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Reducing Dwelling Time Non-Conformance in Outbound Vehicle Logistics: A Toyota Business Practice Approach to Transit-Out Process Diagnosis

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***Abstract*—*This study addresses the transport-logistical problem of dwelling-time non-conformance in the transit-out area of outbound vehicle distribution logistics at an automotive National Distribution Centre (NDC) in the Bandung area of Indonesia. The study aims to diagnose the internal process segments and root causes driving the corridor's ETA performance gap and to propose evidence-based countermeasures using the Toyota Business Practice (TBP) framework. The corridor's ETA punctuality was only 88% against a 98% target, with Dwelling Time Transit Out (DWT/O) identified as the highest internally controllable factor. Data were collected through event-log analytics of 1,477 validated delivery transactions extracted from the company's Logistics System and analysed within the TBP eight-step framework. Process capability analysis established that DWT/O is statistically incapable (PPU = 0.33; PPM ≈ 116,452) against a six-hour upper specification limit. Root causes were identified through a problem-tree analysis triangulated across the three data sources, revealing three causal domains unit-swapping disruption, irregular Car Carrier arrival, and unmonitored post-loading idle time. A set of structured countermeasures is proposed, including a time-based swap penalty scheme. The proposed interventions are expected to raise DWT/O process capability toward PPU ≥ 1.0 and reduce the non-conformance rate from approximately 10% to below 2%.*

Keywords*—*Dwelling Time, Vehicle Distribution Logistics, Toyota Business Practice, Process Capability, Event-Log Analytics

I. INTRODUCTION

Following the downturn of 2023–2024, Indonesia's automotive industry has entered a moderate recovery in sales volume [4]. Within this recovering market, product attributes alone are no longer sufficient to differentiate competitors; operational efficiency and service quality have instead become the primary sources of competitive advantage [14]. Logistics performance reflected in the combination of reliability, responsiveness, and flexibility is increasingly positioned as a competitive asset in its own right, rather than a secondary function to product quality, particularly in an already-mature market [1]. The Agen Tunggal Pemegang Merek (ATPM) the manufacturer-appointed sole distributor in the Indonesian automotive supply chain sits upstream of the branch dealer network, which depends on the ATPM for inventory allocation and replenishment [2], [10]. Because dealer-level inventory availability is contingent on ATPM distribution performance, an ATPM's ability to meet its agreed delivery windows is directly linked to downstream dealer performance and, by extension, to end-customer satisfaction [1], [10]. Within this structure, the Transit Out (T/O) area represents the case company's last internal control point before units are handed over to third-party Car Carriers (CC) for last-mile dispatch, giving it a significant effect on vehicle Estimated Time of Arrival (ETA).

As part of its 2026 KPI escalation roadmap, the company is implementing a 98% ETA punctuality target and is separately evaluating a compression of the Bandung corridor's delivery cycle to a 20-hour standard, internally designated J-20. Over the three-month observation window, however, the corridor's on-time ETA performance stood at only 88%, well below this target. This gap has been identified as a systemic issue rather than an isolated incident, driven in significant part by uncontrolled dwelling behaviour within the corridor's internal delivery process. Although event-log analytics and Lean-based diagnostic frameworks such as TBP are well established in manufacturing contexts, their application to outbound vehicle distribution and specifically to the Transit-Out stage of automotive logistics in Indonesia remains limited, particularly regarding swap-governance policy and sub-process-level data-architecture redesign [6], [19]. This study addresses that gap by applying the TBP framework, supported by event-log analytics and field-based qualitative evidence, to diagnose and structurally address DWT/O non-conformance on the Bandung corridor. Accordingly, this study aims to (i) characterise the current state of the outbound delivery process on the Bandung corridor, (ii) identify the internal process segments and root causes driving its ETA performance gap, and (iii) translate these findings into structured, evidence-based operational countermeasures. In addressing these questions, this study extends TBP application beyond its traditional manufacturing setting into outbound distribution logistics, while offering the case company practical, prioritised countermeasures for closing its ETA punctuality gap.

