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VALUE STREAM MAPPING FOR OPERATIONS AND SUPPLY CHAIN COORDINATION IN INDONESIAN AUTOMOTIVE MANUFACTURING

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Abstract

Operations and supply chain decisions require a consistent view of processing capacity, inventory, and replenishment. This study develops an analytical planning case for an automotive component supplier in West Java, Indonesia. Baseline and proposed value stream maps (VSM) are evaluated using takt time, inventory coverage, ideal capacity, and demand sensitivity. At 360 units per day and 25,920 available seconds, takt time is 72.00 seconds. The proposed design reduces inventory from 3,600 to 1,080 units and processing content from 282 to 230 seconds. The coverage-based lead-time indicator decreases from 10 to 3 working days. Ideal line capacity increases from 316.10 to 446.90 units per day. At demand of 396 units and 90% effective operating time, utilization reaches 98.46%. The analysis connects inventory targets with capacity restrictions and replenishment rules.

Keywords: Inventory control; Lean manufacturing; Operations; Supply chain; Value stream mapping (VSM).

INTRODUCTION

Manufacturers face pressure to improve efficiency while maintaining supply chain continuity during disruptions and digital transformation (Ivanov & Dolgui, 2020). In Indonesia, manufacturing accounted for 18.67% of gross domestic product in 2023, highlighting the economic importance of dependable industrial operations (Badan Pusat Statistik [BPS], 2024, Table 15.1.3). For automotive component suppliers, the practical challenge is to reduce inventory without weakening the capacity and replenishment arrangements needed to meet customer demand.

Recent research provides complementary foundations. Lean manufacturing and digitalization jointly support operational performance (Buer, Semini, Strandhagen, & Sgarbossa, 2021). Information-focused value stream mapping (VSM) connects production control with information quality (Busert & Fay, 2021), while technology-integrated guidelines support lean value-stream design (Tortorella et al., 2020). Dynamic modelling extends VSM to more complex production behaviour (Ferreira, Armellini, Santa-Eulalia, & Thomasset-Laperrière, 2022), and recent process-design research emphasizes reliable inputs and customer value (Klimecka-Tatar & Obrecht, 2024). These advances establish VSM as more than a visual waste-identification tool. However, a specific decision gap remains for the Indonesian supplier planning problem: how should inventory targets, bottleneck capacity, and replenishment-card requirements be assessed together when demand and available operating time change? The need is for a compact, auditable assessment that makes these dependencies explicit alongside the future-state map (Busert & Fay, 2021; Ferreira et al., 2022).

This question is urgent because reducing buffers before checking operating margins can expose a supplier to shortages. Resilience research emphasizes using protective resources actively within normal operations (Ivanov, 2022). The proposed novelty is a methodological refinement: combining VSM with explicit capacity limits, inventory-coverage calculations, and demand-responsive card counts in one analytical planning case for a West Java automotive component supplier. The research aim is to develop and assess a transparent framework for coordinating operations and supply chain replenishment. Its objectives are to identify the capacity-constraining station using cycle and takt times; compare baseline and proposed inventory coverage, processing content, and ideal line capacity; and determine demand and operating-loss thresholds at which capacity or replenishment rules require adjustment. All numerical inputs are stated design assumptions, consistent with evaluating a proposed configuration (Ferreira et al., 2022).

Three research questions follow: RQ1, which station restricts output relative to customer demand? RQ2, how do the proposed changes affect inventory coverage, processing content, and ideal capacity? RQ3, under which demand and operating-loss conditions do the design become infeasible or require additional replenishment cards? These questions connect production coordination with active resilience planning (Busert & Fay, 2021; Ivanov, 2022).

The expected theoretical contribution is to refine VSM as a coordination framework by specifying the conditions linking inventory reduction to capacity and replenishment feasibility. The managerial contribution is a transparent basis for prioritizing bottleneck improvements, adjusting card counts, and testing operating margins before reducing stock, with realized benefits requiring company evidence (Busert & Fay, 2021; Ivanov, 2022).

