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Implementation of Automation and System Integration in The Weighing Process and Documentation of Coal Shipments Using The FOBMV Method At PT XYZ

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Abstract: This research investigates operational challenges in the mining industry, specifically the weighing and documentation of coal shipments at PT XYZ. The process previously relied on manual data entry across three separate systems, resulting in recurring problems of data inaccuracy, process inefficiency, and excessive workload that disrupted operations and delayed managerial decision-making. The study aims to analyze the root causes of these issues, design a practical solution, and evaluate its impact. A mixed-method approach was applied, combining interviews, field observations, and quantitative measures such as error rates, process cycle efficiency, and Full-Time Equivalent calculations. The proposed solution, designed through a user-centered design framework, introduced automation via RFID-based dump truck identification, automatic generation of delivery documents, and integration of weighbridge data across internal and external applications. Implementation reduced errors by 86%, improved efficiency more than fourfold, and decreased workload by 80%, allowing a single operator to manage the process effectively. The findings confirm that automation and system integration significantly improve the accuracy, efficiency, and reliability of coal shipment documentation, demonstrating how digital interventions can enhance both operational performance and strategic decision-making in mining logistics.

Keywords: Data Inaccuracy, Process Inefficiency, Workload, Mining, Automation

INTRODUCTION

Coal remains one of Indonesia's primary energy sources, with PT XYZ, a state-owned enterprise, playing a central role in ensuring supply security. To achieve a production target of 50 million tons and a shipment target of 42 million tons by 2025, the company introduced the Free on Board Mother Vessel (FOBMV) method to complement railway transport. This method employs dump trucks (DT) for coal delivery from stockpiles to ports. However, internal evaluation of FOBMV revealed weaknesses in documentation and system integration. Three separate applications, the Weighbridge Application (WBA), Internal Application System (IAS), and External Verification Application (EVA), operate independently, forcing operators to repeatedly input Delivery Order (DO) and DT numbers, creating risks of error and inefficiency. The fragmented documentation workflow is illustrated in Figure 1 (Rich Picture), which shows the multiple actors and redundant inputs across systems. This condition has led to recurring data inaccuracies: between October 2024 and June 2025, 449 input errors were recorded out of 69,441 transactions, an average error rate of 0.65% (see Table 1; Figure 2). Although small in percentage, the persistence of these errors demonstrates systemic weaknesses.

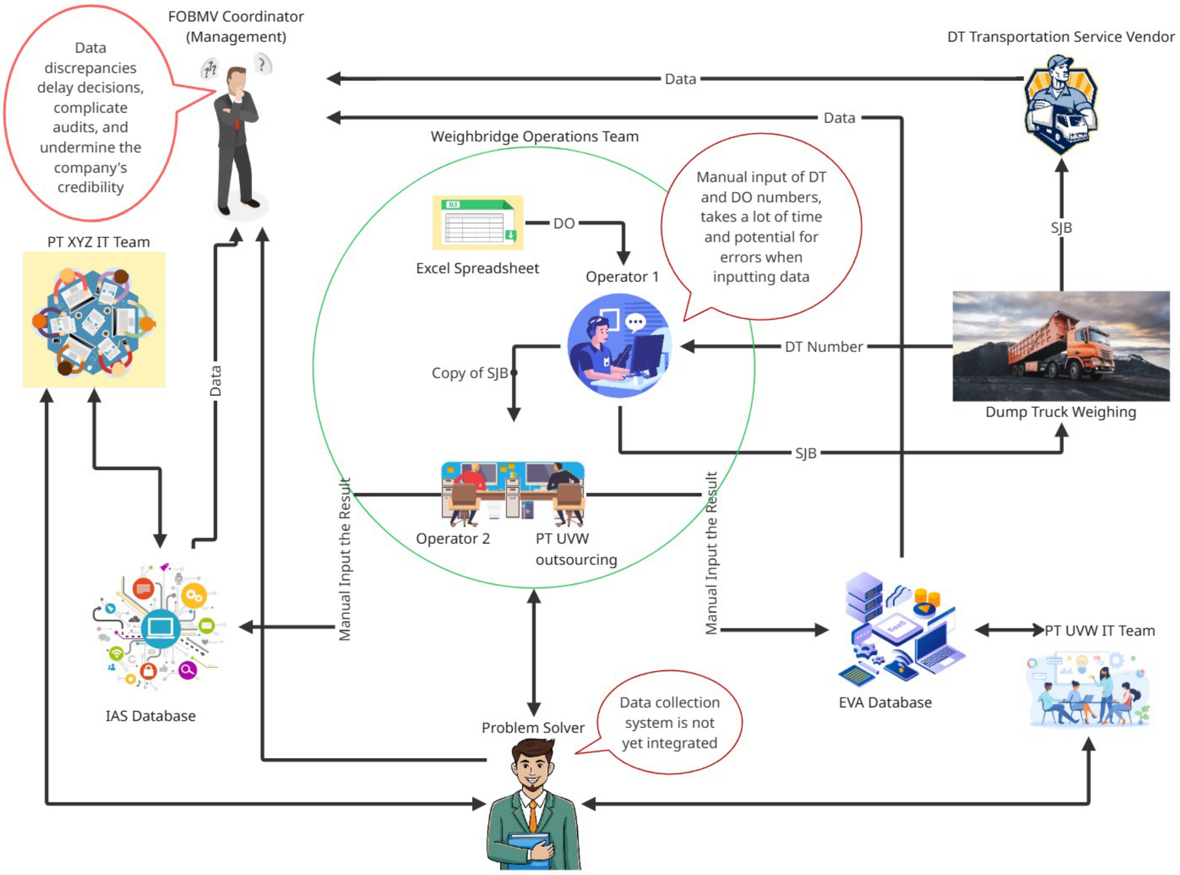


Figure 1. Rich Picture

Table 1. Number of Weightings, Identified Errors, and Error Percentage per Month

	NUMBER OF WEIGHING		**ERROR**	**%**
MONTH	**RITASE**	**TONAGE**		
OCTOBER	15,453.00	534,816.15	89	0.58%
NOVEMBER	8,782.00	316,246.95	40	0.46%
DECEMBER	11,978.00	440,487.90	76	0.63%
JANUARY	8,881.00	340,622.72	30	0.34%
FEBRUARY	4,074.00	157,056.22	22	0.54%
MARCH	6,394.00	252,681.11	74	1.16%
APRIL	8,147.00	320,923.18	48	0.59%
MAY	2,923.00	118,715.46	33	1.13%
JUNE	2,809.00	120,351.50	37	1.32%
TOTAL	**69,441.00**	**2,601,901.18**	**449**	**0.65%**
AVERAGE	**7,715.67**	**289,100.13**	**50**	

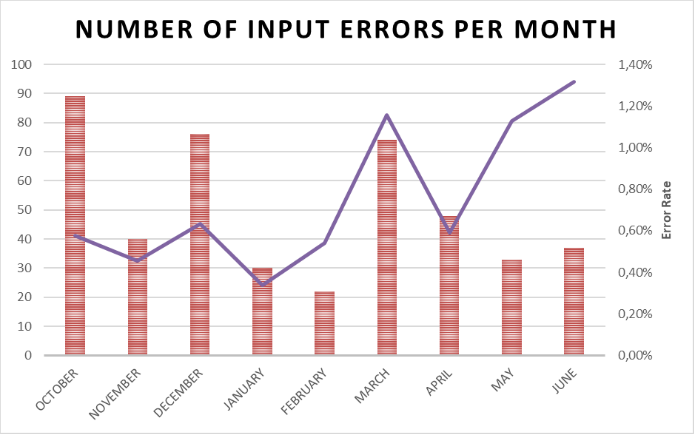


Figure 2. Number of Input Errors and Error Rate per Month

Process inefficiency was also significant. Observation of 50 weighing cycles showed that 79% of total time (407 seconds) was spent on non-value-added (NVA) activities such as repetitive data entry, while only 21% was devoted to value-added (VA) activities like weighing and ticket printing. The imbalance is depicted in Figure 3 and 4. Workload analysis further indicated that the process required 2.83 Full-Time Equivalents (FTE), rounded to three operators, although management expected it to be handled by one. The gap between management expectations and operational reality is summarized in Table 2.

