958/2583-3561.2022.00015.7.

[6] G. Fenny *et al.*, “Aggregate planning to minimize cost of production of ABC Company with forecasting and master production schedule approach,” 2022.

[7] M. Gansterer, “Aggregate planning and forecasting in make-to-order production systems,” *Int. J. Prod. Econ.*, vol. 170, pp. 521–528, 2015, doi: 10.1016/j.ijpe.2015.06.001.

[8] D. Ivanov, B. Sokolov, R. Hartl, and A. Pavlov, “Structure dynamics control-based integration of aggregate distribution and dynamic transportation planning,” *IFAC Proc. Vol.*, vol. 46, no. 9, pp. 1920–1925, 2013, doi: 10.3182/20130619-3-RU-3018.00270.

[9] K. Kang, R. Y. Zhong, and A. Nassehi, “Integrated disassembly and assembly model for heavy duty equipment maintenance,” *Procedia CIRP*, vol. 93, pp. 995–1000, 2020, doi: 10.1016/j.procir.2020.04.086.

[10] M. Kwak, L. Kim, O. Sarvana, H. M. Kim, P. Finamore, and H. Hazewinkel, “Life cycle assessment of complex heavy duty equipment,” in *Proc. ASME/ISCIE Int. Symp. Flexible Autom.*, 2012, pp. 625–635, doi: 10.1115/ISFA2012-7180.

[11] F. Lefta, L. Gozali, and I. A. Marie, “Aggregate and disaggregate production planning, material requirement, and capacity requirement in PT. XYZ,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 852, no. 1, p. 012123, 2020, doi: 10.1088/1757-899X/852/1/012123.

[12] F. Lefta, L. Gozali, and I. A. Marie, “Aggregate and disaggregate production planning, material requirement, and capacity requirement in PT. XYZ,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 852, no. 1, 2020, doi: 10.1088/1757-899X/852/1/012123.

[13] W. Y. Leong, K. Y. Wong, and A. Anjomshoae, “A systematic literature review of aggregate production planning (APP): Social and economic perspectives,” *J. Ind. Eng. Manage.*, vol. 18, no. 1, pp. 48–71, 2025, doi: 10.3926/jiem.7927.

[14] C. Nivasanon, I. Srikun, and P. Aungkulanon, “Aggregate production planning: A case study of installation elevator company,” 2021.

[15] E. Noegraheni and H. Nuradli, “Aggregate planning to minimize cost of production in manufacturing company,” *Binus Bus. Rev.*, vol. 7, no. 1, p. 39, 2016, doi: 10.21512/bbr.v7i1.1448.

[16] I. Nugraha, M. Hisjam, and W. Sutopo, “Aggregate planning method as production quantity planning and control to minimizing cost,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 943, no. 1, 2020, doi: 10.1088/1757-899X/943/1/012045.

[17] S. C. Stefan and I. Popa, *Navigating Digitization and Internationalization in the New Global Economy*, in Contributions to Management Science, O. Nicolescu *et al.*, Eds., 2025.

[18] L. Sophie, “Demands, importance and potential of excavator tracking on earthwork construction sites,” 2022, doi: 10.18154/RWTH-2022-07733.

[19] M. Sultana, S. Shohan, and F. Sufian, “Aggregate planning using transportation method: A case study in cable industry,” *Int. J. Manag. Value Supply Chains*, vol. 5, no. 3, pp. 19–35, 2014, doi: 10.5121/ijmvsc.2014.5302.

[20] M. Trost, T. Claus, and F. Herrmann, “Social sustainability in production planning: A systematic literature review,” *Sustainability*, vol. 14, no. 13, 2022, doi: 10.3990/su14138198.

[21] J. Vidal, M. Lauras, J. Lamothe, and R. Miclo, “Toward an aggregate approach for supporting adaptive sales and operations planning,” in *Proc. IEEE Int. Conf. Ind. Eng. Appl. (ICIEA)*, 2020, pp. 1031–1038, doi: 10.1109/ICIEA49774.2020.9102060.