LITERATURE REVIEW

VSM connects the sequence of production activities with the flow of material and information. Its value lies in making dependencies visible rather than simply drawing a cleaner process chart. A cycle-time reduction concerns the time required by an operation, whereas an inventory reduction concerns the amount waiting between operations. These quantities require separate units and should not be combined into one general improvement percentage (Pradeep & Balaji, 2022; Klimecka-Tatar & Obrecht, 2024).

Information quality is an operational variable because an incomplete or outdated release can produce the wrong item at the right speed. Busert and Fay show how information-focused mapping can support coordination and production control. Recent mapping work also examines informational resources within logistics activities. Together, these studies support recording the release owner, replenishment signal, and stock location alongside the physical process (Busert & Fay, 2021; Nunes, Chika, & Santos, 2024).

Digital lean research supports selective integration. Rosin and colleagues examine how Industry 4.0 technologies relate to lean principles, while research on lean automation considers both social and technical practices. The implication for a smaller supplier is to stabilize work and clarify production rules before automating their execution. A stock display is useful only if the recorded quantity is reliable and someone has authority to respond (Rosin, Forget, Lamouri, & Pellerin, 2020; Tortorella, Saurin, Godinho Filho, Samson, & Kumar, 2021).

Low stock also needs a resilience argument. Ivanov treats resilience assets as active resources that can create value during normal operations. A broader supply-network perspective warns that internal efficiency alone cannot secure continuity. Supplier capabilities, including the ability to replenish consistently, therefore matter when deciding whether a buffer can be reduced. The resource-based supplier perspective informs this boundary decision (Kim, Syamil, & Bhatt, 2007).

Recent studies broaden VSM to sustainability, process mining, and continuous improvement. They also show why a static picture is incomplete: it does not reveal every interruption, route variation, or environmental effect. The present article examines time and inventory feasibility and does not infer lower emissions, better quality, or financial savings from those indicators alone (Batwara, Sharma, Makkar, & Giallanza, 2023; Horsthofer-Rauch et al., 2024; Jamil et al., 2020).

METHOD

Research design and system boundary

The study uses a deterministic analytical planning case representing a metal bracket manufacturer in West Java, Indonesia. The unit of analysis is one product-family flow (Razali et al., 2023). The process begins at the steel allocated to the product family and ends at finished brackets awaiting customer collection. Five sequential stations perform cutting, forming, welding, assembly, and inspection. One bracket-equivalent is the common unit across all stock locations, with no conversion loss in the base calculation. There are 22 working days per month and one 480-minute shift per day. Planned breaks total 48 minutes, leaving 432 minutes, or 25,920 seconds, per day. Base demand is 360 good units per day, equivalent to 7,920 per month. Table 1 lists the station and inventory assumptions used in both maps (Zahraee et al., 2014; Klimecka-Tatar & Obrecht, 2024).

Table 1. Process and inventory assumptions for the planning case

Process or stock location	Baseline CT (seconds/unit)	Target CT (seconds/unit)	Baseline stock (units)	Target stock (units)
Before cutting / cutting	40	36	1,080	360
Before forming / forming	55	47	540	180
Before welding / welding	82	58	360	90
Before assembly / assembly	61	52	720	180
Before inspection / inspection	44	37	360	90
Finished goods	Not applicable	Not applicable	540	180

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Process or stock location	Baseline CT (seconds/unit)	Target CT (seconds/unit)	Baseline stock (units)	Target stock (units)
Total	282	230	3,600	1,080

Note. CT = cycle time. Each stock is counted once.

Time inventory and capacity definitions

Daily production time or A is expressed in seconds and daily demand or D in units. Takt time is T = A/D = 25,920/360 = 72.00 seconds per unit. Processing content P is the sum of the five station cycle times. It includes necessary inspection and therefore is not labelled wholly value-added time. For a station time c, ideal station capacity is A/c. Line capacity C is A divided by the longest station cycle time, assuming dedicated resources and no additional blocking, scrap, or changeover losses (Ferreira et al., 2022). Inventory coverage B is the total stock I divided by demand D, so B = I/D in working days. A coverage-based lead-time indicator is L = B + P/A. This converts processing seconds into the same working-day unit before addition. It is a comparison indicator rather than an observed order-to-delivery duration. In particular, the baseline capacity is below demand, so baseline coverage must not be interpreted as a stable-system waiting-time estimate (Busert & Fay, 2021).