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II. LITERATURE REVIEW

Dwelling time is distinct from total lead time in that it denotes a bounded interval in which an asset remains idle without value-adding activity, a concept originating in port and intermodal operations and since extended to warehousing and distribution contexts [12]. Composite dwell-time metrics that merge multiple sub-intervals under a single timestamp pair obscure accountability and weaken root-cause diagnosis, motivating process decomposition as an analytical strategy consistent with value stream mapping, which distinguishes value-adding activity from pure waste [15].

The Toyota Production System frames waste through the interdependent 3M taxonomy of Muda (non-value-adding activity), Mura (unevenness), and Muri (overburden), in which Mura is treated as the structural driver of Muda, and unresolved Mura manifests as Muri [13]. The Toyota Business Practice (TBP) operationalises this philosophy as an eight-step problem-solving sequence clarify the problem, break down the problem, set the target, analyse root causes, develop and implement countermeasures, then evaluate and standardise typically communicated through the single-page A3 report [9]. Complementing this diagnostic sequence, event-log analytics and process mining reconstruct actual process behaviour from timestamped operational data rather than from assumed process maps, supporting process discovery, conformance checking, and performance analysis [20]. Statistical process control provides the quantitative layer for this diagnosis, distinguishing common-cause from special-cause variation [18] and, through process capability indices such as PPU and PPM, quantifying the extent to which a process reliably meets a specification limit [11].

Empirical research on automotive distribution performance converges on two related findings. First, variability originating upstream propagates downstream: production-schedule variability has been shown to materially inflate distribution-centre lead time [7], while the absence of a demand-change cutoff policy has separately been identified as a direct driver of schedule nervousness, in which practitioners face no cost for late changes and are consequently more likely to submit requests late rather than early [3]. Second, visibility and standardisation are consistently identified as effective countermeasures: lean interventions such as process standardisation and real-time information sharing reduce distribution-related waste [17], real-time visibility is regarded as one of the most significant capabilities for reducing delivery variability [5], IT capability is positively linked to collaborative operational performance [16], and real-time data integration is established as a key enabler of autonomous monitoring in Industry 4.0 logistics contexts [8].

Despite this convergence, literature on automotive outbound logistics in Indonesia remains limited in three respects: Transit-Out-stage diagnostics specifically have received little empirical attention; supply-chain-collaboration policy for swap governance has not been examined as a distinct lever in this context [19]; and sub-process-level data-architecture redesign has not been applied to dwelling-time metrics in vehicle distribution. This study addresses these three gaps by applying the TBP framework to Transit-Out event-log data, examining swap-governance policy as a primary root-cause domain, and proposing a sub-process decomposition of the DWT/O metric.

III. METHODOLOGY

Following case study designs appropriate for phenomena that cannot be detached from their organizational context [21] a single, case study research using a triangulated mixed methods design approach was followed, which includes event-log analytics and qualitative gemba observation and semi-structured interviews. Excluding from the analytical area were the downstream legs of the sequence, which are controlled by third-party logistics providers (LP), including Car Carrier gate-out at the NDC.

Logistics Company data were collected by extracting event-log data in the Bandung corridor for months of September–November 2025 from the company's Logistics System (LS). There were 2,106 extraction transactions initially sent, which on delivery were processed through a system of regular cleaning, using operational checks for missing, duplicated, or disrupted records resulting in 1,477 valid extraction deliveries.

Process capability analysis of the focus process was performed in Minitab using the Moving Range–Individual (MR-I) method, appropriate where natural rational subgroups cannot be formed [11], generating estimates of the Process Performance Index (PPU), Process Capability Index (CPU), and Parts Per Million defective (PPM) against a six-hour upper specification limit (USL). This six-hour threshold is an internal company policy specific to the Bandung corridor, derived as the T/O dwelling-time allocation within the broader breakdown of the corridor's J-20 (20-hour) delivery cycle target; it does not reflect an external contractual or industry-wide standard. Four informants were purposively selected to represent complementary vantage points across the end-to-end T/O process: the Section Head (overseeing the Stockyard and Delivery divisions), the Line Head (responsible for the Delivery division's field operations), a CCR operator (responsible for sequencing orders from Dealer Request through to unit staging), and a Delivery Car Carrier (DCCP) operator a company-internal designation for the role responsible for SJKB issuance. This composition captured both upstream (staging, swap handling) and downstream (loading, CC dispatch, gate-out) mechanisms, alongside managerial and field-level perspectives.

