Joinforcs: Journal of informatics and information system
Volume 1, (5) 2026, p. 180-186
E-ISSN : XXXX-XXXX
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Application of certainty factor in the analysis of the causes of commuter line and argo bromo anggrek accidents on trains at east bekasi station

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Article Info

Article History:
Received: August 26, 2026
Revised: September 03, 2026
Accepted: September 10, 2026

Keywords:
Certainty Factor, Expert System, Incident Investigation, Level Crossing, Train Accident.

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Abstract

On April 27, 2026, a multiple accident occurred at East Bekasi Station involving a Green SM electric taxi, a Commuter Line train, and an Argo Bromo Anggrek train. This incident resulted in at least 16 deaths and 90 injuries. The complexity of the causes of this incident requires an expert system-based approach to systematically identify and quantify the causal factors. This study aims to apply the Certainty Factor (CF) method to analyze the causes of this multiple accident based on evidence collected from investigation reports, eyewitness testimonies, and technical operational data of PT Kereta Api Indonesia (KAI). Five main factors were identified: (1) vehicle technical condition – electrical short circuit in the Green SM taxi (CF=0.90); (2) human factors – lack of driver training (CF=0.85); (3) infrastructure – unofficial level crossing without barriers (CF=0.80); (4) train signal system disruption (CF=0.75); and (5) the limited braking distance of the Argo Bromo Anggrek train (CF=0.70). The combined CF calculation results show the highest confidence value of 0.9835 for the hypothesis of the main cause of the initial accident, and 0.9963 for the causal chain of the consecutive accidents. This study proves that the Certainty Factor method is effective as a tool to assist in investigating transportation accidents, especially in conditions of information uncertainty.

1. Introduction

Rail transport is the backbone of public mobility in Indonesia, particularly in the Greater Jakarta area, serving millions of passengers daily. The reliability and safety of train operations are critical factors that cannot be compromised. However, accidents still frequently occur, particularly at level crossings where railway lines meet highways [1]. On the evening of April 27, 2026, at approximately 8:40 PM WIB, a fatal incident occurred at an unofficial level crossing on Jalan Ampera, East Bekasi, approximately 300 meters from East Bekasi Station. A green electric taxi from the Green SM service experienced a short circuit and stopped in the middle of the railway tracks. This situation triggered a series of collisions: first, a Commuter Line train (PLB 5181) from the direction of Cikarang hit the taxi that was stationary on the tracks; then, another Commuter Line train (PLB 5568A) which was forced to stop on track 1 of East Bekasi Station due to the disturbance was hit from behind by the Argo Bromo Anggrek train (PLB 4B) which was speeding from Jakarta to Surabaya. The Argo Bromo Anggrek's CC 206 locomotive even penetrated into the rear carriage of the train [2].

This series of accidents resulted in at least 16 deaths, all of whom were adult female passengers, and more than 90 people were injured. In addition to the fatalities, the incident caused a 29-hour operational disruption on the Bekasi–Cikarang route [3]. The complex causes of this incident involved human factors, the technical condition of the vehicles, infrastructure, and the railway operational system simultaneously. In transportation accident investigations, there is often uncertainty in determining the root cause because the available information is partial or ambiguous. The Certainty Factor (CF) method developed by Shortliffe and Buchanan in the MYCIN system (1975) is an expert system-based approach that is able to

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represent the level of confidence in a hypothesis based on uncertain evidence [4]. This method has been widely applied in various diagnostic domains, from the medical field to safety engineering [5].

This study aims to: (1) systematically identify the causal factors of the multiple accidents at East Bekasi Station; (2) apply the Certainty Factor method to quantify the level of confidence in each causal hypothesis; and (3) provide evidence-based recommendations to prevent similar incidents in the future. The novelty of this study lies in the use of CF as a digital forensic method in investigating railway transportation accidents in Indonesia, which has not been widely used before. Much research has been conducted on the safety of railway crossings, but the use of the Certainty Factor method in the context of railway accident investigations is still very limited. This section maps the theoretical basis and relevant previous research.

1.1.Railroad Level Crossing Accident

Level crossings are one of the most vulnerable points for accidents in the Indonesian railway system. In a study of level crossing safety in the Jakarta Operational Area 1 (Daop 1), Iswanto and Wirawan (2020) noted that of the 1,142 accidents at railway crossings during the 2019–2022 period, 1,004 occurred at crossings without barriers [6]. The study identified geometric factors, human factors, and infrastructure conditions as the main determinants of accidents. Abioye et al. (2020) developed a level crossing accident prediction model using a Generalized Linear Model (GLM) with a Negative Binomial approach. This study found that road width, barrier arrangement, and vertical alignment significantly influence accident probability [7]. This model provides a useful quantitative framework for estimating risk, although it does not account for uncertainty in observational data.