Redesign rules and stress conditions

The proposed process targets represent fixture preparation at welding, standardized forming and assembly tasks, point-of-use materials, and a simpler inspection arrangement. They are candidate engineering targets requiring a time study. The material-control design replaces multiple independent releases with a daily assembly schedule and upstream withdrawal signals. Buffer targets are explicit planning limits (Tortorella et al., 2020; Schumacher, Hall, Bildstein, & Bauernhansl, 2023). For the buffer before welding, a replenishment-card rule uses N = ceiling[D × r × (1 + s)/q], where r is replenishment time in working days, s is a proportional allowance, and q is container capacity. With r = 0.20, s = 0.25, and q = 15, base demand requires six cards and 90 units. Other buffer targets remain independent planning choices. A supplier-capability review is necessary before adopting these limits (Kim et al., 2007; Ivanov, 2022).

Capacity sensitivity varies demand and the effective operating fraction g. Adjusted line capacity is Cg = gA/58 and utilization is U = D/Cg. The factor g captures additional aggregate time losses after planned breaks; it is not a measured equipment-effectiveness score. Feasibility requires $U \leq 1$. The analysis examines demand of 324, 360, and 396 units per day and operating fractions from 0.85 to 1.00. It tests capacity and the welding-buffer card count, without recalculating all stock targets or predicting delivery reliability (Ferreira et al., 2022; Ivanov & Dolgui, 2020).

RESULTS AND DISCUSSION

Baseline constraint and proposed flow

Figure 1 shows the baseline and proposed value stream maps. Baseline inventory totals 3,600 units, corresponding to 10.00 days of demand coverage. The largest single location is the 1,080-unit raw-material stock before cutting. The proposed map retains all five stations but changes their cycle-time targets, release structure, and inventory limits. Its 1,080-unit total corresponds to 3.00 days of coverage. The maps show the specified design comparison (Zahraee et al., 2014; Busert & Fay, 2021).

