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Implementation of the PIECES Framework and the Effectiveness of the Online Weighbridge System on Road Traffic Safety through Driver Compliance

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Abstract: Over Dimension and Over Loading (ODOL) violations remain a major contributor to infrastructure degradation and traffic accidents in Indonesia, particularly in Banten Province. The Online Weighbridge System (Jembatan Timbang Online/JTO) at UPPKB Cikande was designed as a technology-based monitoring instrument to mitigate these violations. This study aims to analyze the implementation of the PIECES Framework (Performance, Information, Economics, Control, Efficiency, Service) and the effectiveness of JTO on road traffic safety, with driver compliance acting as a mediating variable. A quantitative approach was employed through a questionnaire survey of 385 freight drivers selected via purposive sampling at UPPKB Cikande, and the data were analyzed using Structural Equation Modeling–Partial Least Square (SEM-PLS) on SmartPLS. The results demonstrate that JTO effectiveness has a positive and significant impact on driver compliance (0.689) and on traffic safety (0.666); Furthermore, driver compliance significantly influences traffic safety (0.294). The PIECES Framework significantly affects both compliance (0.298) and safety (0.314), with compliance serving as a significant mediator in both pathways. The "Performance" and "efficiency" dimensions obtained the highest scores, indicating that JTO has successfully accelerated the weighing process, whereas "service" and "control" require further enhancement. The study concludes that integrating PIECES Framework with JTO operations strengthens compliance and supports safer freight transportation. It recommends the optimization of system technology, supervisory services, and consistent law enforcement to foster adaptive and data-driven transportation policies.

Keywords: PIECES Framework, Online Weighbridge, ODOL, Driver Compliance, Traffic Safety.

INTRODUCTION

Transportation is the activity of moving goods or people from a point of origin to a destination, making it a fundamental need that supports the economy and national development

(Puspawardani, 2017). To build a safe and sustainable transportation system, the government has progressively developed technology-based information systems to monitor commercial vehicles, one of which is the Motor Vehicle Weighing Implementation Unit (Unit Pelaksana Penimbangan Kendaraan Bermotor/UPPKB), commonly known as the weighbridge (Anam, 2022; Kiram et al., 2022). Compliance with load capacity, vehicle dimensions, and road class requirements is mandatory for drivers and freight companies, as mandated by Law Number 22 of 2009 on Road Traffic and Transportation.

Banten Province is characterized by high freight traffic density, due to its strategic position as a logistics corridor connecting industrial estates and seaports. According to Indonesian Traffic Police (Korlantas Polri) data, 1,682 traffic accidents were recorded in Banten Province in 2023, with the highest concentration in Greater Tangerang. Data from the National Criminal Information Center further indicates that 454,543 vehicles were involved in accidents nationwide, dominated by motorcycles (76%), followed by minibuses, medium trucks, and pickup vehicles. The Ministry of Public Works and Public Housing (PUPR, 2024) emphasizes that without addressing ODOL violations, maintaining the 541,217 km national road network remains a challenge, ODOL induced damage increases road maintenance costs by approximately IDR 43.45 trillion per year.

Over Dimension and Over Loading (ODOL) vehicles are highly susceptible to causing accidents because they exceed road capacity, compromise vehicle stability, and extend braking distances. Furthermore, ODOL accelerates infrastructure deterioration and disrupts traffic flow. UPPKB Cikande, situated on National Road Section 003.1 (Serang City - Tangerang Regency boundary), occupies a strategic position to monitor freight vehicles bound for the Cikande Industrial Estate, the Modern Cikande Industrial Estate (MCIE), and the Bojonegara and Merak seaports. However, several operational issues persist, including limited information technology, a shortage of supervisory personnel, and the suboptimal digitization of data recording.

To address these challenges, the Directorate General of Land Transportation developed the Online Weighbridge System (Jembatan Timbang Online/JTO), which integrates Weight in Motion (WIM) sensors, CCTV, electronic gates, and supporting systems such as BLU-E (Electronic Pass Certificate), E-Manifest, and E-Tilang (Purnomo, 2023). Nevertheless, prior studies report inconsistent findings regarding JTO effectiveness and its impact on traffic safety. To evaluate the system comprehensively, this study adopts the PIECES Framework, which encompasses six dimensions Performance, Information, Economics, Control, Efficiency, and Service and has been widely recognized model for measuring the effectiveness of public-sector information systems and services (Ariadi et al., 2021; Pangri et al., 2021; Rachmawati et al., 2024).

Based on this background, the study aims to: (1) analyze the impact of the PIECES Framework on driver compliance and traffic safety; (2) analyze the effectiveness of JTO on driver compliance and traffic safety; (3) examine the effect of driver compliance on traffic safety; and (4) test the mediating role of driver compliance in the relationship between the PIECES Framework, JTO effectiveness, and traffic safety within the supervisory area of UPPKB Cikande.