Engagement with informants was conducted over a one-month field observation period, with recurring semi-structured conversations held at a minimum frequency of three to four times per week per informant, each lasting approximately 30 to 60 minutes. This iterative, embedded format was adopted to accommodate informants' operational availability and to allow emerging event-log findings to be validated and clarified progressively as the analysis developed.

Analysis followed a three-bracket structure mapped to TBP Steps 1–6: Bracket 1 (clarify, break down, set target), Bracket 2 (root-cause analysis via problem tree), and Bracket 3 (countermeasure proposals), with Steps 7–8 (evaluate and standardise) left as conditional guidance beyond the researcher's operational authority.

IV. FINDINGS AND DISCUSSION

A. Current Performance Gap

The Bandung corridor observed about 88% punctuality in the observation period, which is still lower than the ETA target of 98%, suggesting that their non-conformance rate is not just a coincidental issue but a systemic one, with monthly non-conformance rates ranging between 7% in October and 15% in September, respectively.

B. Process Segmentation and Focus Selection

The end-to-end delivery process was broken down into five segments, as summarized in Table I, where Lead Time NDC-to-Relay-Point (LTCC) was excluded from the scope of improvement because it was an externally controlled, LP dependent process with a higher raw NG rate. Dwelling Time Transit Out (DWT/O) at about 12% was found to be the largest internally controllable NG contributor as compared to the other internal processes (2-4%). This process was therefore chosen for root-cause analysis.

Table I.
Process-Level Non-Conformance (Ng) Rate Summary (n = 1,477)

Process Segment	Code	Avg. LT	Units	% NG
Lead Time Picking	LT Picking	~2h 36m	1,477	2%
Dwelling Time Transit Out	DWT/O	3h 39m	1,477	12%
Lead Time NDC → RPGa	LTCC	~5h 08m	1,477	63%
Dwelling Time RPG	DWRPG	~1h 02m	1,477	4%
Lead Time to Branch	LTSD	0h19m–3h36m	1,477	2%

a LTCC (63% NG) is externally controlled by third-party logistics providers and is excluded from the improvement scope; DWT/O (12% NG) is the highest internally controllable contributor and is selected as the focus process.

C. Process Capability of DWT/O

MR-I analysis of the 1,477 validated DWT/O transactions (Fig. 1) shows a process mean of 3.65 hours nominally within the six-hour USL but a standard deviation of 2.40 hours, with a right-skewed distribution and a maximum observed value of 27.25 hours. This combination yields a Process Performance Index (PPU) of 0.33 and a Process Capability Index (CPU) of 0.67, against an estimated 116,452 PPM (parts per million) falling outside the USL. Because a PPU below 1.0 indicates that a process cannot reliably meet its specification limit even under its own observed variation and a PPU of 1.33 is generally regarded as the minimum threshold for acceptable process control [11] the DWT/O process is statistically incapable of consistently meeting the six-hour USL. Critically, the gap does not stem from central tendency, since the process mean itself falls within specification; rather, it stems from excessive and right-skewed variability, indicating that the dominant improvement lever is process stability, not a shift in the average. This distinction directly motivates the root-cause analysis in Section D, which focuses on identifying the sources of variability rather than sources of mean-shift.

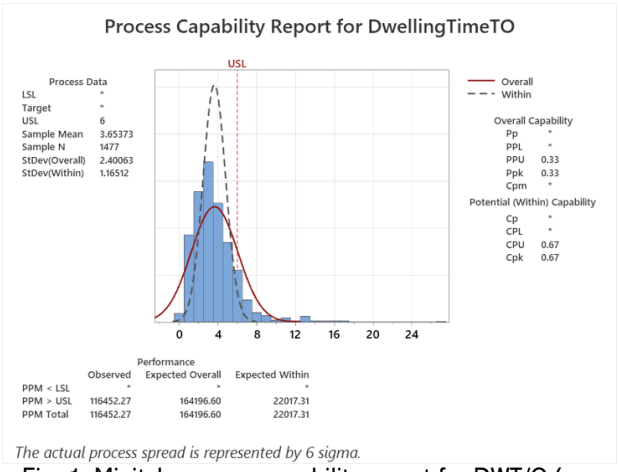


Fig. 1. Minitab process capability report for DWT/O (n = 1,477), showing the distribution of dwelling time against the six-hour USL and the resulting overall/within capability indices (PPU = 0.33; CPU = 0.67).