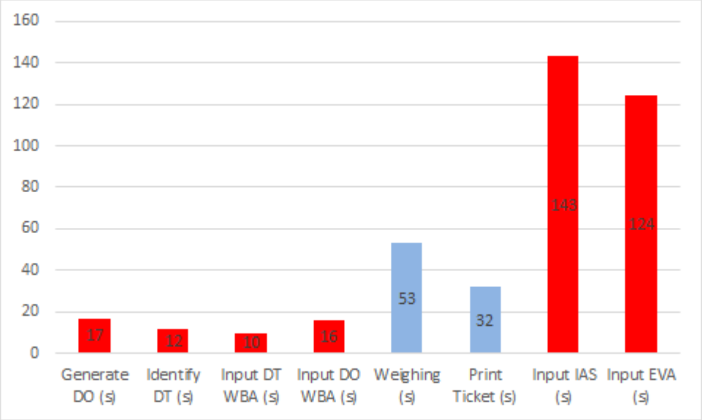


Figure 3. Average Time per Activity in the Weighing Process

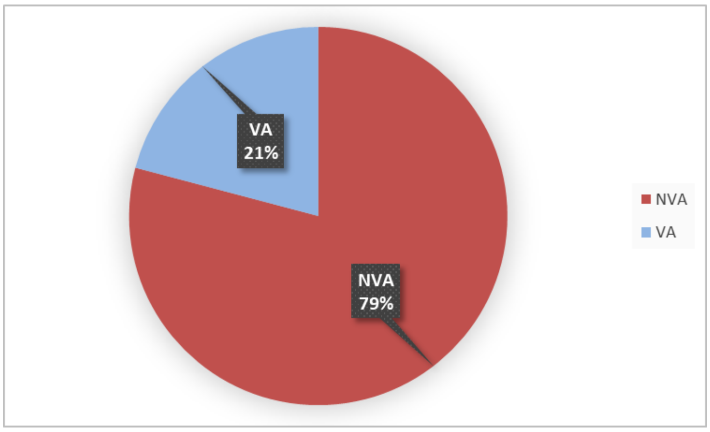


Figure 4. Proportion of Value-Added vs Non-Value-Added Activities

Table 2. Business Issues, Management Expectations, and Associated Risks

Business Issue	Management Expectations	Risks Identified
Data Inaccuracy	Shipment documentation must be accurate (with 0% error), consistent, and real-time to serve as a reliable basis for monitoring and decision-making.	Data inaccuracy may hinder operational decision-making and undermine confidence in the reliability of recorded information.
Process Inefficiency	Documentation should run efficiently under the principle of single data entry without repeated inputs by multiple personnel, with management targeting the elimination of activities that do not add value.	Process inefficiency can slow down operational flow and increase the risk of errors due to redundant input activities.

These conditions raise three critical research questions: (1) What are the root causes of inaccuracy, inefficiency, and risk in the weighbridge process? (2) How can automation and integration among WBA, IAS, and EVA improve performance? (3) What measurable impacts result from implementing this solution?mpacts result from implementing such a solution?

Table 3. Linkage of Literature Review Items to Research Questions

Literature Item	Relevance to Research Question
II.1.1 Data Quality and Reliability Metrics	RQ1 – Identifies the root causes of data inaccuracy and mismatches across systems.
II.1.2 Process Performance Measurement (PCE)	RQ1 & RQ2 – Explains process inefficiencies and provides the basis for designing system integration.
II.1.3 Workload Analysis	RQ1 – Assesses workload through FTE calculations and workforce capacity analysis.
II.1.4 Risk in Operations	RQ1 & RQ3 – Identifies and evaluates operational risks.
II.1.5 Automation in Operations	RQ2 – Provides the theoretical foundation for designing automation to reduce NVA activities.
II.1.6 User-Centered Design (UCD)	RQ2 – Ensures the system design aligns with operator needs and reduces resistance to adoption.
II.1.7 Evaluation Tools for System Design	RQ3 – Provides methods for evaluating the effectiveness of the integration solution using improvement ratio metrics.

1. *Data Quality and Reliability Metrics*

Data quality dimensions, accuracy, completeness, consistency, and timeliness, form the foundation of reliable operations (Lindström et al., 2023). In FOBMV, recurring DO and DT input errors reflect systemic weaknesses, emphasizing the need to measure and control error rates as shown in Table 3. Inconsistent and delayed updates across systems reduce decision-making reliability (Lu et al., 2021).

2. *Process Cycle Efficiency (PCE)*

PCE evaluates efficiency by comparing VA to total cycle time. In FOBMV, VA activities accounted for only 21% of the cycle, confirming heavy reliance on NVA tasks. This condition is aligned with Lean principles, where re-entry and waiting are classified as waste (Adeodu et al., 2023). Prior studies confirm that automation can substantially improve PCE (Daniyan et al., 2022).

3. *Workload Analysis (WLA)*

Workload analysis links task demand with worker capacity. Using FTE, this study revealed that three operators were required to meet throughput, although the core process should require only one. Excessive workload reduces accuracy and raises the likelihood of human error (Kudelska & Niedbał, 2020). Similar findings in logistics demonstrate that unbalanced workloads increase errors and reduce productivity (Kumar et al., 2025).

4. *Risk Identification in Operations*

Risks emerge when manual systems delay shipments, reconciliation, and vendor billing. Qualitative identification through interviews helps capture actual vulnerabilities (Md Hanafiah et al., 2022). In FOBMV, delays in truck unloading and reconciliation illustrate the consequences of inaccuracy and inefficiency. This aligns with supply chain risk models emphasizing the cost of unsynchronized data (Schroeder & Lodemann, 2021).

5. *Automation in Operations*

Automation eliminates repetitive input and ensures consistent workflows. RFID has proven effective in minimizing errors in logistics (Ferdousmou et al., 2024). For FOBMV, RFID-based DT recognition and automatic DO generation directly address error-prone manual tasks.

6. *User-Centered Design (UCD)*

UCD emphasizes aligning system design with operator needs to reduce resistance and ensure adoption. Involving users in prototyping and testing ensures systems are intuitive and reduce workload (Cepero et al., 2025). Applied in FOBMV, UCD ensures automation supports operators rather than complicating tasks.

7. *Evaluation Tools for System Design*

The improvement ratio offers a transparent method to assess pre- and post-implementation conditions (Jacobs & Chase, 2018). By measuring changes in error rate, PCE, and workload, the method quantifies whether integration delivers meaningful improvements. The logical connection between theories and the research design is illustrated in Figure 5.

