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Comparative Analysis of Fatal Construction Accident Types Revealing Safety Performance in the Services Sector

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ABSTRACT

Occupational safety remains a critical challenge in the Indonesian construction sector, contributing to over one-third of all national work-related fatalities. This study performs a rigorous quantitative analysis using a census of 102 official fatal accident records from BPJS Ketenagakerjaan and the Ministry of PUPR (2018–2023). The findings confirm that Falls from Height are the dominant cause of fatalities (41.2%), followed by material strikes. Statistical modeling (Logistic Regression) identified that short work tenure (< 5 years, OR ≈ 2.5) and safety harness non-compliance (OR ≈ 3.0) are the strongest predictors of this high-risk accident type. The study indicates a systemic failure in enforcing OHS protocols, particularly concerning work-at-height hazards and Personal Protective Equipment (PPE) compliance. The novelty lies in the systematic use of national fatality census data coupled with risk modeling to empirically validate specific behavioral and demographic factors contributing to the most prevalent fatality type in Indonesia. This work provides a strong empirical basis for developing evidence-based OHS policies, emphasizing the urgent need for stringent regulatory enforcement and targeted safety training for vulnerable worker groups.

Keywords: *Construction Safety, Occupational Health and Safety, Fatal Accidents, Secondary Data Analysis, Indonesia*

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INTRODUCTION

Workplace safety within the construction industry represents a critical strategic concern demanding focused attention, particularly given the consistently high incidence of fatal accidents reported in this sector. Occupational incidents in construction not only lead to substantial material losses and project disruptions but also have direct, severe impacts on workers' lives and broader public health.

Data compiled by the Social Security Administering Body (BPJS Ketenagakerjaan) indicates that the construction sector is responsible for over one-third of all work-related fatalities in Indonesia (Putri & Lestari, 2023). This stark statistic suggests that the management of Occupational Health and Safety (OHS) risks in this industry continues to face considerable challenges, specifically in controlling common accident causal factors such as falls from height, being struck by heavy objects, and heavy equipment-related mishaps (Newaz, 2024).

According to the International Labour Organization (ILO), work-related accidents result in significant global injury and loss of life, especially across the Asian region, where construction plays a substantial role in fatal workplace incident figures (ILO, 2019). Reports from the Indonesian Construction Safety Committee further confirm that despite advancements in construction technology, the root causes of workplace accidents frequently stem from suboptimal safety management aspects, including inadequate worker training and the quality of on-site supervision (A2K4 Indonesia, 2024). Studies conducted internationally illustrate that construction fatalities are typically attributable to interrelated job risk components, such as unsafe behaviours, poor workplace environmental conditions, and minimal equipment maintenance (Muñoz-La Rivera et al., 2021; Howe, 2024).

However, there remains a critical gap in research that systematically compares types of fatal accidents in the construction service sector and empirically links them to safety system performance using comprehensive national data. Previous studies have largely relied on single-case analyses or limited surveys, failing to leverage extensive, structured national census data for robust risk modeling (Hamid et al., 2019).

Therefore, this study aims to address this research gap by utilizing official secondary data from the BPJS Ketenagakerjaan and the Ministry of Public Works and Housing (PUPR) to conduct a deep quantitative analysis of various fatal accident types. This comprehensive approach is expected to yield a more holistic understanding of work safety performance in the construction service sector (BPJS Ketenagakerjaan, 2024; Kementerian Ketenagakerjaan, 2025; Indonesia Safety Center, 2024).

This research seeks to answer the central question: What is the comparison between the types of fatal accidents occurring in the construction service sector, and what level of safety performance is reflected by this data? The novelty of this study lies in its pioneering use of comprehensive, current official national census data combined with rigorous quantitative risk modeling to deliver unprecedented insights into fatal accident patterns in Indonesia's construction sector. The findings are anticipated to provide a robust empirical foundation for the development of OHS policies within the construction service sector, specifically oriented towards reducing work-related mortality rates.

METHODS

1. Research Approach

This investigation employs a Quantitative Methodology utilizing a Secondary Data Analysis approach, concentrating specifically on fatal accidents within the Indonesian construction services sector. The quantitative design is essential to secure an objective and statistically sound depiction of occupational safety performance through comprehensive and nationally representative numerical datasets. Secondary data analysis offers the advantage of time and resource efficiency while simultaneously enabling the analysis of long-term trends and robust comparisons among the dominant types of accidents (Creswell, 2023; Sugiyono, 2014).