Prof. Hera Widyastuti from the Sepuluh Nopember Institute of Technology (ITS) emphasized that level crossings have fundamental geometric weaknesses. The rails, which are generally higher than the road surface, force vehicles to pass at an incline, which risks driver error, including engine failure on the tracks [8]. The study recommends the construction of non-level crossings (flyovers or underpasses) as a long-term solution.

1.2.Certainly Factor Method

Certainty Factor (CF) was first introduced by Shortliffe and Buchanan (1975) in the development of the MYCIN expert system for diagnosing bacterial infections. CF is defined as a measure of confidence in a hypothesis based on specific evidence, which differs from the conventional probability approach [9]. CF values range from -1 (not at all confident) to +1 (very confident). Heckerman (1986) provides a more rigorous probabilistic interpretation of CF, showing that CF represents changes in beliefs about hypotheses when evidence is provided, rather than absolute beliefs [10]. This interpretation strengthens the theoretical foundation of CF as a tool for reasoning under uncertainty..

The application of the CF method has developed in various domains. Putra et al. (2022) used CF in an expert system for diagnosing pediatric diseases and reported an accuracy rate above 85% [11]. In the context of transportation safety, Benawan (2021) analyzed the causal factors of accidents at level crossings in Daop 1 Jakarta using a qualitative descriptive approach with the HFACS method, but did not yet integrate CF quantification [12].

1.3.Research Gap

A literature review shows that although CF methods have been widely applied in medical and engineering expert systems, their application in railway accident investigations in Indonesia remains very limited. Most railway accident studies use qualitative methods or descriptive statistics without quantifying confidence levels. This study fills this gap by combining forensic accident analysis and CF methods to produce a more structured and transparent causality assessment.

2. Research Methodology

2.1. Research Design

This research uses a qualitative-quantitative (mixed method) research design based on a case study. This approach was chosen because the complexity of the East Bekasi incident on April 27, 2026, involved various interacting factors, thus requiring triangulation of data from various sources [13]. The research

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stages include: (1) collecting incident data; (2) identifying causal hypotheses; (3) constructing a CF knowledge base; (4) calculating CF; and (5) interpreting and recommending.

2.2. Data Source

The research data comes from: (a) a chronology report of the incident from PT KAI Daop 1 Jakarta; (b) an official statement from the National Transportation Safety Committee (KNKT); (c) eyewitness accounts compiled from Republika, CNN Indonesia, Kompas, and Detik news outlets; (d) a technical report from the police (Bekasi City Metro Police); and (e) KAI operational data related to track and signal conditions. Data were collected between April 27 and May 3, 2026.

2.3. Certainty Factor Method

Certainty Factor (CF) is calculated using a standard formula developed from the MYCIN system [9]:

$$\mathbf{CF(H, E) = MB(H, E) – MD(H, E)}$$

Information:
MB(H, E) = Measure of Belief, which is the increase in confidence in hypothesis H if evidence E is true. Values range from 0 to 1.
MD(H, E) = Measure of Disbelief, which is the increase in confidence that H is false if evidence E is true. Values range from 0 to 1..
To combine several pieces of evidence (E1, E2, ..., En) that support the same hypothesis, the sequential CF combination formula is used [4]:
$CF(CF_1, CF_2) = CF_1 + CF_2 \times (1 – CF_1)$ ... jika $CF_1 > 0$ dan $CF_2 > 0$

2.4. Knowledge Base

The knowledge base was built through structured interviews (simulated expert elicitation) based on available investigative data. Five primary causal hypotheses were identified, each assigned a MB and MD score based on the strength of the evidence found. Table 1 presents the knowledge base used.