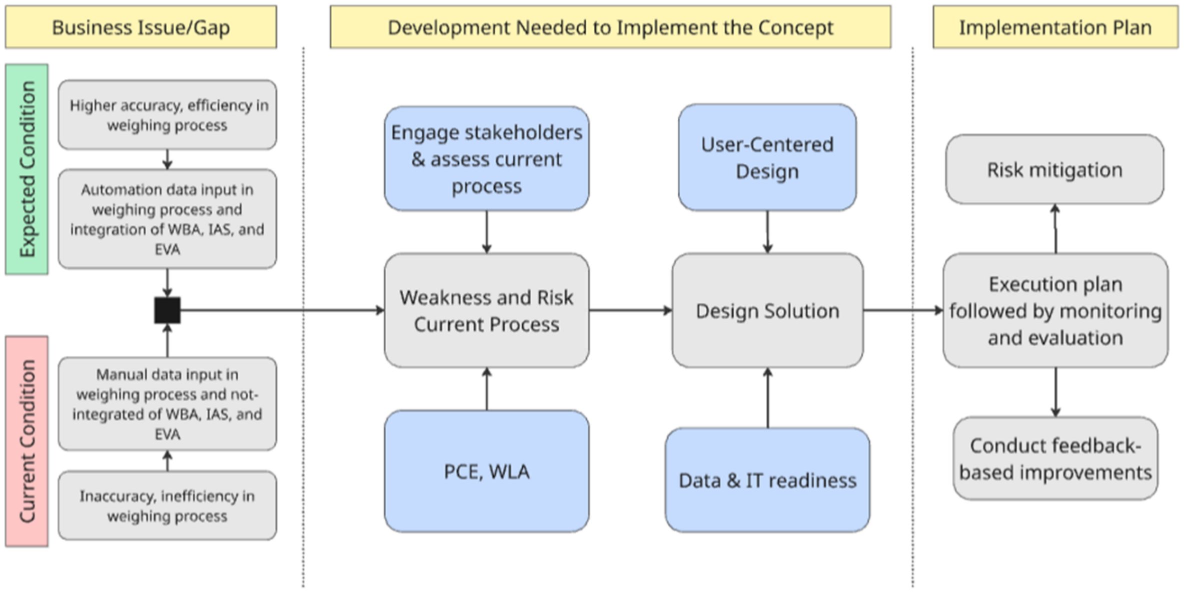


Figure 5. Conceptual Framework

METHOD

This study adopts a mixed-method approach to investigate inefficiencies and inaccuracies in the coal shipment documentation process under the FOBMV method at PT XYZ. The qualitative component was used to identify root causes and explore user requirements, while the quantitative component provided measurable evidence of process performance. The research employed an explanatory case study design, with the FOBMV weighbridge process and its three supporting applications (WBA, IAS, and EVA) serving as the unit of analysis. The overall framework of the study is presented in Figure 6.

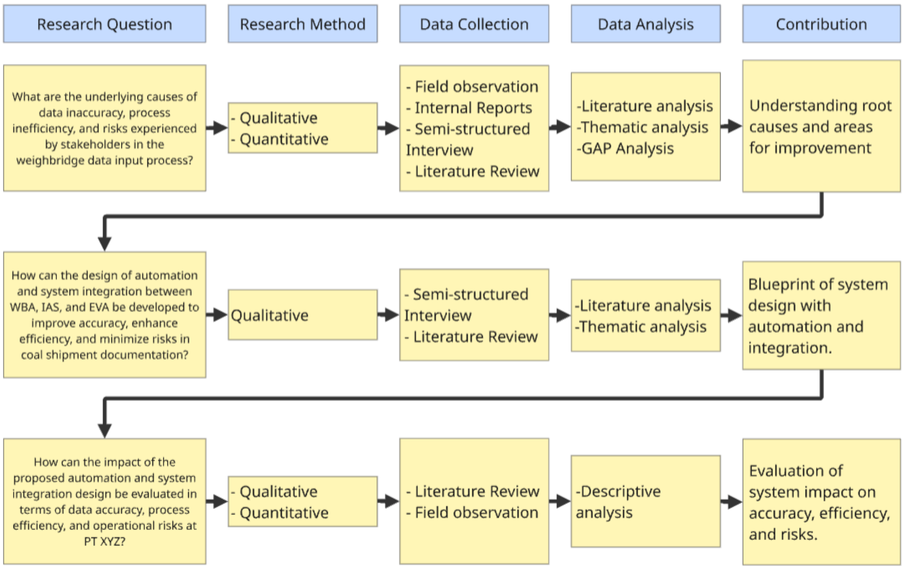


Figure 6. Research Design

Research Site and Period

The study was conducted between October 2024 and August 2025 at PT XYZ's weighbridge facilities in the Tanjung Enim mining area. This location was selected because it represents the operational hub of FOBMV documentation activities and reflects the daily interaction between operators, coordinators, and external verifiers.

Research Subjects

Respondents included seven key stakeholders directly involved in the documentation process, covering weighbridge operators, FOBMV administrators, operational supervisors, and IT staff from both PT XYZ and PT UVW. The distribution of research participants is shown in Table 4.

Table 4. Respondent Target Interview

No	Initial	Job Position	Role
1	MZ	Weighbridge Operator 1	Responsible for inputting DT & DO data at weighbridge and printing SJB
2	HF	Weighbridge Operator 2	Responsible for re-inputting weighbridge ticket data into IAS
3	EB	Operator PT UVW	Responsible for re-inputting weighbridge ticket data into EVA for external verification
4	FZ	Operational Supervisor	Responsible for supervising daily activities in the stockpile and weighbridge area, monitoring operator performance, ensuring smooth truck flow, and handling operational issues in the field
5	YG	FOBMV Coordinator	Management, Responsible for supervising weighing process, shipment documentation, and ensuring data accuracy
6	AR	PT XYZ IT Team	Responsible as PT XYZ IT team
7	RP	PT UVW IT Team	Responsible as PT UVW IT team

Data Collection

Qualitative data were collected through semi-structured interviews and field observations. The structure of data collection is illustrated in Figure 7.

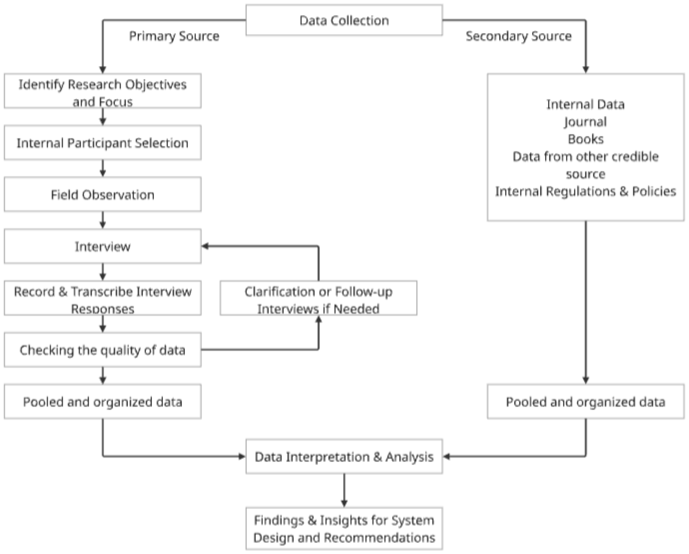


Figure 7. Data Qualitative Collection Method Diagram

Interview questions were tailored to capture the specific challenges and expectations of each role, as summarized in Table 5. These instruments provided insights into manual input practices, perceived inefficiencies, and risks encountered in daily operations.

