Crowd Understanding in Railway Station using Video Analytics and Hybrid Belief Rule Base

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***Abstract*— Crowd management in public places, such as railway stations, is critical to ensuring the security, safety, and convenience of passengers. Crowd control includes managing crowd density, crowd flow, and crowd evacuation. The aim of crowd control is to prevent fatalities caused by overcrowding. While CCTV technology has frequently been utilized to monitor crowds at train stations, CCTV monitoring by officers is perceived as less effective due to the human aspect, as individuals quickly become bored and exhausted while performing repetitive tasks. Integrating video analytics techniques into the CCTV system can help evaluate density in specific areas, but further data processing and analysis are required to create an evaluation index that can aid decision-making and reduce the likelihood of overcrowding. This study employs a hybrid belief rule-based approach to process individual counting data obtained from video analytics into a safety and security index. The primary contribution of this study is the utilization of people counting data from video analytics, train schedule data, and event data as attributes of the Hybrid Belief Rule Base. Using the Bandung train station as an example, these three characteristics are believed to influence the crowd quantity in public areas.**

Keywords—Crowd understanding, hybrid belief rule base, safety, and video analytics.

I. Introduction

One of the most important public spaces in cities is railway stations. Railway stations serve as hubs of activity and movement in several nations. The Transit Oriented Development (TOD) concept, which many nations have embraced, enhances the function of railway stations as hubs of urban activity and commerce. Consequently, railway stations need to enhance their safety and security services. The Station Design Strategy issued by Network Rail in 2018 [1] highlights the importance of security and safety in improving the quality of railway station services.

Evaluations of security and safety quality involve the examination of potential safety risks. These risks are identified by analyzing incident reports that threaten security and safety. The causal factors are studied, modeled, and then subjected to a scientific risk analysis for security and safety at railway stations [2]. An assessment of the level of security and safety in a train station area can reveal multiple potential events or indicators that may threaten the safety and security of visitors, including train departure and arrival schedules, changes in passenger flow, and events such as national holidays. These three factors were selected due to their potential to create crowds. Crowd management is a control process implemented to prevent fatalities resulting from crowded situations [3]. Crowd understanding in public facilities like train stations plays a crucial role in managing crowd density, mass flow, and mass evacuation.

Several factors need to be considered in crowd management, including detecting potential threats [4], feedback control [5], designing the layout and managing the flow of human movement [6], and segregating the crowd into specific clusters to reduce density [7]. The most utilized tools for collecting crowd data are CCTV, cell phone signals, and trespassing sensors. CCTV devices serve as surveillance media to monitor all activities related to crowds, while analytical CCTV aims to serve as monitoring control[8] to detect and prevent potential fatalities in crowd control. This is an advantage of CCTV compared to telephone signals or trespassing sensors. Researchers have shown a keen interest in using CCTV video analysis to comprehend crowd behavior. Studies by [9] and [10] focused on estimating visitor numbers using CCTV analytics technology in public areas.

Video analytics techniques can be integrated into the CCTV module to assess density in a specific area, but further data processing analysis is required to generate an evaluation index that can assist in decision-making and decrease the likelihood of crowding. This study employs a hybrid belief rule-based approach to process individual counting data obtained from video analytics into a safety and security index. The main contribution of this study is the utilization of people counting data from video analytics, train schedule data, and event data as attributes of the Hybrid Belief Rule Base. Using the Bandung train station as an example, these three characteristics impact the quantity of crowds in public areas.

The upcoming chapter will cover topics such as crowd comprehension, video analytics for people counting, safety and security measures, and the concept of hybrid belief rule-based systems.

II. Methodology

A. Crowd Understanding

Crowd understanding involves comprehending and extracting information from crowd data within a particular area It can be utilized for various purposes, including economic, social, urban planning, safety, and security analysis, etc. Currently, CCTV is widely used to observe crowd behavior in specific areas. However, since CCTV merely presents monitoring videos without providing feedback to managers, researchers have developed various video analytics techniques to enhance crowd understanding. Currently, CCTV is widely employed for observing crowd behavior in specific areas. Nevertheless, since CCTV merely presents monitoring videos without providing feedback to managers, researchers have been prompted to develop various video analytics techniques for comprehending crowds. Techniques associated with crowd understanding encompass crowd segmentation, crowd counting, crowd tracking, and crowd behavior analysis [11].

B. Crowd Counting using Video Analytics

Crowd counting is crucial for developing video surveillance and traffic control applications. Crowd counting plays a role in monitoring the system [3]. Crowd counting, which is people counting, can be classified into two categories depending on the purpose of use. First, a calculation that counts the number of people in a specific area. The second is people counting, which counts the number of people passing through a door or hallway [12]. This research applies the first category to crowd counting: counting the number of people in a specific area at the Bandung train station.