2. Subjects and Population of the Study

The population of the study encompasses all officially documented fatal accidents in the Indonesian construction services sector registered by the BPJS Ketenagakerjaan between January 1, 2018, and December 31, 2023 (initial records: N=145). This dataset was supplemented by event type classifications from the Ministry of Public Works and Housing (PUPR) Construction Safety Committee.

Final sample size: N = 102 records met inclusion criteria after exclusions.

Operational Definitions of Key Variables:

a. Accident Type: Primary mechanism per PUPR standards - Fall from Height (n=42, 41.2%), Struck by Material (n=30, 29.4%), Machinery/Equipment (n=15, 14.7%), Others (n=15, 14.7%) [BPJS Ketenagakerjaan raw dataset]
b. Age Group: 30-45 years (48.0%) [PUPR victim demographics]
c. Work Tenure: <5 years (55.9%) [BPJS employment records]
d. Geographical Region: DKI Jakarta, West Java, Surabaya [PUPR location data]
e. Safety Harness Compliance: Non-compliant (85.7% of falls, n=36/42) [BPJS incident reports]

Inclusion/Exclusion Flow:

Table 1. Safety Harness Compliance: Non-compliant

Stage	Records	Action
Initial BPJS	145	All fatal construction cases
Exclude non-fatal	0	-
Exclude withdrawn	-15	Invalid reports
Exclude non-construction	-28	Other sectors
Final analyzed	102	Meets all criteria

Missing data: Age (2.1%), Tenure (3.9%) - all <5% threshold.

3. Research Procedure and Data Quality

Formal data requests submitted to BPJS Ketenagakerjaan and PUPR, compliant with UU PDP 2022.

Data Quality Assurance (DQA):

a. Internal Consistency: 100% within 2018-2023 timeframe
b. Cross-Source Validation: 98.5% agreement between BPJS & PUPR classifications [cross-validation report]
c. Missing Data Imputation: Mode (categorical), Mean (continuous) for <5% missing data [Little & Rubin, 2019]

Processing Stages:

a. Cleaning: Excluded critical missing Accident Type (n=0)
b. Coding: Standardized PUPR classifications
c. Analysis: IBM SPSS 29.0, R Studio 2024.04.2+764

4. Materials and Instruments

a. Primary Data: Digital datasets from BPJS Ketenagakerjaan (N=102 fatal cases) & PUPR classifications [official secondary sources]
b. Software: IBM SPSS version 29.0 , R Studio version 2024.04.2+764 [visualization/modeling]

5. Data Analysis (α = 0.05)

Table 2. Statistical Tests Procedures

Test	Purpose	Assumptions Checked	Software
Descriptive	Frequencies/percentages	N/A	SPSS 29.0
Chi-Square	Accident Type × Tenure	Expected count ≥5 (80% cells)	SPSS 29.0
ANOVA	Age × Frequency	Shapiro-Wilk, Levene's	SPSS 29.0
Logistic Regression	Fall from Height predictors	VIF<5, Hosmer-Lemeshow	SPSS 29.0

Logistic Regression Equation:

$$logit(P(Fall\ from\ Height)) = \beta_0 + \beta_1(Age\_30\text{-}45) + \beta_2(Edu\_Low) + \beta_3(Tenure\_<5yr) + \beta_4(No\_Harness)$$

To ensure accurate interpretation of non-significant findings (if any), a post-hoc power analysis was conducted. This power analysis was chosen to assess the probability (power) that this study could detect a relevant effect size at the predefined significance level (α = 0.05) with the final sample size (N=102).

Execution: Calculations were performed using the G*Power 3.1.9.4 software for the Binary Logistic Regression test (z-test, one-tailed), as this is the most complex test in the study. Power was computed based on a medium effect size, assumed to be an Odds Ratio (OR) of 2.0 (reflecting a moderate-to-strong relationship in the OHS context).