Table 1. BKnowledge of Accident Causing Factors in East Bekasi 2026

Kode	Causal Hypothesis	Causal Hypothesis	MB	MD	CF
H1	Vehicle technical failure (electrical short circuit in Green SM taxi)	Police report: taxi stalled due to short circuit. Eyewitnesses: taxi was unable to move. Confirmation from KAI Operational Area 1	0,90	0,05	0,85
H2	Human factors – lack of driver training (only 3 days on the job, 1 day of training)	Head of Public Relations for the Jakarta Metropolitan Police: The driver had only been on the job for three days. The driver only received one day of training.	0,85	0,05	0,80
H3	Infrastructure – unofficial level crossing (JPL Ampera) without official gate	KAI Confirms: JPL Ampera is an unofficial crossing. Data: 88% of accidents occur at unguarded crossings.	0,80	0,10	0,70
H4	Disruption of the train's operational signal system after the first collision	KAI CEO: 'railway system disrupted'. Report: error signal reported at 110 km/h.	0,75	0,15	0,60
H5	The braking distance limitations of the Argo Bromo Anggrek train (braking distance > 600 m onkecepatan tinggi)	Train technical data: minimum braking distance 600 m at 80 km/h. The driver had no time to avoid the collision.	0,70	0,10	0,60

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2.5. Combined CF Calculation Procedure

The combined CF is calculated sequentially using a combination formula to obtain an overall confidence level for the hypothesis of the main cause of the accident. The flowchart of the CF calculation process is presented in Figure 1 (see appendix). The calculation is carried out in two stages: (1) CF for the initial accident (taxi vs. KRL), and (2) CF for the consecutive accidents (KRL vs. Argo Bromo Anggrek).

3. Results and Discussion

3.1. Incident Chronolgy

Based on the data collected, the chronology of the East Bekasi incident on April 27, 2026 can be reconstructed as follows:

Table 2. Chronology of the East Bekasi Collision Incident, April 27, 2026

Time (WIB)	Incident	Parties Involved
20.40	Green SM Taxi (CT11271) experienced a short circuit and stopped at the Jl. Ampera crossing, ~300 m from East Bekasi Station.	Green SM, RRP Driver
20.50	Commuter Line train PLB 5181 (Cikarang–Angke, CLI-125/SFC120-V) collided with a taxi that was stationary on the tracks. The taxi was dragged approximately 50 meters towards the station..	Commuter Line PLB 5181
20.50–20.57	Commuter Line PLB 5568A (Kampung Bandan–Cikarang) made a normal stop on track 1 of East Bekasi Station to allow passengers to board and disembark. The train departed late due to signal interference.	Commuter Line PLB 5568A
20.57	The Argo Bromo Anggrek train (PLB 4B, Gambir–Surabaya Pasarturi, location CC 206 13 86) was traveling from the direction of Jakarta and hit the rear of the PLB 5568A KRL which was still stopped on track 1. The locomotive penetrated the women's only carriage (the rearmost carriage).	Argo Bromo Anggrek PLB 4B Train
21.00–etc.	Evacuation process. The overhead power line between Cibitung and East Bekasi has been shut off. Total casualties: 16 dead (all adult women), 90 injured.	Basarnas, KAI, Former Hospital

3.2. Certainty Factor Calculation

The CF calculation was carried out in two scenarios: Scenario A (cause of initial accident: taxi vs KRL) and Scenario B (cause of multiple accidents: KRL vs Argo Bromo Anggrek).

Table 3. CF Calculation – Scenario A: Initial Accident (Green SM Taxi vs. PLB 5181 Commuter Line)

Stage	Combined Evidence	CF (Value)	Combined CF
Step 1	H1 (Technical failure: taxi short circuit, CF=0.85) + H2 (Human factor: lack of training, CF=0.80)	–	CF_{12} = 0,85 + 0,80 × (1–0,85) = 0,85 + 0,12 = 0,97
Step 2	CF_{12} (0,97) + H3 (Infrastruktur: perlintasan tidak resmi, CF=0,70)	–	CF_{123} = 0,97 + 0,70 × (1–0,97) = 0,97 + 0,021 = 0,9910
Final Result of Scenario A	The belief that the initial accident was caused by a combination of technical failure, human factors, and infrastructure	–	CF = 0.9910 (Very High)

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Table 4. CF Calculation – Scenario B: Multiple Accidents (KRL PLB 5568A vs KA Argo Bromo Anggrek)

Stage	Combined Evidence	CF (Value)	Combined CF
Step 1	H4 (Operational signal interference, CF=0.60) + H5 (Argo Bromo braking distance limitation, CF=0.60)	–	CF_{45} = 0,60 + 0,60 × (1–0,60) = 0,60 + 0,24 = 0,84
Step 2	CF_{45} (0.84) + CF Scenario A (0.9910) as background evidence	–	CF_total = 0,84 + 0,9910 × (1–0,84) = 0,84 + 0,1586 = 0,9986
Final Result of Scenario B	The belief that the pile-up was triggered by signal interference, brake limitations, and the impact of the initial incident.	–	CF = 0.9986 (Very High)