C. Safety and Security

According to [13], safety is a condition free from unacceptable risks or dangers and protects the system's environment. Meanwhile, security can be defined as being free from danger or threat and protecting the system from the environment. Safety can also be defined as the property of a system that avoids harming people or the surrounding environment [14], [15] states that the term safety indicates the possibility of being involved in an accident, while security refers to the possibility of becoming a victim of an accident. Safety is more related to preventing accidents (Accidents) by identifying potential threats (Hazards) and then implementing appropriate mitigation to reduce the risks associated with threats to a tolerable level. Meanwhile, security prevents violations by identifying potential threats and implementing appropriate controls to reduce risks.

This study uses three factors that cause crowds: the number of people, train schedules, and events. If the number of people is significant, many trains schedules transit at the station, and during holidays, the station's condition will become very unsafe and insecure. For this reason, this condition must be avoided.

D. Hybrid Belief Rule Based

Hybrid belief rule-based is a method for assessing the level of security and safety [16] based on the factors that cause crowds at stations. Using a hybrid approach, these factors are operated using a combination of AND (conjunction) and OR (disjunction) logical operators, which show the relationship between these factors and their impact on the safety and security index. For example, the conditions that must be avoided, as mentioned above, can be formulated as the following notation (1).

IF (people counting is high) AND (schedule is high) AND (event is high) THEN safety is low, security is low (1)

Hybrid rules consist of various attribute groups where each attribute group is correlated with each other on different assumptions, but attributes in the same attribute group can be correlated with each other with the same assumptions. The hybrid rule formulation can be formed as follows:

$$R_k = if\left(\left(x_1\ is\ A_1^k\right) \vee \left(x_2\ is\ A_2^k\right)\right) \wedge \ldots\ldots \wedge \left(\left(x_{M-1}\ is\ A_{M-1}^k\right) \vee \left(x_M\ is\ A_M^k\right)\right),\ Then\{(D_1, \beta_{1,k}), \ldots, (D_N, \beta_{N,k})\}\ with\ rule\ weight\ \theta_k, attribute\ weight\ \delta_m \quad (2)$$

The inference approach in hybrid BRB consists of four stages: matching degree calculations for single attributes, matching degree calculations for hybrid patterns, weight calculations, integration using Evidential Reasoning (ER), and utility calculations.

III. DEVELOPING SAFE AND SECURE RULES

A. Define Hybrid Belief Rule-Based Attribute

Three attributes will be used in this research, namely People Counting, Schedules, and Events, with indicator criteria for each attribute per 10 minutes as shown in Table 1 below:

Table 1. Attributes and reference value

No.	Attributes	Reference	Value per 10 Minutes
1.	*People counting*	*Low*	0 - 30 people
		Medium	35 – 64 people
		High	≥ 65 people
2.	Schedule	*Low*	0 – 2 schedules
		Medium	3 – 4 schedules
		High	≥ 5 schedules
3.	*Event*	*Low*	0 – 2 events
		Medium	3 – 5 events
		High	≥ 6 events

This indicator may vary at each station. In this research, we used a case study at the Bandung station.

B. Generate Rules

This step is part of implementing the hybrid BRB pattern. Defining attribute patterns is carried out to map possible conditions for each attribute and possible relationships between attributes. At this stage, the rules formed consist of a combination of conjunction and disjunction. We determined several combinations of rules with the **People counting AND (Schedule OR Event)** formulation as in table 2 below.

Table 2. Attribute rules.

No	*People Counting*	*AND*	Schedule	*OR*	*Event*
1.	*Low*	$\wedge$	*Low*	$\vee$	*Low*
2.	*Medium*	$\wedge$	*Low*	$\vee$	*Low*
3.	*High*	$\wedge$	*Low*	$\vee$	*Low*
4.	*Low*	$\wedge$	*Medium*	$\vee$	*Medium*
5.	*Medium*	$\wedge$	*Medium*	$\vee$	*Medium*
6.	*High*	$\wedge$	*Medium*	$\vee$	*Medium*
7.	*Low*	$\wedge$	*High*	$\vee$	*High*
8.	*Medium*	$\wedge$	*High*	$\vee$	*High*
9.	*High*	$\wedge$	*High*	$\vee$	*High*
10.	*Low*	$\wedge$	*Low*	$\vee$	*Medium*
11.	*Medium*	$\wedge$	*Low*	$\vee$	*Medium*
12.	*High*	$\wedge$	*Low*	$\vee$	*Medium*
13.	*Low*	$\wedge$	*Medium*	$\vee$	*Low*
14.	*Medium*	$\wedge$	*Medium*	$\vee$	*Low*
15.	*High*	$\wedge$	*Medium*	$\vee$	*Low*
16.	*Low*	$\wedge$	*Low*	$\vee$	*High*