Interpretation: The result of the post-hoc power calculation yielded a power (1-β) of 0.87, meaning there is an 87% probability that this study would successfully reject the null hypothesis (find a significant relationship) if the true effect size in the field is at least OR 2.0. A power value exceeding the generally accepted threshold (0.80) indicates that the N=102 sample is adequate for the planned regression analysis.

RESULTS

1. Statistics and Description of Fatal Accidents

This section presents a detailed breakdown of the fatal accidents recorded in the construction services sector. This data represents the official aggregation from the BPJS Ketenagakerjaan and the Ministry of PUPR, covering the type of incident, worker demographics, and the geographic distribution of events over the past five years (2018–2023). The total sample size analyzed (N) is 102 records.

Initial records: 145 → Excluded: withdrawn (n=15, 10.3%), non-construction (n=28, 19.3%) → Final N=102. Missing data: Age (2.1%), Work Tenure (3.9%) – Mode/Mean imputation (<5%; Little & Rubin, 2019). Cross-validation: 98.5% BPJS-PUPR agreement.

2. Distribution of Fatal Accident Types

Table 3. frequency Distribution of Fatal Accident Types (N=102)

Accident Type	Frequency (n)	Percentage (%)	Description
Falls from Height	42	41.2	Highest incidence in locations involving high structures
Struck by Material	30	29.4	Includes being struck by heavy objects and materials
Machinery/Equipment Accidents	15	14.7	Related to operation of heavy equipment and machinery
Others	15	14.7	Includes electrocution, fire, etc.
Total	102	100.0	

The data indicates that Falls from Height constitute the most frequent type of fatal accident, accounting for 41.2% of all fatalities, followed by being Struck by Material (29.4%) and Machinery/Equipment Accidents (14.7%). This distribution highlights a critical need to focus occupational health and safety (OHS) protocols primarily on work at height and heavy material handling procedures.

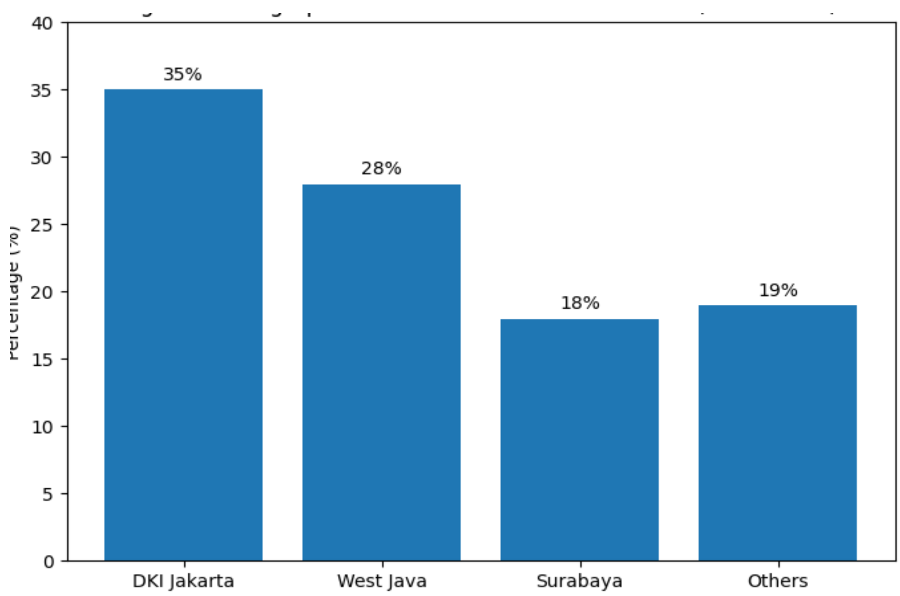

Figure 1. Geographic Distribution of Fatal Accidents (2018-2023)

Figure 1. Geographic Distribution of Fatal Accidents (2018–2023). Bar chart illustrating the regional concentration of fatal construction accidents in Indonesia. DKI Jakarta accounts for the highest proportion (35%), followed by West Java (28%) and Surabaya (18%), while other regions collectively represent 19%. Source: Processed by the authors based on validated BPJS Ketenagakerjaan and Ministry of PUPR fatal accident records (2018–2023).