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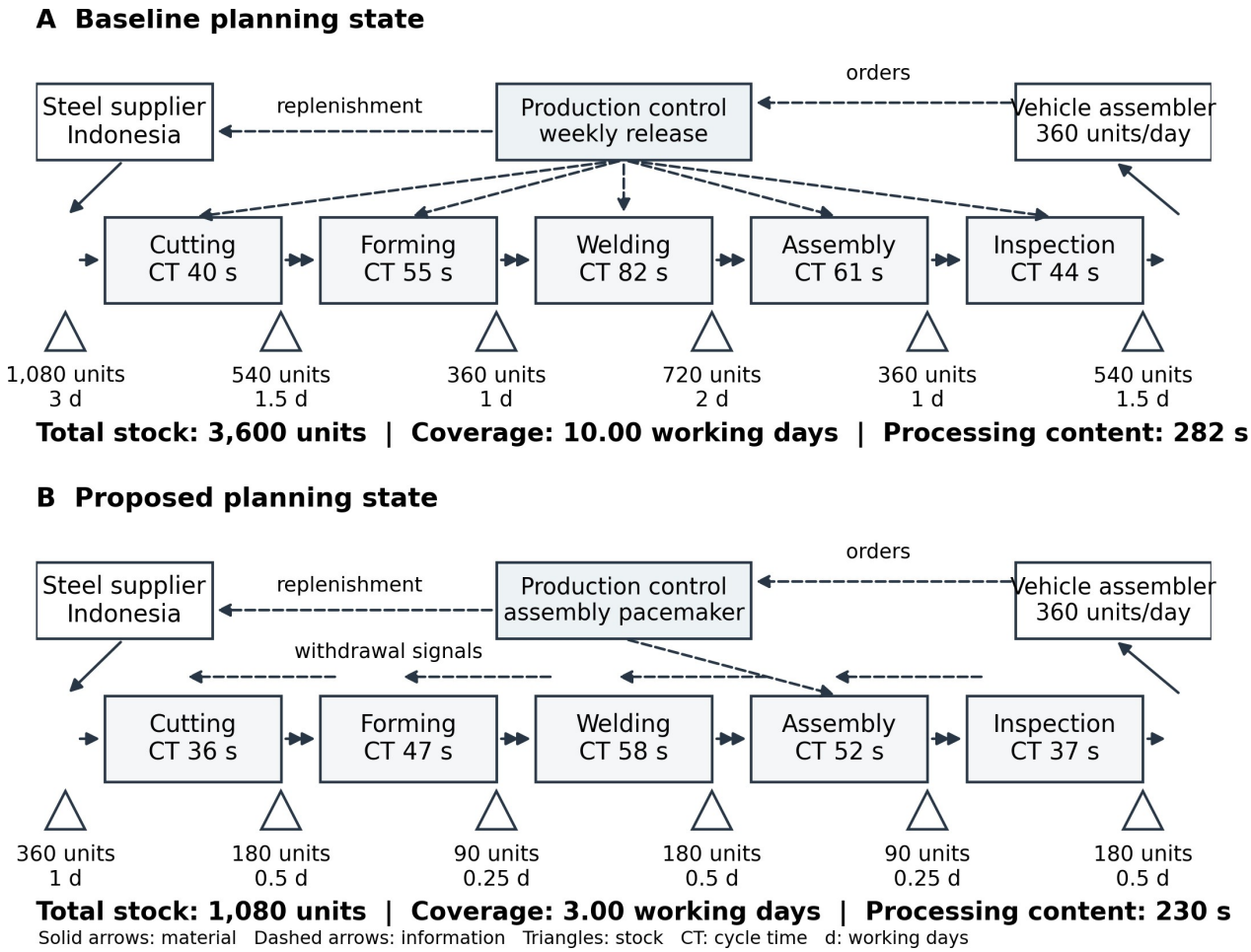


Figure 1. Baseline and proposed value stream maps for the analytical planning case. All stock quantities and cycle times are design assumptions. Material flows from supplier to customer; information and withdrawal signals coordinate releases. Map logic follows material and information flow principles.

Welding is the baseline constraint at 82 seconds per unit, exceeding the 72.00-second takt. The resulting ideal line capacity is 316.10 units per day, leaving a daily capacity gap of 43.90 units against base demand. Stock elsewhere cannot remove that recurring gap. Figure 2 shows that reducing only cutting or inspection time would leave the original welding constraint intact. This distinction separates a local activity improvement from a flow-level capacity decision (Ferreira et al., 2022; Tortorella et al., 2020).