No	*People Counting*	*AND*	Schedule	*OR*	*Event*
17.	*Medium*	∧	*Low*	∨	*High*
18.	*High*	∧	*Low*	∨	*High*
19.	*Low*	∧	*Medium*	∨	*High*
20.	*Medium*	∧	*Medium*	∨	*High*
21.	*High*	∧	*Medium*	∨	*High*
22.	*Low*	∧	*High*	∨	*Low*
23.	*Medium*	∧	*High*	∨	*Low*
24.	*High*	∧	*High*	∨	*Low*
25.	*Low*	∧	*High*	∨	*Medium*
26.	*Medium*	∧	*High*	∨	*Medium*
27.	*High*	∧	*High*	∨	*Medium*

Table 2 defines the rules that will be used with conjunction, implication, and disjunction, and each attribute consists of three types of reference values: Low, Medium, and High. Based on this table, in this study, the δ value for each attribute is assumed to be 1, while the θ value for the rule will also be assumed to be 1.

C. *Inferencing*

This step is part of implementing the hybrid BRB pattern. This research uses three reference values, as shown in Table 1. These reference values are then formulated into rules consisting of conjunction patterns, disjunction patterns or a combination of both. The rule pattern for implementing hybrid BRB is shown in notation (2). The result of this stage is the belief degree value. The belief degree is a quantity with a range of 0 to 1, representing the degree of confidence in the system's safety and security index values. The belief degree value of the safety and security index, which gets closer to 1, is believed to be the accurate index.

IV. Experimental Result

A. *Scenario*

In this research, we used a case study at the Bandung station. We choose one of the areas in Bandung Station, as illustrated in Figure 1. This location was chosen because it is a traffic area for people entering and exiting the train. Aside from that, this area features various food court counters, which can lead to long lines. We use a CNN-based people counting algorithm to determine the number of persons going through this location [17]. Every 10 minutes, the data generated by the people counting algorithm is pooled. Data collection was carried out at peak hours between 13.00-17.00 local time and was a national holiday. This timing was picked since there are several trains arriving and departing at once.

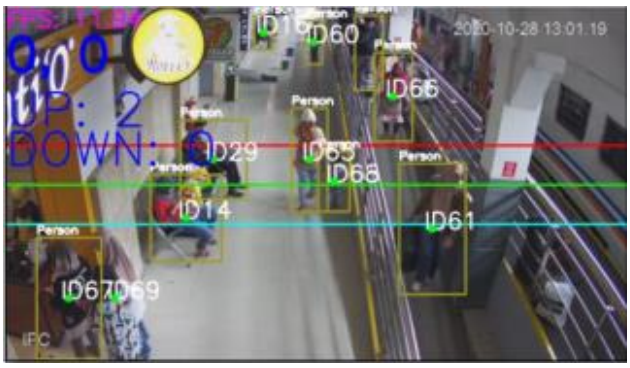

Figure 1. Camera position.

When collecting data, the camera position is positioned perpendicular to the top to allow for more precise capture and identification of people counting, as illustrated in Figure 1 above.

B. *Data Collection*

The data used in this research were taken from CCTV cameras at the Bandung train station in the southbound lane area. 124 safety and security incidents were captured at this location from 27-31 October 2020. The number of incidents based on aggregate data can be seen in the following graph, Figure 2:

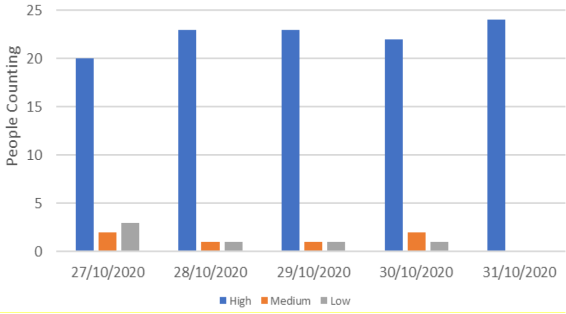

Figure 2. People counting data from 27-31 October 2020.

Figure 2 shows the number of people counting, which indicates safety and security incidents. This data shows that people counting was at a high level for five consecutive days, especially on October 31, 2020. The train schedule and events data did not vary in indicating safety and security events on that day. The train schedule is at a low level, and the event is at a medium level.

C. *Result*

The results of this research are in the form of an assessment index for safety and security to understand crowd understanding based on each rule formed. Figure 3 shows that the belief degree in the south entrance lane area has a β value for the low safety index, namely 0.01% to 0.85%, the medium safety index is in the value range of 0.07% to 0.24%, the safety index high has a value of 0.09% to 0.77%. Meanwhile, the belief degree for the low-security index is in the range of 0.16% from to 0.85%, the medium-security index has a belief value of between 0.09% to 0.24%, and the high-security index is in the range of values between 0.04% to 0.73%.