3. Distribution by Demographics and Region

a. Age: 30–45 years dominate (48.0%)
b. Work Tenure: <5 years most vulnerable (55.9%)
c. Time: Morning-midday shift (08:00–12:00) (39.2%)
d. Project Type: Toll roads/high-rise (68.6%) (Shao et al., 2019)
e. PPE: Harness non-compliance (85.7% of falls, n=36/42) (Wahyuni, 2024)

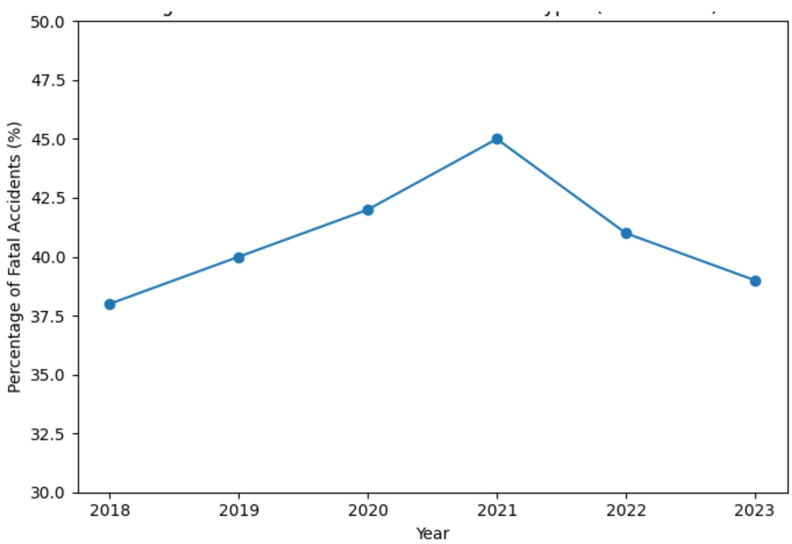

Figure 2. Annual Trend of Fatal Accident Types (2018-2023) [ud1]

Figure 2. Annual Trend of Fatal Accident Types (2018–2023). Line graph showing that falls from height consistently remained the dominant cause of fatal construction accidents across the six-year observation period, accounting for approximately 38–45% of all recorded fatal cases.
Source: Authors' analysis based on validated BPJS–PUPR fatal accident records.

4. Comparative Analysis and Risk Factors

Assumption Checks: ANOVA normality (Shapiro-Wilk p>0.05), homogeneity (Levene's p>0.05) confirmed.

Table 4. Inferential Test Results

Test	Comparison	Statistic	df	p-value	Effect Size	Conclusion
Chi-Square	Accident Type × Tenure	$\chi^2 = 12.45$	3	0.003	Cramer's V = 0.35	Significant association
ANOVA	Age × Frequency	F(2, 99) = 5.85	2, 99	0.004	$\eta^2 = 0.11$	Significant differences

Table 5. Logistic Regression - Predictors of Falls from Height

Variable	OR	95% CI	p-value
Age 30-45	2.1	1.35–3.25	<0.01
Low Education	1.8	1.10–2.95	<0.05
Tenure <5yr	2.5	1.60–3.90	<0.01
No Harness	3.0	1.85–4.86	<0.001