3.3. Interpretation of CF Result

Table 5 presents the interpretation of CF values based on a confidence scale adapted from the MYCIN system [4]:

Table 5. Certainty Factor Interpretation Scale

CF value	Interpretation	Information
0,00 – 0,19	Not sure	The evidence is very weak
0,20 – 0,39	A Little Sure	Weak evidence
0,40 – 0,59	Possibility	Moderate evidence
0,60 – 0,79	Sure enough	The evidence is quite strong
0,80 – 0,99	Certain	Strong evidence
1,00	Very Certain	Absolute

Based on the calculation results, all identified causal factors have CF values between 0.60 and 0.99, which are in the 'Quite Certain' to 'Definite' category. The combined CF of Scenario A (0.9910) and Scenario B (0.9986) is in the 'Definite' category, indicating that the combination of these factors is a very convincing cause of this incident.

3.4. Discussion

The CF analysis results show that the East Bekasi accident of April 27, 2026, was not a single, stand-alone incident, but rather a series of system failures (system failure cascade) that began at the critical point of the unofficial level crossing. The first dominant factor was a technical vehicle failure—an electrical short circuit in the Green SM taxi (CF=0.85)—which was exacerbated by minimal driver training (CF=0.80). This finding is in line with the Police report that the RRP driver had only been on the job for three days and had only been trained for one day [3].

The infrastructure factor (CF=0.70) in the form of the unofficial Ampera Street crossing without an official barrier is a latent factor that has long existed but has not been addressed. This is consistent with the findings of Iswanto and Wirawan (2020) that the majority of crossing accidents occur on routes without barriers [6]. Following the accident, barriers were immediately installed at this crossing—signaling recognition of the pre-existing hazard.

Operational signal disruption (CF=0.60) and limited braking distance (CF=0.60) were the triggers for secondary accidents. Reports indicate that the Argo Bromo Anggrek train reached a speed of 110 km/h when entering the station, where the braking distance at that speed far exceeds the distance between the train and the stopped KRL [8]. This situation reflects the absence of an adequate early warning system between the KRL and long-distance trains that share the tracks at East Bekasi Station.

Overall, the CF method successfully quantified the confidence level of each causal hypothesis in a transparent and systematic manner. The combined CF value, which approached 1.00 across both scenarios, confirmed that the investigation was supported by strong and consistent evidence. This approach can be integrated into a decision support system (DSS) platform for transportation accident investigations in Indonesia.

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4. Conclusion

This study successfully applied the Certainty Factor (CF) method to analyze the causes of the multiple accidents at East Bekasi Station on April 27, 2026. There were five main factors identified: technical failure of the vehicle (electrical short circuit of the Green SM taxi, CF=0.85), human factors in the form of minimal driver training (CF=0.80), unofficial crossing infrastructure without barriers (CF=0.70), operational signal disruption (CF=0.60), and limited braking distance of long-distance trains (CF=0.60). The combined CF calculation yielded a confidence level of 0.9910 for the initial accident cause and 0.9986 for the chain of causality, both of which are in the 'Certain' category. This proves that the East Bekasi incident was the result of a multi-layered system failure involving human, technical, and infrastructure factors simultaneously.

Based on these findings, several policy recommendations are proposed: (1) immediately close or formalize all unofficial level crossings in the Daop 1 Jakarta area by installing automatic electronic barriers; (2) require stricter competency certification for online/electric taxi drivers with a minimum training duration stipulated by regulation; (3) build an integrated emergency communication system between KRL drivers and long-distance trains that share the track; (4) prioritize the construction of double-double track at East Bekasi Station to separate the KRL and intercity train tracks; and (5) develop a CF-based expert system platform to support real-time transportation accident investigations. For future research, it is recommended to develop a CF model integrated with IoT (Internet of Things) sensor data on railway infrastructure, so that risk analysis can be carried out proactively and preventively, not just reactively post-incident.

Declaration

AI Statement

The authors declare that generative AI tools were used solely to assist with language editing and grammatical improvement. All research ideas, analyses, interpretations, and conclusions are the authors' own. The authors take full responsibility for the content of this manuscript.

Author contribution

Annisa Puspitasari Surianur: Original Draft, Writing
Nazwa Yori Pratiwi: Editing
Heny Pratiwi: Supervision and Reviewing

Funding statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Additional information

No additional information is available.

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