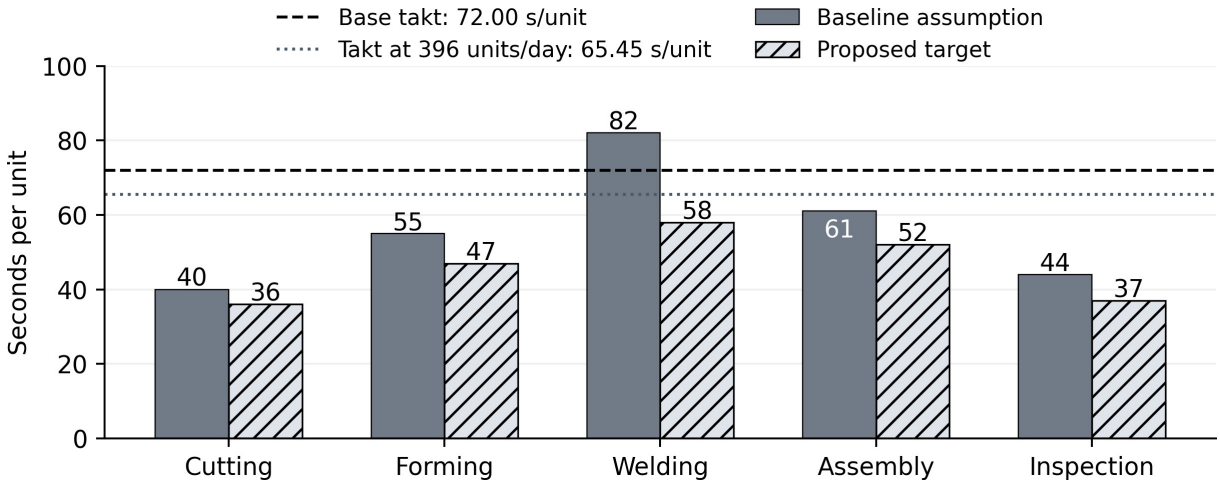


Figure 2. Station cycle-time assumptions against demand-based takt. The second takt line corresponds to demand 10% above the base level. Values are deterministic inputs, with no sampling uncertainty or inferential comparison. The chart supports the capacity check accompanying the maps.

In the proposed design, welding remains the slowest station at 58 seconds, but its ideal capacity rises to 446.90 units per day. This is a 41.38% increase in the calculated upper bound, not a forecast of realized output. Base-demand utilization falls from 113.89% to 80.56%. The shorter welding target is therefore a necessary engineering priority; a replenishment rule cannot compensate for failure to achieve adequate processing capacity (Tortorella et al., 2021; Ferreira et al., 2022).

Inventory coverage and processing content

Table 2 separates stock, time, and capacity results. Total processing content changes from 282 to 230 seconds, an 18.44% reduction. Inventory falls by 2,520 units, or 70.00%. The coverage-based lead-time indicator changes from 10.0109 to 3.0089 working days, a 69.94% reduction. These percentages differ because inventory coverage and processing content contribute differently to the indicator. Keeping the two components separate avoids interpreting less necessary inspection time as a direct reduction in customer-valued transformation time (Pradeep & Balaji, 2022; Batwara et al., 2023).

Table 2. Calculated outcomes under the base planning assumptions

Indicator	Baseline	Proposed	Interpretation
Inventory (units)	3,600	1,080	70.00% lower
Inventory coverage (working days)	10.00	3.00	70.00% lower
Processing content (s/unit)	282	230	18.44% lower
Lead-time indicator (working days)	10.0109	3.0089	69.94% lower
Longest station CT (s/unit)	82	58	29.27% lower
Ideal line capacity (units/day)	316.10	446.90	41.38% higher
Base-demand utilization (%)	113.89	80.56	33.33 percentage points lower
Work-content staffing bound (persons)	4	4	No staffing reduction established

Note. Demand = 360 units/day; production time = 25,920 s/day. Staffing bound = ceiling (processing content/takt), assuming divisible labor content. Capacity is ideal.

The work-content staffing calculation is equally limited. Dividing 282 seconds by 72 gives 3.92 person-equivalents, while 230/72 gives 3.19. Both round upward to a theoretical minimum of four people. Five physical stations do not automatically imply five operators, but neither does this aggregate bound establish that four operators can run the route safely. A task allocation study must examine machine attendance, walking, precedence, and inspection responsibility before any staffing decision (Zahraee et al., 2014; Tortorella et al., 2021).

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Demand and operating loss sensitivity

Table 3 shows where the proposed design loses its capacity margin. At demand of 396 units per day, full operating time gives 88.61% utilization. With 95% effective operating time, utilization reaches 93.27%; at 90%, it reaches 98.46%. A further reduction to 85% produces utilization of 104.25%, so the line cannot meet the required daily volume under that condition. The threshold is g = 396 × 58/25,920 = 0.8861. It is a deterministic limit (Ivanov, 2022; Ferreira et al., 2022).