Table 5. Interview Question

Initial	Question
MZ	Can you tell me how you usually input DT numbers and DO data at the weighbridge?
	Which part of that job often causes mistakes?
	What usually happens if the data in the ticket is wrong?
	What kind of change would make your job easier?
HF	How do you usually re-enter weighbridge ticket data into IAS?
	What problems do you face most often when doing this?
	What happens if the data in IAS doesn't match the ticket?
	What would make this re-entry work faster and easier for you?
EB	What challenges do you face when entering data into EVA?
	How often do you see data in EVA that's different from other systems?
	What do you usually do when the data doesn't match?
	What changes would help EVA data stay the same as the other systems?
FZ	From what you see in the field, what problems come up most in the weighing and documentation process?
	Have you ever seen this weighing and data input process done by only one person? What happened?
	What risks do you notice when data is wrong?
	What should change so operators can work smoother with fewer errors?
YG	From your position, what problems do you often see in weighing and documentation?
	What's the biggest impact when the data is not accurate or consistent?
	What risks do you see that can disturb shipment or reduce trust in the data?
	What changes would help you better supervise and make decisions?
AR & RP	How did your team start designing the new system to cut down manual work?
	Which part of the process did you think should be automated first?
	What difficulties came up when connecting WBA, IAS, and EVA?
	What steps are being prepared to make sure the data is the same across all systems?

Quantitative data were obtained from internal operational records and direct time-and-motion studies of 50 weighing cycles. The data included transaction counts, error reports, correction logs, and duration of each activity in the weighing process. This allowed for the calculation of key indicators such as Error Rate (ER), Process Cycle Efficiency (PCE), and Full-Time Equivalent (FTE).

1. **Data Analysis**
   The study employed three complementary analytical approaches:
2. **Thematic analysis** was used to code and categorize qualitative responses, identifying themes such as manual input, lack of system integration, and operational burden. Results were consolidated into thematic tables and later compared against field observations.
3. **Workload Analysis (WLA)** was applied using FTE calculations to determine the number of operators required to sustain daily throughput.
4. **Descriptive analysis** was conducted to compare conditions before and after system implementation. Performance indicators included error rate, efficiency (PCE), and workload (FTE). The improvement ratio (IR) was used to quantify the degree of change between pre- and post-implementation conditions.

Together, these methods provided a comprehensive evaluation, ensuring that qualitative user insights were supported by quantitative performance data.

RESULTS AND DISCUSSION

The analysis was structured around the three research questions (RQ1–RQ3), combining thematic interview insights, observation data, and quantitative indicators.

Root Causes of Inaccuracy and Inefficiency (RQ1)

Thematic analysis of interviews revealed two fundamental causes: reliance on manual input and the absence of system integration. Operators repeatedly emphasized that typing DT and DO numbers was error-prone, while re-entry into IAS and EVA created additional inconsistencies. These findings are consolidated in Table 6. The frequency of code shows that *Manual Input* and *Not Integrated* were the most dominant themes, as visualized in Figure 8.

Table 6. Interview Result – Thematic Analysis: Root Cause and Risk

Initial	Question	Answer	Initial Code	Theme (Root Cause/Risk)
EB	What challenges do you face when entering data into EVA?	In addition, several times I have also made mistakes myself because of typo or wrong seeing numbers.	Manual Input	Inaccuracy
EB	How often do you see data in EVA that's different from other systems?	Because this data is the result of retyping, if in the previous system there is already a mistake, then in EVA it also follows wrong.	Not Integrated	Inaccuracy
FZ	From what you see in the field, what problems come up most in the weighing and documentation process?	This situation adds work pressure and finally is at risk of making wrong input of DT number or DO.	Manual Input	Inaccuracy
FZ	What should change so operators can work smoother with fewer errors?	In my opinion, the operator should no longer be burdened with too much manual input that is prone to mistakes.	Manual Input	Inaccuracy
MZ	Which part of that job often causes mistakes?	The most frequent mistakes happen when I type the DT number or DO number.	Manual Input	Inaccuracy
MZ	Which part of that job often causes mistakes?	In addition, because the DO number is taken from a separate spreadsheet, sometimes I wrongly copy-paste or the formula in the spreadsheet itself is wrong, so the DO that I enter into the weighing system is not correct.	Manual Input	Inaccuracy

Initial	Question	Answer	Initial Code	Theme (Root Cause/Risk)
MZ	What usually happens if the data in the ticket is wrong?	If there is a wrong input in the weigh ticket, automatically the data that I enter into the weighing system is also wrong.	Not Integrated	Inaccuracy
MZ	What kind of change would make your job easier?	With that I just need to make sure the weighing is correct without having to bother typing repeatedly.	Manual Input	Inaccuracy
EB	What challenges do you face when entering data into EVA?	My job is to retype data from the weigh ticket into EVA.	Repetitive Workload	Inefficiency
HF	How do you usually re-enter weighbridge ticket data into IAS?	After the weigh ticket (SJB) is printed from the application, I receive one copy to re-enter into IAS.	Repetitive Workload	Inefficiency
MZ	Can you tell me how you usually input DT numbers and DO data at the weighbridge?	All of that data is entered one by one, then the system prints the weigh ticket (SJB).	Manual Input	Inefficiency
MZ	What kind of change would make your job easier?	If possible, the input parts that are important like the DT number and DO number are no longer typed manually by me.	Manual Input	Inefficiency
YG	What changes would help you better supervise and make decisions?	The most needed change is reducing dependence on manual input and ensuring data is consistent in all systems.	Not Integrated	Inefficiency
EB	What do you usually do when the data doesn't match?	If there is data that does not match with other systems, I have to recheck the weigh ticket.	Not Integrated	Inaccuracy
FZ	Have you ever seen this weighing and data input process done by only one person? What happened?	Under the current conditions, it is clearly too heavy if handled by just one person	Operational Burden	Inefficiency
FZ	What risks do you notice when data is wrong?	If there is wrong data, usually the transportation service vendor directly contacts me because their truck is held and cannot unload.	Not Integrated	Risk
MZ	Which part of that job often causes mistakes?	If the queue of trucks is long, I have to quickly input so as not to hold other trucks that want to enter the stockpile area.	Operational Burden	Risk
MZ	What usually happens if the data in the ticket is wrong?	Later when that data is used again in IAS or EVA, the mistake is carried along.	Not Integrated	Risk
YG	What risks do you see that can disturb shipment or reduce trust in the data?	From the operational side, wrong data causes delay of loading and unloading, long queues, and additional workload for cross-system checking.	Operational Burden	Risk
YG	What risks do you see that can disturb shipment or reduce trust in the data?	This long process delays the determination of definite numbers that are used as the basis of vendor billing.	Not Integrated	Risk
YG	What risks do you see that can disturb shipment or reduce trust in the data?	If payment to the vendor is late, they can stop shipments, and that clearly hampers the achievement of company targets.	Operational Burden	Risk
YG	What risks do you see that can disturb	Finally, when data from the three systems are all different, the validation process	Not Integrated	Risk

Initial	Question	Answer	Initial Code	Theme (Root Cause/Risk)
	shipment or reduce trust in the data?	becomes very time-consuming, so operational decisions are also delayed.		
YG	What changes would help you better supervise and make decisions?	With that, the operator is not burdened with repetitive work, the field supervisor can focus on monitoring operational smoothness, and I as coordinator can more quickly make decisions based on valid data.	Repetitive Workload	Risk