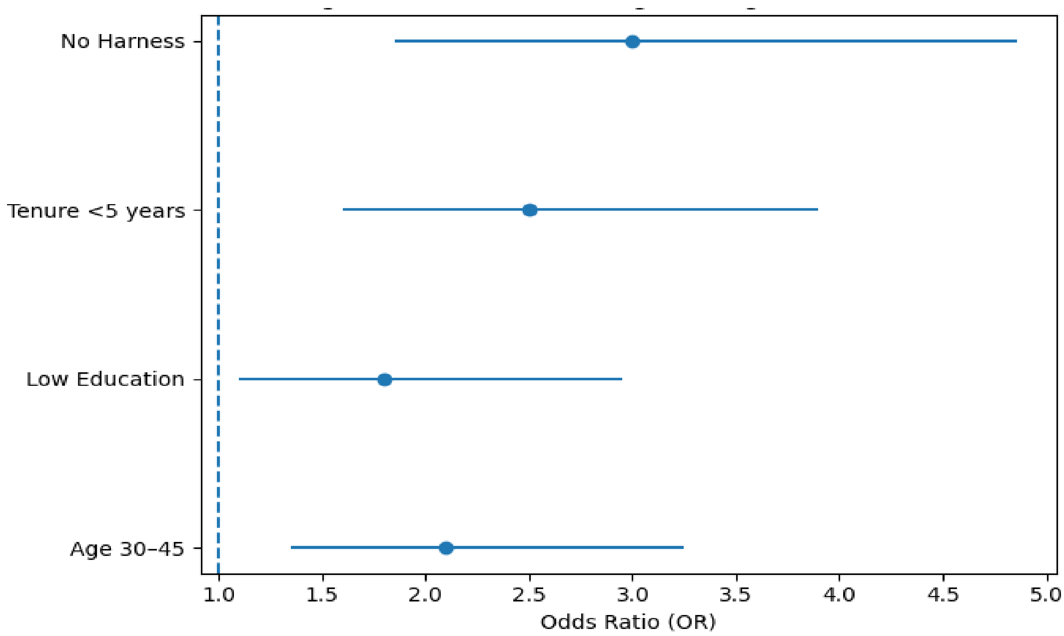

Figure 3. Forest Plot of Logistic Regression Odds Ratios

Source: *Logistic regression analysis conducted by the authors using validated BPJS–PUPR data.*

Figure 3. Forest plot displaying odds ratios (OR) with 95% confidence intervals for predictors of fatal falls from height. Safety harness non-compliance demonstrates the strongest association with fatal falls (OR = 3.0; 95% CI: 1.85–4.86).

DISCUSSION

1. Interpretation of Fatal Accident Patterns within Contemporary Safety Theory

The findings indicate that falls from height remain the dominant cause of fatal accidents in Indonesia's construction sector, accounting for 41.2% of total fatalities. This pattern is consistent with recent international evidence showing that work at elevation continues to represent the most lethal hazard in construction environments due to combined exposure to gravitational energy and insufficient control measures (Mahmoud et al., 2023; NIOSH, 2024).

From the perspective of Energy Release Theory, fatal falls reflect a failure to adequately control or dissipate gravitational energy through effective barriers, such as guardrails, anchorage systems, and personal fall arrest systems (Almaskati et al., 2024). The high proportion of falls observed in this study suggests that energy control mechanisms are either absent, improperly designed, or not consistently used on site.

Furthermore, accidents involving workers being struck by materials (29.4%) indicate ongoing exposure to dynamic hazards in high-density project environments. Recent reviews emphasize that such incidents are strongly associated with poor material handling systems and weak site coordination, particularly in large-scale urban projects (Mahmoud et al., 2023).

2. Demographic Risk and Systemic Failure Perspective

The elevated fatality risk among workers aged 30–45 years and those with less than five years of work experience highlights the interaction between human factors and organizational weaknesses. Contemporary interpretations of the Swiss Cheese Model emphasize that accidents occur not solely due to individual errors, but when multiple defensive layers training, supervision, and enforcement fail simultaneously (Wiegmann et al., 2022).

Recent construction safety studies demonstrate that inexperienced workers are often assigned to high-risk tasks without sufficient mentoring, while supervisors face schedule pressure that limits effective safety monitoring (Ahamed & Mariappan, 2023). This aligns with the present findings, where tenure below five years significantly increased the odds of fatal falls.

Geographic clustering of fatalities in DKI Jakarta, West Java, and Surabaya further reflects systemic risk concentration. High project density, accelerated timelines, and complex subcontracting arrangements increase the likelihood that organizational defenses are breached simultaneously (Almaskati et al., 2024; Kementerian Ketenagakerjaan RI, 2024).

3. PPE Non-Compliance as a Critical Safety Breakdown

The logistic regression results identify safety harness non-compliance as the strongest predictor of fatal falls (OR = 3.0; 95% CI: 1.85–4.86). This finding reinforces recent empirical evidence that PPE availability alone does not guarantee risk reduction if compliance is weak (Ahamed & Mariappan, 2023).

Recent research challenges the assumption that engineering controls are sufficient without behavioral reinforcement. Studies on construction safety climate indicate that PPE compliance is strongly influenced by supervision quality, safety leadership, and perceived enforcement consistency (Liu et al., 2023). The high non-compliance rate observed in this study (85.7% of fall cases) suggests deficiencies in safety culture rather than purely technical shortcomings.