D. Root Causes

Of the 171 non-conforming DWT/O transactions, 102 about 60% were related to unit swapping missions, which are transactions that a dealer initiates near the time for a 'Car Carrier' to depart, but in which there is no time-based cutoff to conform a transaction. Two additional domains also emerged as grouping together most of the instances: Car Carrier arrival irregularity; and post-loading idle time. Table II summarises the six root causes across the three causal areas, which are based on multiple and independent data sources (event log, gemba observation, interview); each domain has gained at least two independent data sources and been triangulated.

Table II.
Consolidated Root Cause Summary (Dwt/O Focus)

No.	Causal Domain	Root Cause	Operational Impact
1	Unit Swapping Disruption	Multi-step swap verification executed too close to CC departure	Loading delays when swaps are initiated within the critical CC window

No.	Causal Domain	Root Cause	Operational Impact
2	Unit Swapping Disruption	No unified swap-timing standard across branches	Structural vulnerability to late-swap disruption on all branch routes
3	CC Arrival Irregularity	No real-time integrated dashboard for CC load tracking	Late detection of CC abnormality; no proactive recovery possible
4	CC Arrival Irregularity	No LP change-time restriction policy for reserved licence plate	Last-minute LP schedule changes disrupt pre-confirmed loading plans
5	Post-Loading Idle Time	Post-loading pre-departure interval not independently tracked	Invisible idle time inflates DWT/O without triggering a monitoring alert
6	Post-Loading Idle Time	No dashboard integration between loading completion and gate-out clearance	Communication lag between loading completion and departure authorisation

E. Financial Impact

Two cost components were quantified to estimate the financial impact of DWT/O non-conformance. Idle Capital Cost captures the shipping-cost differential incurred when a swap event redirects a unit to a destination with a higher logistics cost than its original allocation; this differential was aggregated across all destination-changing swap events recorded during the observation window. Labor Cost reflects the fully-loaded monthly wage, based on the Karawang Regional Minimum Wage (UMK), of two personnel across two shifts whose role is dedicated to coordinating swap-related activity, extended over the three-month period. As summarised in Table III, the resulting estimate totals approximately IDR 117 million over three months (IDR 61 million idle capital cost, IDR 56 million labor cost), projecting to roughly IDR 468 million annually if unaddressed.

Table III.
Financial Impact of Dwt/O Non-Conformance (3-Month Window)

Cost Component	Basis	Amount (IDR)
Idle Capital Cost	Aggregated shipping-cost differential from destination-changing swap transactions, Sep–Nov 2025	61,000,000
Labor Cost	Estimated wage of 2 personnel across 2 shifts, based on Karawang Regional Minimum Wage (UMK), over 3 months	56,000,000
Total (3 months)	Idle Capital Cost + Labor Cost	117,000,000
Projected Annual Impact	Extrapolated from the 3-month total	468,000,000

F. Discussion

The consolidated root-cause picture in Table II indicates that DWT/O instability is not a capacity constraint but a governance and visibility deficit: the process mean itself sits within specification, yet variability pushes over 10% of transactions beyond the USL. Where prior work identifies the absence of a demand-change cutoff policy as a general driver of late, uncosted changes [3], this study locates that mechanism at a specific operational chokepoint the interval between a dealer's swap request and CC departure and quantifies its contribution (60% of non-conforming cases).

The co-occurrence of the three causal domains swapping, CC arrival irregularity, and post-loading idle time is itself informative. Each domain independently reflects a missing feedback loop: swap requests are accepted without a cost signal tied to timing; CC arrivals are not visible in real time; and loading completion is not communicated automatically to gate-out. This pattern is consistent with information-systems evidence that real-time visibility is a key enabler of reduced delivery variability [5] and that data integration underpins autonomous exception-handling in Industry 4.0 logistics contexts [8]; however, it also suggests a more specific mechanism than "poor visibility" in the abstract namely, that each sub-process in the T/O sequence was designed and measured in isolation, with no shared real-time reference point across CCR, DCCP, and gate functions.