METHOD

Research Approach and Design

This study employs a quantitative approach using a survey technique through questionnaires. This design was selected to statistically test the relationships between latent variables and produce generalizable findings. The research is explanatory in nature, designed to elucidate the influence of the PIECES framework and JTO effectiveness on traffic safety, as mediated by driver compliance.

Research Location and Time

The research was conducted at UPPKB Cikande, located at Jalan Raya Cikande KM 66, Cikande Sub-district, Serang Regency, Banten Province. As the westernmost weighbridge facility on Java Island, it serves as a critical node connecting industrial estates and major seaports. Data collection took place from 7 to 9 July 2025, focusing on peak freight traffic hours of 06:00–09:00 and 15:00–18:00 local time.

Population and Sampling Technique

The population consists of all freight drivers utilizing the JTO system at UPPKB Cikande, with the exact size unknown. The sample size was determined using the Lemeshow formula at a 95% confidence level (Z = 1.96), an estimated proportion of 0.5, and a margin of error of 5%, resulting in 385 respondents. Purposive sampling was applied, targeting drivers who underwent the weighing process during the study period.

Variables and Indicators

This study uses four main variables: (1) the PIECES Framework as an independent variable, formed by six indicators (P1–P6) representing performance, information, economics, control, efficiency, and service; (2) JTO Effectiveness as an independent variable, measured by five indicators (E1–E5); (3) Driver Compliance as a mediating variable, measured by six indicators (KP1–KP6); and (4) Traffic Safety as the dependent variable, measured by six indicators (KS1–KS6). All indicators were measured using a five-point Likert scale.

Data Collection Techniques

Data were collected using three techniques. First, field observation was conducted to identify the most influential PIECES indicators in the operations of UPPKB Cikande. Second, questionnaires were distributed directly to drivers at the entry gate of UPPKB and collected before they exited the facility, with the process documented. Third, a literature review was conducted using regulations, official reports, and relevant academic publications.

Data Analysis Techniques

Data were analyzed using Structural Equation Modeling–Partial Least Square (SEM-PLS) with SmartPLS software. The analysis was carried out in two stages. First, outer model evaluation was performed to assess indicator validity and reliability through convergent validity (loading factor > 0.5), Average Variance Extracted (AVE > 0.5), Fornell-Larcker Criterion, cross loading, Composite Reliability (CR > 0.7), and Cronbach's Alpha (> 0.6). Second, inner model evaluation involved R-Square, Goodness of Fit, Q-Square, and Variance Inflation Factor (VIF) assessments. Hypothesis testing was conducted through bootstrapping, with acceptance criteria of t-statistic > 1.96 and p-value < 0.05.

RESULT AND DISCUSSION

Respondent Profile

Of the 385 respondents collected, 100% were male, reflecting the male-dominated nature of the freight driver profession. In terms of occupation, 97.92% of respondents were drivers, 0.52% were freight company owners, and 1.56% reported other occupations. The dominant age group was 37–46 years (74.55%), followed by 25–36 years (25.45%), indicating that the majority of drivers are in productive age ranges with relatively mature driving experience.

Outer Model Evaluation

Convergent validity testing confirmed that all indicators had loading factor values above 0.5 and were therefore declared valid, with outer loadings ranging from 0.552–0.922 for

PIECES, 0.609–0.976 for Effectiveness, 0.687–0.964 for Compliance, and 0.910–0.958 for Safety. The cross-loading analysis further confirmed satisfactory discriminant validity at the indicator level. As summarized in Table 1, AVE values for all latent variables exceeded the 0.5 threshold, while Composite Reliability values were all above 0.7 and Cronbach's Alpha values were above 0.6, confirming both convergent validity and the reliability of all constructs.

Table 1. Construct Reliability and Convergent Validity

Variable	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
PIECES Framework	0.792	0.840	0.501
JTO Effectiveness	0.919	0.950	0.769
Driver Compliance	0.910	0.939	0.699
Traffic Safety	0.973	0.975	0.882

Source: Primary data processed (2025).

The Fornell-Larcker Criterion in Table 2 confirms discriminant validity, as the square root of AVE for each construct (diagonal values, in bold) is greater than its correlations with the other constructs.

Table 2. Discriminant Validity (Fornell-Larcker Criterion)

	Effectiveness	Compliance	Safety	PIECES
Effectiveness	**0.877**			
Compliance	0.963	**0.836**		
Safety	0.955	0.952	**0.939**	
PIECES Framework	0.921	−0.932	0.927	**0.708**

Source: Primary data processed (2025).