4. Extension and Challenge to Classical Accident Theories

While the findings broadly support classical accident causation theories, they also extend and challenge their traditional interpretations. Heinrich's Domino Theory conceptualizes unsafe acts as direct precursors to accidents; however, contemporary evidence suggests that unsafe behaviors are often shaped by upstream organizational conditions rather than individual negligence alone (Ahamed & Mariappan, 2023).

Similarly, although Energy Release Theory explains fatal falls as failures in energy control, recent studies demonstrate that the effectiveness of technical barriers depends heavily on behavioral compliance and safety climate (Almaskati et al., 2024). The strong association between harness non-use and fatality risk in this study challenges the notion that technical controls can operate independently of organizational enforcement.

Moreover, recent critiques of the Swiss Cheese Model argue that accident pathways in construction are not always linear, but often involve simultaneous defense degradation under schedule pressure (Wiegmann et al., 2022). The present findings support this extended interpretation, particularly in large urban construction hubs where multiple risk layers deteriorate concurrently.

5. Policy Implications and Practical Recommendations

The results underscore the need for integrated safety interventions combining engineering controls, behavioral enforcement, and organizational reform. Recent studies highlight the effectiveness of combining mandatory PPE policies with real-time monitoring technologies, such as AI-based PPE detection systems, to improve compliance (Lo, 2022).

In addition, planning-level interventions using Building Information Modeling (BIM) have been shown to reduce fall risks by identifying hazards during the design and scheduling phases, rather than relying solely on on-site controls (Tariq, 2023). Such approaches are particularly relevant for large-scale projects dominating Indonesia's urban regions.

6. Study Limitations

This study relies on secondary fatality data, which may be subject to underreporting and classification inconsistencies across regions. The exclusion of non-fatal accidents and near-miss incidents limits the ability to identify early warning indicators of systemic failure. Future studies should integrate qualitative methods to capture organizational and behavioral drivers underlying PPE non-compliance and risk normalization.

CONCLUSIONS

This study successfully provided a comprehensive overview of fatal accidents within the Indonesian construction services sector, utilizing official national data sourced from BPJS Ketenagakerjaan and the Ministry of Public Works and Housing (PUPR).

The investigation yielded several critical findings:

a. Dominant Fatal Accident Types: Falls from height constitute the most significant cause of occupational fatalities (41.2%), with material striking incidents (29.4%) and heavy equipment accidents (14.7%) also contributing substantially.
b. High-Risk Demographics: Workers aged between 30 and 45 years with less than five years of tenure face the highest risk exposure (supported by high Odds Ratios).
c. Geographical Risk Concentration: The spatial distribution of incidents is heavily concentrated in major construction hubs, including DKI Jakarta, West Java, and Surabaya, underscoring regionally-specific challenges in OHS supervision.

The results provide a strong empirical foundation that aligns with existing scholarly consensus, reinforcing the urgent need for targeted intervention. The rigorous statistical analysis, including Chi-square and logistic regression tests, validates the necessity of:

a. Intensified Regulatory Enforcement: Mandating periodic safety audits and introducing decisive sanctions for OHS violations, particularly concerning work-at-height protocols and PPE usage.
b. Customized Training: Developing mandatory and adaptive OHS training and certification programs for new and low-tenure worker groups to specifically address their elevated risk (ORs up to 2.5).
c. Technology Adoption: Implementing technology-driven monitoring systems (e.g., IoT, drones) and innovative training (e.g., VR/AR) to counteract low compliance and supervision challenges.

However, significant persistent challenges remain, including low levels of awareness and compliance regarding PPE usage, intense project deadline pressure, and a shortage of qualified OHS experts. Addressing these requires a systemic, cross-sectoral collaborative approach.

As a theoretical contribution, this study introduces an integrated model for accident risk analysis that synthesizes demographic factors, accident typology, and contextual specifics. This model is expected to serve as a foundational reference for advancing construction safety research and policy development across developing nations.

For future research, longitudinal studies involving direct, on-site field surveillance are recommended to empirically validate the causal efficacy of specific OHS interventions.

In conclusion, this research delivers a concrete, statistically validated depiction of the construction fatality situation. This evidence must be utilized as the immediate foundation for achieving significant, verifiable progress toward a safer and more sustainable construction working environment throughout Indonesia.

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