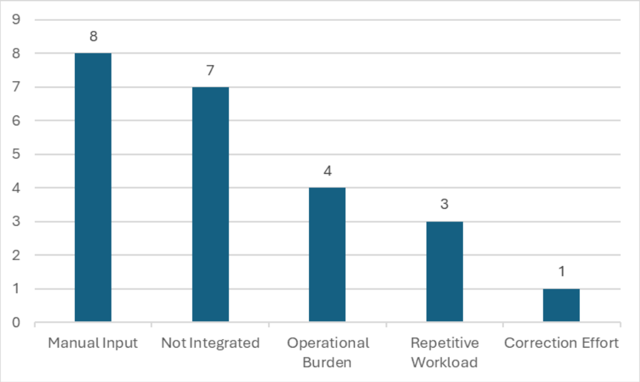


Figure 8. Distribution of Thematic Codes from Interview

Error logs further confirmed this issue. Between October 2024 and June 2025, 449 errors occurred in 69,441 transactions (0.65%). The composition of these errors is detailed in Figure 9, showing that most were revisions of DO and DT numbers.

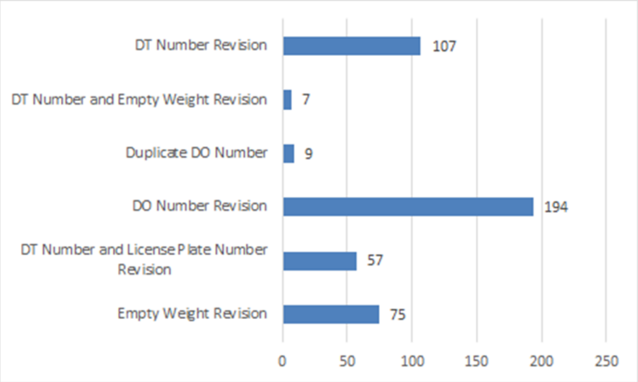


Figure 9. Types of Weighbridge Data Input Errors

Thematic coding of inaccuracy, presented in Figure 10, reinforces that manual entry and lack of integration were the primary sources.

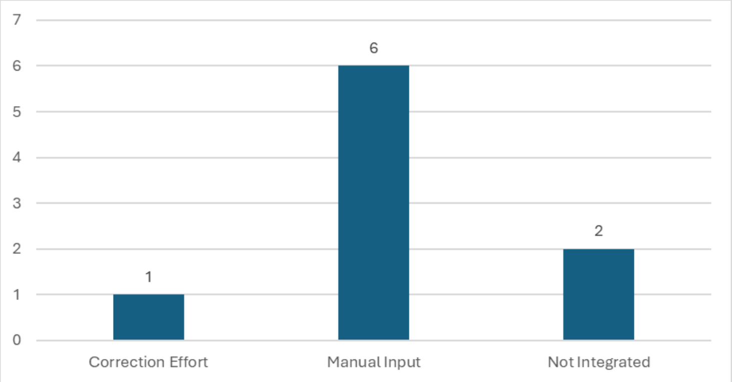


Figure 10. Thematic Code Distribution for Inaccuracy

Inefficiency was equally systemic. Observation of 50 weighing cycles showed that re-entry into IAS and EVA consumed 143 and 124 seconds respectively, compared to only 53 seconds for actual weighing. As shown in Figure 11, inefficiency codes clustered around *Manual Input*, *Repetitive Workload*, and *Operational Burden*.

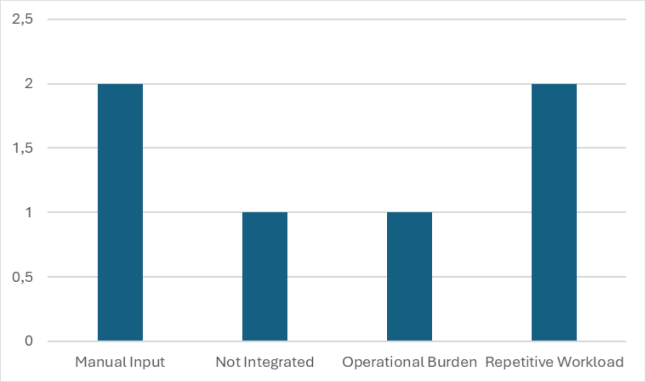


Figure 11. Thematic Code Distribution for Inefficiency

Risk Identification (RQ1 Extension)

Manual inaccuracy and fragmented systems created direct operational risks. Errors delayed unloading, triggered vendor disputes, and prolonged reconciliation. Interviews with coordinators emphasized how reconciliation sometimes took over two days, delaying billing and decision-making. These risks are systematically compared in Table 7, which demonstrates their reduction post-solution.

Table 7. Operational Risks Before and After Implementation

Risk Aspect	Before	After	Improvement
Truck detention at unloading	Frequent due to wrong DT/DO, correction needed before unloading	Eliminated (no DT/DO errors recorded)	100% reduction
Data reconciliation delays	Often >2 days due to multi-system inconsistency	Completed within hours (single source)	Processing time reduced >75%
Audit finding potential	High: 449 corrections in 9 months	Very low: only 3 minor QR-scan issues	Corrections reduced >99%
Vendor billing disputes	Occasional due to inconsistent tonnage/documents	None reported after go-live	Disputes reduced to zero

User Requirements and Technical Confirmation (RQ2)

User needs, captured via the UCD approach, prioritized automated DT/DO entry, elimination of repetitive tasks, and cross-system consistency. These are summarized in Table 8. Technical confirmation by PT XYZ and PT UVW IT teams validated that RFID and automatic DO generation were feasible, as outlined in Table 9.

Table 8. Summary of User Requirements – UCD

Initial	Focus of Requirement	Key Point
MZ	Automated entry of DT and DO data	Operator only needs to weigh and print SJB, no manual typing required.
FZ	Data validity from the outset	SJB is already correct, eliminating downstream corrections.
YG	Cross-system consistency	Data recorded in the weighbridge application is automatically transferred to other systems without additional manual entry, ensuring consistency across applications.

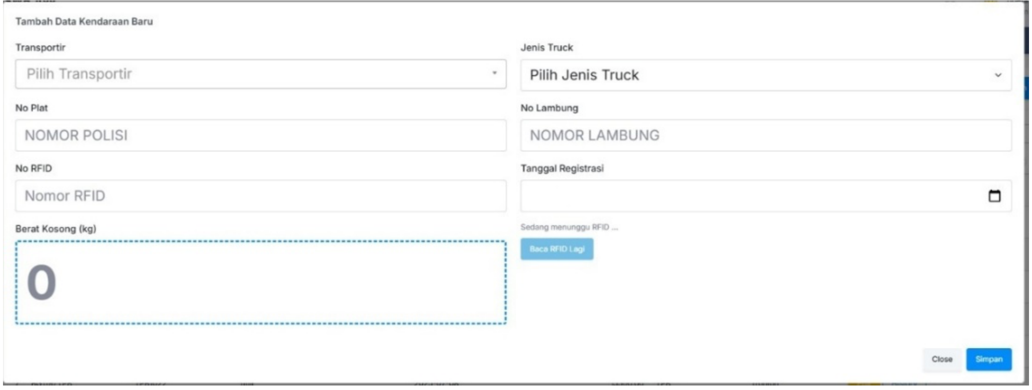
Table 9. Summary of IT Confirmation

Initial	Focus of Requirement	Key Point
AR	Input to IAS	Errors often come from re-entry. IAS can receive data from WBA, but full integration will take time due to internal processes.
RP	WBA Redesign	Web-based WBA replaces the old system. It reads trucks via RFID and generates DOs automatically, with data mirrored to EVA.