Inner Model Evaluation

Inner model evaluation showed strong predictive capability of the model. The R-Square values for compliance (0.942) and safety (0.932) indicate that the exogenous variables explain 94.1% and 93.2% of the variance in the endogenous constructs, respectively. The Q^2-Square values of 0.940 (compliance) and 0.925 (safety) confirm large predictive relevance, both exceeding the 0.35 threshold. The Goodness of Fit (GoF) value reached 0.798, classified as a strong model fit. All Variance Inflation Factor (VIF) values fell below 5, indicating no multicollinearity, and the SRMR value of 0.096 below the 0.10 threshold demonstrates an acceptable model fit.

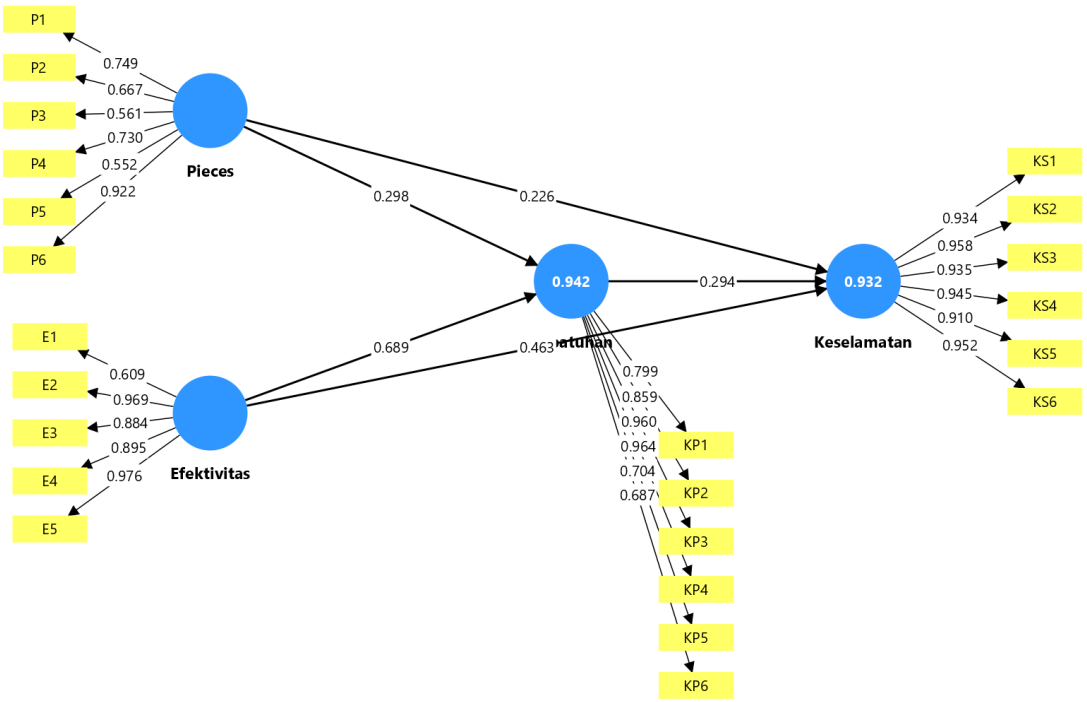

Figure 1. Graphical Output PLS-Sem
Source: Primary data processed (2025).

Hypothesis Testing Results

Bootstrapping results in SmartPLS revealed that all seven research hypotheses were accepted, as summarized in Table 3. JTO effectiveness has a positive and significant effect on driver compliance (β = 0.689, t = 16.978, p = 0.000) and on traffic safety (β = 0.666, t = 10.416, p = 0.000). Driver compliance has a positive and significant effect on traffic safety (β = 0.294, t = 3.664, p = 0.000). The PIECES Framework has a positive and significant effect on driver compliance (β = 0.298, t = 7.094, p = 0.000) and on traffic safety (β = 0.314, t = 4.927, p = 0.000). The mediation analysis confirms that driver compliance significantly mediates the effect of JTO effectiveness on traffic safety (β = 0.203, t = 3.674, p = 0.000) and the effect of the PIECES Framework on traffic safety (β = 0.088, t = 3.059, p = 0.002).

Table 3. Hypothesis Testing Results (Direct and Indirect Effects)

Path	Original Sample (O)	Std. Deviation (STDEV)	T-Statistics (|O/STDEV|)	P-Values	Result
Effectiveness → Compliance	0.689	0.041	16.978	0.000	Accepted
Effectiveness → Safety	0.666	0.064	10.416	0.000	Accepted
Compliance → Safety	0.294	0.080	3.664	0.000	Accepted
PIECES → Compliance	0.298	0.042	7.094	0.000	Accepted
PIECES → Safety	0.314	0.064	4.927	0.000	Accepted
Effectiveness → Compliance → Safety	0.203	0.055	3.674	0.000	Accepted
PIECES → Compliance → Safety	0.088	0.029	3.059	0.002	Accepted

Source: Primary data processed (2025).