Table 3. Capacity and welding-buffer sensitivity for the proposed design

Demand (units/day)	Operating fraction g	Capacity (units/day)	Utilization (%)	Welding cards	Capacity condition
324	1.00	446.90	72.50	6	Feasible
360	1.00	446.90	80.56	6	Feasible
396	1.00	446.90	88.61	7	Feasible
396	0.95	424.55	93.27	7	Feasible
396	0.90	402.21	98.46	7	Narrow margin
396	0.85	379.86	104.25	7	Infeasible

Note. Capacity = g × 25,920/58. Card count uses a 0.20-day replenishment time, 25% allowance, and 15-unit containers, independently of g. Feasible means adequate aggregate capacity only. Seven cards equal 105 units.

The inventory policy also requires adjustment when demand changes. At 396 units per day, the welding-buffer formula gives 6.60 cards, which must be rounded upward to seven. Retaining six cards would violate the specified replenishment rule even though the ideal line still has sufficient capacity. The increase to 105 units is local to that buffer. The 3.00-day total-coverage result belongs only to the base case and must not be carried unchanged into the higher-demand rows (Kim et al., 2007; Ivanov, 2022).

Implications for operations and supply chain management

The main managerial implication is sequencing. First confirm that welding and the surrounding stations can support demand. Then reduce release fragmentation and introduce replenishment limits. Finally review the operating margin as demand changes. Digital tools can make those decisions faster, but their benefit depends on valid timestamps, accurate stock balances, and a response rule. This interpretation is consistent with evidence on the complementary roles of lean practices and digitalization (Buer et al., 2021; Rosin et al., 2020; Schumacher et al., 2023). Implementation would also require shared responsibility. Production planning should own the assembly release, purchasing should confirm supplier replenishment capability, and shop-floor teams should investigate missed cycle-time targets and stock discrepancies.]That evidence supports attention to implementation conditions; it does not verify this article's station targets or predict the size of a manufacturing benefit (Hamsal, et al. 2022).

Before reducing buffers, managers could use a short supplier-plant-customer exercise to explain how independent releases create mismatches. A practical supply chain game organized around those three entities (Vanany & Syamil, 2020). Such an exercise can support understanding of withdrawal signals and shared inventory decisions. It remains a training option rather than evidence that the proposed production arrangement will achieve its numerical targets The design also calls for a careful view of resilience. A larger upstream stock can sometimes protect a replenishment exposure, while another stock merely hides an internal bottleneck. Its location and purpose matter more than the total alone. The proposed analysis does not optimize the trade-off between holding cost and continuity, but it makes that trade-off visible through explicit buffer assumptions and a capacity threshold (Ivanov, 2022; Ivanov & Dolgui, 2020).

Limitations and validation requirements

The numerical comparison establishes internal consistency under stated assumptions. Product-mix changes, rework, correlated downtime, transport schedules, and supplier variability are outside the base model. More detailed dynamic modelling could examine these interactions, while a field study would be needed to establish actual operating performance (Ferreira et al., 2022; Pradeep & Balaji, 2022). A field validation should record product-family demand, timestamped station cycles, inventory at consistent observation points, replenishment lead times, quality losses, and delivered quantities before and after the change. The comparison periods should cover comparable demand and product mix. Process mining may help reconcile event records with the physical route, while a repeated

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improvement cycle can test whether buffer limits remain appropriate. Environmental or financial conclusions require their own measurements (Horsthofer-Rauch et al., 2024; Jamil et al., 2020; Batwara et al., 2023).

CONCLUSION

This analytical design shows how value stream mapping can connect operations capacity with supply chain replenishment decisions in an Indonesian automotive-supplier setting. Under the stated assumptions, inventory coverage falls from 10.00 to 3.00 working days, processing content falls from 282 to 230 seconds, and ideal line capacity rises from 316.10 to 446.90 units per day. The contribution is the explicit connection among the map, the denominators, and the feasibility checks (Busert & Fay, 2021; Ferreira et al., 2022). The proposed design is capacity-feasible at base demand, but its margin becomes narrow when demand rises by 10% and additional operating losses reach 10%. At 15% losses it is infeasible. Managers should therefore validate the welding target, review replenishment exposure, and adjust card counts before reducing stock. This keeps the future-state map tied to operational evidence and an active view of supply chain resilience (Ivanov, 2022; Jamil et al., 2020).

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