Solution Design (RQ2)

The new WBA incorporated RFID for DT recognition, automated DO generation, and SJB issuance with embedded QR codes. Figure 12 and Figure 13 show how truck identities were digitized, while Figure 14 illustrates the redesigned shipment document.

Figure 12. RFID Tag Mounted on DT Windshield


Tambah Data Kendaraan Baru

Transportir: Pilih Transportir

Jenis Truck: Pilih Jenis Truck

No Plat: NOMOR POLISI

No Lambung: NOMOR LAMBUNG

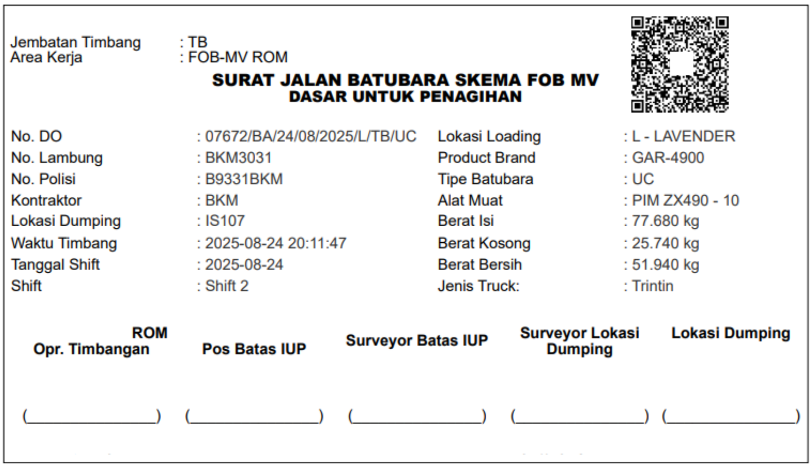
No RFID: Nomor RFID

Tanggal Registrasi:

Berat Kosong (kg): 0

Sedang menunggu RFID ...

Figure 13. DT Registration in the New WBA


Jembatan Timbang : TB
Area Kerja : FOB-MV ROM

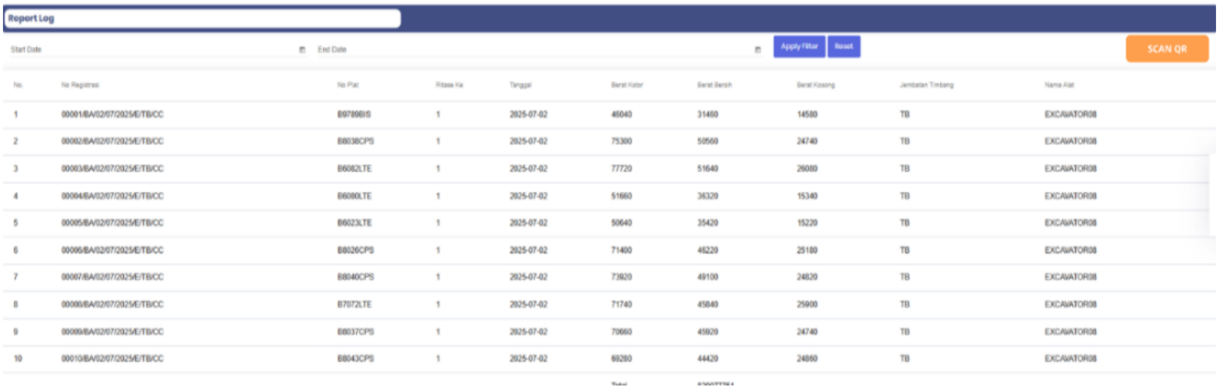
SURAT JALAN BATUBARA SKEMA FOB MV
DASAR UNTUK PENAGIHAN

No. DO	: 07672/BA/24/08/2025/L/TB/UC	Lokasi Loading	: L - LAVENDER
No. Lambung	: BKM3031	Product Brand	: GAR-4900
No. Polisi	: B9331BKM	Tipe Batubara	: UC
Kontraktor	: BKM	Alat Muat	: PIM ZX490 - 10
Lokasi Dumping	: IS107	Berat Isi	: 77.680 kg
Waktu Timbang	: 2025-08-24 20:11:47	Berat Kosong	: 25.740 kg
Tanggal Shift	: 2025-08-24	Berat Bersih	: 51.940 kg
Shift	: Shift 2	Jenis Truck:	: Trintin

ROM Opr. Timbangan	Pos Batas IUP	Surveyor Batas IUP	Surveyor Lokasi Dumping	Lokasi Dumping
(__________)	(__________)	(__________)	(__________)	(__________)

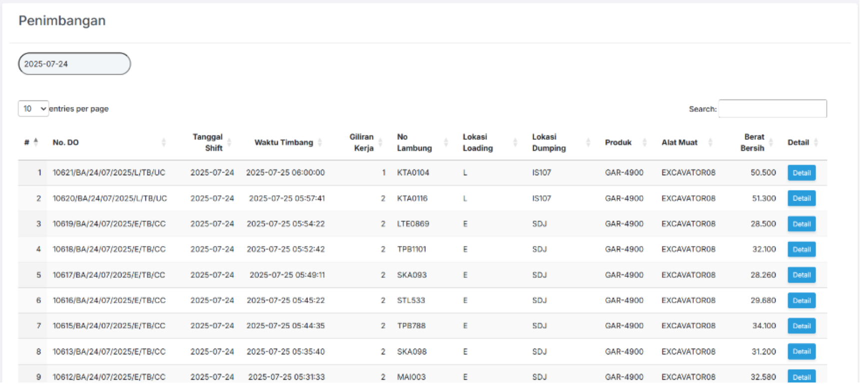
Figure 14. New SJB with QR Code

Integration ensured that SJB data could be transferred to IAS via QR scanning (Figure 15) and mirrored automatically to EVA (Figure 16). The overall transformation is depicted in Figure 17.



No.	No Registrasi	No Plat	Ritase Ke	Tanggal	Berat Kotor	Berat Bersih	Berat Kosong	Jembatan Timbang	Nama Alat
1	00001/BA/02/07/2025/E/TB/CC	B9789BIS	1	2025-07-02	46040	31460	14580	TB	EXCAVATOR08
2	00002/BA/02/07/2025/E/TB/CC	B8038CPS	1	2025-07-02	75300	50560	24740	TB	EXCAVATOR08
3	00003/BA/02/07/2025/E/TB/CC	B6082LTE	1	2025-07-02	77720	51640	26080	TB	EXCAVATOR08
4	00004/BA/02/07/2025/E/TB/CC	B6080LTE	1	2025-07-02	51660	36320	15340	TB	EXCAVATOR08
5	00005/BA/02/07/2025/E/TB/CC	B6023LTE	1	2025-07-02	50640	35420	15220	TB	EXCAVATOR08
6	00006/BA/02/07/2025/E/TB/CC	B8026CPS	1	2025-07-02	71400	46220	25180	TB	EXCAVATOR08
7	00007/BA/02/07/2025/E/TB/CC	B8040CPS	1	2025-07-02	73920	49100	24820	TB	EXCAVATOR08
8	00008/BA/02/07/2025/E/TB/CC	B7072LTE	1	2025-07-02	71740	45840	25900	TB	EXCAVATOR08
9	00009/BA/02/07/2025/E/TB/CC	B8037CPS	1	2025-07-02	70660	45920	24740	TB	EXCAVATOR08
10	00010/BA/02/07/2025/E/TB/CC	B8043CPS	1	2025-07-02	69280	44420	24860	TB	EXCAVATOR08