Discussion

The impact of JTO effectiveness on driver compliance, at 68.9%, is the strongest pathway in the model. This suggests that process speed, the accuracy of the data, the clarity of procedures, and the reliability of the technology are key factors driving compliance with cargo regulations. This finding aligns with Sutrisno (2018) and Hidayat et al. (2021), who emphasize that effective and well-structured work procedures increase user compliance with applicable rules.

JTO effectiveness also exerts a direct effect on traffic safety of 66.6%. When the system functions optimally, every freight vehicle is properly controlled within its prescribed load limits, reducing accident risks caused by overloading, suboptimal braking, or unroadworthy vehicles. This result is consistent with Karlinda et al. (2021) and Widianto et al. (2021), who confirm that effective systems minimize accident risk and create safer operational conditions.

Driver compliance contributes 29.4% to traffic safety. Although smaller than the effect of system effectiveness, compliance remains a critical factor because compliant drivers fulfill their weighing obligations, keep loads within permitted limits, and operate vehicles meeting safety standards. This finding is in line with Rahayu and Santosa (2021), who explain that compliance with standard operating procedures is directly related to lower accident risk.

The PIECES Framework affects compliance (29.8%) and safety (31.4%). The control dimension reduces opportunities for cargo manipulation, the efficiency dimension accelerates the weighing process without disrupting delivery schedules, the information dimension ensures transparency of weighing results, and the service dimension provides convenience for drivers. These findings reinforce the work of Rachmawati et al. (2024) and Ariadi et al. (2021), demonstrating that good PIECES Framework governance improves both user discipline and the performance of public-sector systems.

The indirect effects through compliance show that driver compliance functions as a mediating variable, strengthening the relationship between JTO effectiveness and traffic safety (20.3%) as well as between the PIECES Framework and traffic safety (8.8%). This confirms that traffic safety cannot be achieved solely through a well-functioning system, but also through cultivating a culture of compliance among drivers. Yuliana et al. (2022) emphasize that compliance reinforces the link between system effectiveness and safety, making the integration of technology and behavior a prerequisite for successful transportation policy.

Overall, the performance and efficiency dimensions received the highest scores, confirming that JTO has accelerated the weighing process and simplified work procedures. In contrast, the service and control dimensions still require improvement, particularly in service quality, technical support response time, sensor accuracy in detecting violations, and consistency of law enforcement. The GAP analysis across the six PIECES dimensions further reveals that actual conditions do not yet fully meet ideal conditions, making optimization in these areas a priority for further improvement.

CONCLUSION

Based on the SEM-PLS analysis of 385 freight driver respondents at UPPKB Cikande, this study concludes that the effectiveness of the Online Weighbridge System (JTO) has a positive and significant effect on driver compliance (68.9%) and on traffic safety (66.6%). Driver compliance significantly influences traffic safety (29.4%), while the implementation of the PIECES Framework significantly affects compliance (29.8%) and safety (31.4%). Driver compliance is also confirmed as a significant mediating variable in the relationship between JTO effectiveness, the PIECES Framework, and traffic safety. These findings emphasize that the success of JTO in supporting traffic safety depends not only on technology but also on the formation of a culture of compliance among drivers, achieved through system management based on the six PIECES Framework dimensions. The performance and efficiency dimensions

are the main strengths of JTO, while the service and control dimensions still need improvement, particularly in service quality, technical support, and consistent law enforcement.

In light of these findings, several recommendations are proposed. First, JTO operators should optimize the system to be more accurate, transparent, and tamper-resistant through real-time monitoring, big-data integration, and full connectivity to the central database of the Directorate General of Land Transportation. Second, human resources should be strengthened through recruitment, rotation, and routine training based on certified equipment competencies, enabling officers to operate ODOL supervision technologies independently. Third, fines for ODOL violations should be revised to be more proportional to the road damage and accident impact they generate, accompanied by consistent legal follow-up. Fourth, the government should run continuous education and outreach programs targeting logistics associations, freight companies, and drivers regarding the dangers and economic consequences of ODOL practices. Fifth, cross-sector collaboration is needed among the Ministry of Transportation, the National Police, the Ministry of Public Works, driver associations, and academic institutions, both for joint supervision and evidence-based policymaking. Future researchers are encouraged to expand the study to other UPPKB sites, incorporate moderating variables such as the characteristics of freight companies, or develop a longitudinal model to observe changes in compliance and safety over time.

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