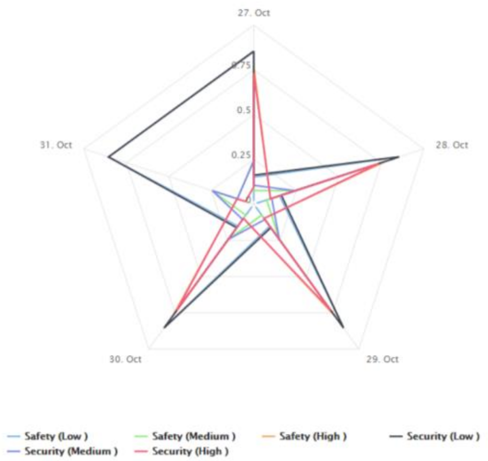

Figure 3. Safety and security index

In the last nine time periods, the safety index visualization results show that the low category has quite varied values, with the lowest value reaching 0.70% and the highest value being 0.77%. On the other hand, the high category also shows a similar range of values, namely in the range of 0.70% to 0.77% at 13.00 - 17.00 WIB. An increase in the safety index to the high category reflects an increase in safety risks or unsafe environmental conditions.

The visualization results also highlight that the safety index on the south entrance route experienced low-intensity values, especially on 27 - 30 October, at 17.00 - 17.10 WIB. During this period, there was a potential safety risk on the south entrance route due to the low safety index.

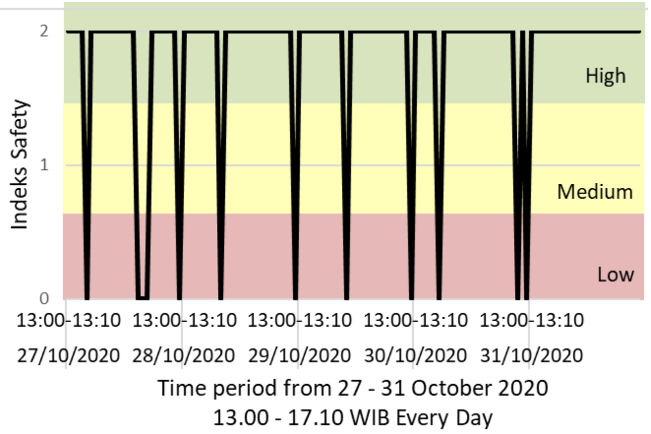

Figure 4. Safety index

Based on the results of the security index in Figure 8, it can be seen that the lowest percentage values occur in specific periods, namely 13.40 – 14.00 WIB, 14.20 – 14.30 WIB, 14.40 – 14.50 WIB, 15.50 – 16.00 WIB, and 16.40 – 16.50 WIB, with percentages the value reached 0.43%. Interestingly, the average security index on this route reached 0.73% at 17.00 – 17.10 WIB. These findings indicate that at certain time intervals, the southbound lanes experience lower levels of security, creating potential risks or vulnerabilities that require special attention. Evaluation and improvement of security during these hours can be a proactive step to increase the overall security index on the south entrance route.

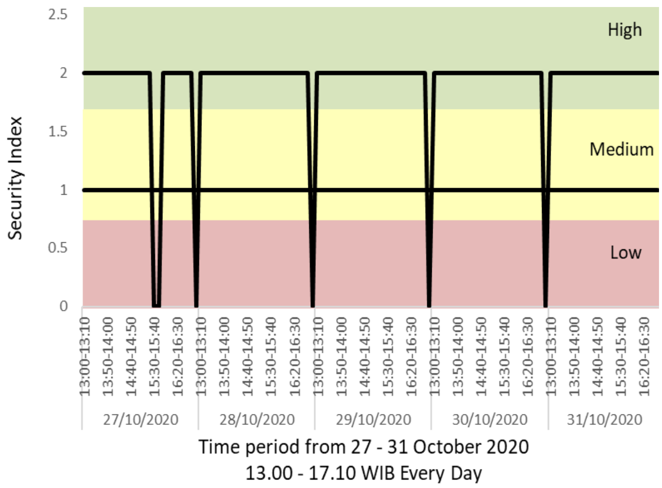

Figure 5. Security Index

V. Conclusion and Future Works

In this study, we incorporated three aspects that produce crowds: the number of people, train schedules, and events, into a safety and security evaluation model based on hybrid belief rules. From October 27 to 31, 2020, we conducted experiments at one of Bandung station's busiest sections. According to the testing results, we discovered patterns at this area that posed a threat to passenger safety and security owing to passenger buildup.

Thus, we can conclude that the assessment of crowd behavior using a hybrid belief rule based on three indicators has been able to assess the level of security and safety of an area very well. Apart from that, the results of this assessment can provide understanding and identify potential security and safety risks in an area that will occur at certain times. For future works, this research will try to improve the models' accuracy by considering various conditions, environments, and more specific potential risks.

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