Figure 15. IAS Display for FOBMV Transactions



#	No. DO	Tanggal Shift	Waktu Timbang	Giliran Kerja	No Lambung	Lokasi Loading	Lokasi Dumping	Produk	Alat Muat	Berat Bersih	Detail
1	10621/BA/24/07/2025/L/TB/UC	2025-07-24	2025-07-25 06:00:00	1	KTA0104	L	IS107	GAR-4900	EXCAVATOR08	50.500	Detail
2	10620/BA/24/07/2025/L/TB/UC	2025-07-24	2025-07-25 05:57:41	2	KTA0116	L	IS107	GAR-4900	EXCAVATOR08	51.300	Detail
3	10619/BA/24/07/2025/E/TB/CC	2025-07-24	2025-07-25 05:54:22	2	LTE0869	E	SDJ	GAR-4900	EXCAVATOR08	28.500	Detail
4	10618/BA/24/07/2025/E/TB/CC	2025-07-24	2025-07-25 05:52:42	2	TPB1101	E	SDJ	GAR-4900	EXCAVATOR08	32.100	Detail
5	10617/BA/24/07/2025/E/TB/CC	2025-07-24	2025-07-25 05:49:11	2	SKA093	E	SDJ	GAR-4900	EXCAVATOR08	28.260	Detail
6	10616/BA/24/07/2025/E/TB/CC	2025-07-24	2025-07-25 05:45:22	2	STL533	E	SDJ	GAR-4900	EXCAVATOR08	29.680	Detail
7	10615/BA/24/07/2025/E/TB/CC	2025-07-24	2025-07-25 05:44:35	2	TPB788	E	SDJ	GAR-4900	EXCAVATOR08	34.100	Detail
8	10613/BA/24/07/2025/E/TB/CC	2025-07-24	2025-07-25 05:35:40	2	SKA098	E	SDJ	GAR-4900	EXCAVATOR08	31.200	Detail
9	10612/BA/24/07/2025/E/TB/CC	2025-07-24	2025-07-25 05:31:33	2	MAI003	E	SDJ	GAR-4900	EXCAVATOR08	32.580	Detail

Figure 16. EVA Display for FOBMV Transactions

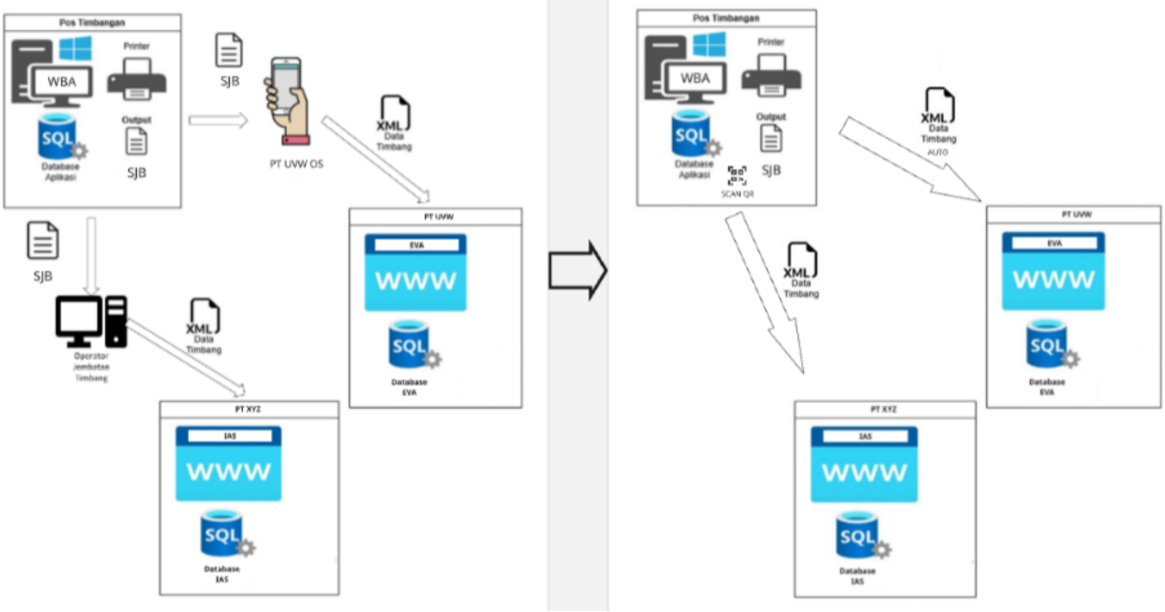


Figure 17. Architecture of WBA–IAS–EVA Before-After Integration

Implementation Plan and Evaluation (RQ3)

Deployment followed a phased plan (see Table 10), including parallel trials, debugging, and go-live by July 2025. Initial testing confirmed technical feasibility, and by August 2025, full monitoring showed significant improvements.

Table 10. Implementation Schedule

Phase / Main Activities	Period	Description
Coordination & Kick-off	Early June 2025	Coordination meeting among PT XYZ, PT UVW, operators, and supervisors to agree on implementation steps.
Development of New WBA (UVW)	June – Early July 2025	Development of a web-based WBA with RFID, automatic DO, and SJB with QR code.

Phase / Main Activities	Period	Description
Integration of IAS & EVA	June – Mid July 2025	Preparation of QR scanning in IAS and database mirroring to EVA.
Pilot Test (Dual System)	Mid July 2025	Limited pilot test by running both old and new WBA in parallel.
Inline RFID Registration of DT	Mid July 2025	Registration performed when trucks enter the weighbridge, without disrupting operations.
Debugging & Refinement	20–30 July 2025	System refinement based on pilot test results.
Go-Live Deployment	31 July 2025	Full activation of new WBA, QR scan in IAS, and mirroring to EVA.
Monitoring & Feedback	August 2025	Initial performance evaluation, measurement of accuracy, efficiency, and workload indicators.

Data Accuracy: Errors declined from 0.65% to 0.09%, as shown in Table 11.

Table 11. Error Rate After Implementation

NUMBER OF WEIGHING			ERROR	%
PERIOD	RITASE	TONAGE		
04-08-25	502	19,226.37	2	0.004
05-08-25	488	18,216.41	0	-
06-08-25	437	16,706.51	0	-
07-08-25	429	15,945.93	1	0.002
08-08-25	432	16,951.68	0	-
09-08-25	472	18,492.96	0	-
10-08-25	421	15,206.52	0	-
TOTAL	**3181**	**120,746.4**	**3**	**0.09%**
AVERAGE	**454.43**	**17,249.48**	**0**	

Efficiency: Average cycle time dropped from 407 seconds to 82 seconds, with Process Cycle Efficiency (PCE) rising from 21% to 85%. These changes are illustrated in Figure 18 and Figure 19.