Theoretically, these findings extend business process redesign (BPR) principles [6] to the sub-process measurement layer: the DWT/O metric's conflation of staging and loading time is not merely a data-quality issue but a structural barrier to accountability. Managerially, the findings imply that the company's KPI escalation strategy (98% ETA, prospective J-20) is unlikely to be achieved through downstream monitoring alone; without addressing the swap-governance policy gap identified here, tightening the delivery-cycle target would compress the buffer available to absorb existing variability rather than resolve its source.

G. Proposed Countermeasure

Five countermeasures are proposed, each addressing specific root causes identified in Table II.

Addressing Root Causes 1–2 (Unit Swapping Disruption): A Swap Governance Contract introduces a three-tiered, time-based penalty scheme full penalty within one hour of CC departure, 50% penalty between one and three hours, and no penalty beyond three hours, calibrated to the observed 3.65-hour process mean to discourage late swap requests while preserving operational flexibility.

Addressing Root Cause 5 (Post-Loading Idle Time, untracked interval): DWT/O is decomposed into two independently tracked sub-metrics, Pure Dwelling Time and Loading Time [15]; an interim Power BI dashboard is proposed pending a formal Logistics-System change request.

Addressing Root Causes 3–4 (CC Arrival Irregularity): An integrated licence-plate change gateway propagates Car Carrier substitutions automatically to the Logistics System, replacing manual radio or phone coordination.

Addressing Root Cause 3 (documentation gap in loading NG events): A mandatory loading-delay reason-code and evidence system closes the visibility gap identified in loading non-conformance records.

Addressing Root Causes 5–6 (Post-Loading Idle Time, general): A field-level Standard Operating Procedure targets Muda, Mura, and Muri directly at the T/O bay, CCR workstation, and gate [13].

The swap-timing and process-decomposition interventions are prioritised first, as they require no

system development and directly address the dominant 60% root-cause domain; gateway and evidence-system interventions are treated as medium-term, IT-dependent initiatives with manual interim workflows.

V. CONCLUSION

DWT/O non-conformance is caused mainly by the lack of governance that leads to unit-swapping without control, Car Carrier arrival irregularity and post-loading idle time that will not be tracked due to data-architecture limitation that combines Staging and Loading time. The research builds on the existing TBP application in manufacturing and applies it to evidence from event log, observation and interview evidence and suggests five evidence-based, sequenced countermeasures to raise the process capability for DWT/O towards PPU ≥ 1.0 and to reduce the non-conformance to below 2% to support sustained large-scale meeting of the corporate 98% ETA punctuality target in outbound distribution.

This study has a number of scope limitations and boundary constraints. The process scope also includes only the internal process parts that are in the scope of the researcher's observation in the NDC and are fully controlled by the NDC, while parts of the processes related to outside the scope of the NDC which are exclusively under the control of third party logistics providers, such as transit time and last-mile delivery are entered as contextual factors in this process, but not as part of the main improvement process. Because of the structured delivery and fixed schedule for the Bandung distribution corridor, which tends to minimise the influence of variation in delivery schedule present in other corridors, and because of its strategic role as the designated pilot corridor for the company's J-20 delivery-cycle initiative, this corridor was selected as the empirical site. Because the absence of a formalised swap-timing cutoff policy is a company-wide policy gap rather than a Bandung-specific contractual arrangement, the dominant root-cause domain identified here unit-swapping disruption is expected to extend to other pull-system corridors served by the same Logistics System and swap governance structure. At the level of substantive findings, the precise magnitude of each causal domain's contribution to DWT/O non-conformance (e.g., the 60% weighting of swap-related disruption) was empirically established only for Bandung, and corridor-specific validation is recommended before company-wide rollout. In relation to data limitations, financial data such as wages paid to employees, unit values and logistics costs have been kept confidential in accordance with non-disclosure agreements signed by the company and have therefore been estimated with a small margin from the original data for the need to conduct a Lost Opportunity Cost analysis, resulting in indicative rather than actual financial figures. Lastly, under the terms of the non-disclosure agreement with the company, the company's name was anonymised to that of PT Kendaraan Niaga Indonesia (KNI), and division and area names were also anonymised, while all the other quantitative data was kept the same as those in the Logistics System event log.

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