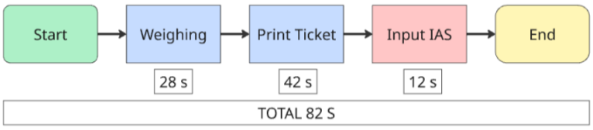


Figure 18. New Workflow of One Dump Truck Weighing Cycle

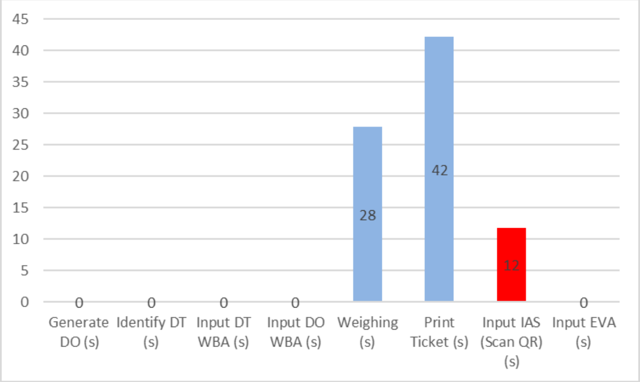


Figure 19. The Average Time per Activity in the Weighing Process After Implementation

Workload: Operator requirements fell from 2.83 FTE to 0.57 FTE, showing that one operator could handle the process with capacity to spare.

Overall Impact: Improvements are summarized in Table 12, showing an 86% reduction in error rate, fourfold efficiency improvement, and 80% workload reduction.

Table 12. Overall Improvement Ratios

Aspect	Before	After	Improvement Ratio (IR)	Interpretation
Error Rate	0.65%	0.09%	0.14	Error decreased by 86%
Process Efficiency (PCE)	21%	85%	4.05	Efficiency increased more than 4x
Workload (FTE)	2.83	0.57	0.20	Workload reduced by 80%

Discussion

The results confirm that automation and integration directly addressed the root causes of FOBMV documentation problems. RFID eliminated manual DT entry, automatic DO reduced spreadsheet dependency, and QR-coded SJB ensured traceable and consistent documentation. As a result, reconciliation delays, vendor disputes, and audit risks were almost completely eliminated (Table 13). These findings align with Lean efficiency principles (Womack, 2003) and recent evidence on RFID's impact on logistics accuracy (Ferdousmou et al., 2024). Furthermore, the adoption of a UCD approach ensured operator acceptance, reducing resistance and smoothing implementation.

Table 13. Operational Risks Before and After Implementation

Risk Aspect	Before	After	Improvement
Truck detention at unloading	Frequent due to wrong DT/DO, correction needed before unloading	Eliminated (no DT/DO errors recorded)	100% reduction
Data reconciliation delays	Often >2 days due to multi-system inconsistency	Completed within hours (single source)	Processing time reduced >75%
Audit finding potential	High: 449 corrections in 9 months	Very low: only 3 minor QR-scan issues	Corrections reduced >99%
Vendor billing disputes	Occasional due to inconsistent tonnage/documents	None reported after go-live	Disputes reduced to zero

Table 14. Comparison with Prior Literature (Pro and Cons)

Theme	This study (evidence)	Prior research evidence supporting (Pro)	Prior research evidence cautioning/limits (Cons)	Synthesis
Data accuracy	Error rate 0.65% → 0.09% after RFID + single entry	RFID reduces transaction and counting errors; integration improves info quality value	Read reliability and lifecycle costs vary by context	Gains are strongest when RFID is paired with elimination of duplicate entry and end-to-end integration. (Salehi Shahrabi, 2023)
Efficiency (PCE)	PCE 21% → 85%, cycle time 407s → 82s	LSS case studies improve PCE substantially, often double-digit	Not all lean programs reach step-change without automation	Combining lean waste removal with automation yields outsized PCE gains. (Adeodu et al., 2023; Daniyan et al., 2022)
Cross-sector automation (IoT/Mining vs Smart City)	RFID + integration reduced errors by 86%, raised PCE fourfold, and cut workload by 80%	IoT-based streetlight automation reduced manual errors and improved energy efficiency using LDR/IR sensors	Connectivity issues, sensor reliability, and installation costs may limit effectiveness	Across sectors, automation reduces manual errors and boosts efficiency, but reliability and connectivity challenges must be addressed. (Sellamuthu et al., 2022)

Theme	This study (evidence)	Prior research evidence supporting (Pro)	Prior research evidence cautioning/limits (Cons)	Synthesis
Application/System Integration for Error Reduction	Integration of RFID, weighbridge app, IAS, and EVA reduced documentation error from 0.65% to 0.09%	ERP and workflow integrations reduce manual effort, uncertainty, and errors; integrated BIM-ERP improves logistics accuracy	Implementation complexity, cost, and interoperability challenges may limit benefits	Application-level integration consistently reduces manual entry errors and improves accuracy, provided rollout is phased and supported by data cleansing (Elbir, 2025; Lu et al., 2021)
Application/System Integration for Time Efficiency	Integration of WBA, IAS, and EVA reduced cycle time from 407s to 82s (PCE increased from 21% to 85%)	DevOps test optimization with integrated prioritization reduced CI cycle times by 18–35% while maintaining fault detection and risk coverage	Minor trade-offs were observed, with up to 3% reduction in fault detection and risk coverage in some cases	Both studies demonstrate that integration significantly accelerates processes by minimizing redundant steps. While mining logistics achieved fourfold PCE improvement, DevOps integration cut CI cycle times by up to one-third, showing that integration consistently enhances time efficiency, though careful design is needed to avoid small quality trade-offs. (Marijan et al., 2018)

The comparison with prior studies highlights both alignments and distinctions. In terms of efficiency, Lean Six Sigma case studies generally reported double-digit improvements in process cycle efficiency (Adeodu et al., 2023; Daniyan et al., 2022), whereas this study achieved a fourfold increase, suggesting that the combination of automation and system integration produces greater performance gains. Regarding accuracy, the 86% reduction in documentation errors is consistent with previous findings that RFID and integration improve information quality and reduce transaction errors (Lu et al., 2021; Salehi Shahrabi, 2023). From a cross-sector perspective, IoT-based automation in smart street lighting also demonstrated reductions in manual error and efficiency gains, though connectivity and reliability issues were noted as constraints (Sellamuthu et al., 2022). Furthermore, DevOps research confirms that integration and test optimization reduced cycle times by 18–35% with only minor trade-offs in coverage (Marijan et al., 2018). Unlike those cases, however, the FOBMV implementation simultaneously improved efficiency and accuracy without measurable quality loss, reinforcing the argument that integration can deliver comprehensive improvements when designed for both process speed and data reliability.

CONCLUSION

This study examined coal shipment documentation at PT XYZ under the FOBMV method, where manual data entry and the absence of system integration caused recurring inaccuracy, inefficiency, and excessive workload. Using a User-Centered Design approach, a new system was developed with RFID-based truck recognition, automatic DO generation, and QR-coded shipment documents, positioning WBA as the single source of truth and ensuring integration with IAS and EVA. The implementation reduced error rates by 86%, improved process efficiency more than fourfold, and cut operator workload by 80%. Beyond these improvements, the solution minimized operational risks, accelerated reconciliation, and enhanced data reliability for decision-making. From a theoretical perspective, this study contributes to automation and system integration literature by providing empirical evidence from the mining logistics sector, complementing previous research in manufacturing, IoT, and DevOps. From a practical standpoint, it demonstrates that automation combined with end-to-end integration can simultaneously deliver improvements in accuracy, efficiency, and resilience, without the trade-offs often reported in other domains. Nevertheless, the findings are limited to a single case study context, which may constrain generalizability. Future studies could extend the analysis to other mining sites or different industries to validate the scalability of the proposed approach..

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