

Pedestrian Detection Systems at Road Intersections and Crossings Using the Entropy-Moora Method

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ABSTRACT

Pedestrian safety at road intersections and crossings is a growing concern in urban areas, and selecting the most effective pedestrian detection systems is essential to reduce incident risks and improve overall traffic efficiency. This research evaluates three pedestrian detection system alternatives with several contradictory criteria. Thus, for this research, Multi-Criteria Decision Making (MCDM), which integrates Entropy and Multi-Objective Optimization by Ratio Analysis (MOORA), was used to select the optimal pedestrian detection system. Seven evaluation criteria were considered to evaluate the pedestrian detection systems, namely cost (C1), detection accuracy (C2), response time (C3), reliability (C4), maintenance (C5), safety (C6), and user-friendliness (C7). The alternatives assessed in this research were standard push button (A1), smart pedestrian push button (A2), and Wireless Vehicle Detector (WVD) in the pedestrian system (A3). The results indicated that the ranking order for the criteria was $C4 > C1 > C2 > C3 > C5 > C6 > C7$, while the ranking order for the alternatives was $A3 > A2 > A1$. In conclusion, the integrated Entropy-MOORA method offers a reliable and effective way for assessing and ranking pedestrian detection systems, thus helping decision-makers identify suitable solutions to improve pedestrian safety.

1. INTRODUCTION

Pedestrian detection is one of the crucial topics in object detection and has attracted considerable attention (Ouyang & Wang, 2013) in recent years. It serves as a key component of urban traffic management, as it helps to ensure the safety of individuals who are crossing the roads (Gandhi & Trivedi, 2007). This focus

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is particularly important because pedestrians are widely considered to be the most vulnerable road users, especially at high-risk locations such as traffic-signalized intersections (Sahu et al., 2025). Based on studies by Gitelman et al. (2020) and Ma et al. (2023), urban traffic locations have the highest rates of pedestrian deaths and injuries due to factors such as heavy traffic volumes, complex crossing and intersection layouts, and insufficient pedestrian infrastructure. Therefore, this research proposed a structured framework method, such as Multi-Criteria Decision Making (MCDM) methods, to select a suitable pedestrian detection system.

One of the critical problems to be solved using MCDM approaches in urban traffic management is pedestrian safety, particularly at road intersections and crossings. This problem arises as cities become more congested with the growth in the number of road users, which substantially contributes to higher rates of pedestrian fatality (Gitelman et al., 2020). Consequently, urban planners must identify effective and efficient pedestrian detection systems to enhance traffic safety for traffic users (Evstatiev et al., 2019). Despite this, many traffic agencies are still relying on traditional decision-making methods. For instance, Dommès et al. (2015) reported that decision-making at road intersections is frequently affected by subjective biases, where traffic agencies may unintentionally rely on personal judgment or informal experience instead of developing a structured evaluation process. As a result, this makes it challenging for urban planners to evaluate safety, cost, and quality properly (Mardani et al., 2016).

Therefore, the present research employs the MCDM method, which is the Multi-Objective Optimization by Ratio Analysis (MOORA) method, as a reliable decision-making technique in evaluating pedestrian detection systems. MOORA is known for its ability to rank decision options from best to worst while considering trade-offs between two or more conflicting criteria (Chakraborty et al., 2023). Moreover, the MOORA method is easy to understand and apply and is able to accommodate quantitative and qualitative data, making it suitable to be used in various applications like business, engineering, and management decision-making (Arshad et al., 2024). However, this method requires criteria weights, which represent the relative importance of each evaluation criterion and ensure an accurate and fair evaluation of the alternatives (Chakraborty et al., 2023).

To address this limitation, the present research employs the Entropy method to determine the weights based on the variability of the data across the entire dataset. The Entropy approach can measure sources of information about the importance of each criterion (Srdjevic et al., 2004). In addition, this method enhances the objectivity of the results by eliminating human involvement in assigning weight (Mete et al., 2023). Although the present research utilized subjective data obtained from decision-makers' personal judgments through Likert-scale responses, the responses were converted objectively into numerical values using established mathematical procedures, as conducted by past research such as Neogi (2021). The integration of the Entropy-MOORA method enables decision-makers to select the best pedestrian detection system by considering various available alternatives with their conflicting criteria.

Accordingly, this research integrates the Entropy weighting approach with the MOORA method to evaluate and select the optimal pedestrian detection system to be applied at road intersections and crossings. The paper is organized into five main sections: an introductory overview, a review of related studies, a detailed explanation of the methodology (highlighting the Entropy–MOORA approach), an analysis of results and discussion, and a final section presenting conclusions.

2. METHODOLOGY

This section reviews a discussion of the literature, applications, and background theory of the Entropy and the MOORA methods.

2.1 Entropy Method

The Entropy method is one of the objective weighting methods that evaluates value dispersion in decision-making. This method was introduced by Shannon and Weaver in 1947 (Chodha et al., 2022). According to Mete et al. (2023), it is useful in MCDM for weighting each of the relevant criteria. The Entropy method is used as a parameter that describes how closely the various alternatives resemble one another with respect to a particular criterion (Wang et al., 2007). The entropy weight decreases as the entropy value increases, which means that the differences among alternatives for that criterion are small. Therefore, the specific criterion contributes less information and becomes of lower importance in the decision-making process (Wang et al., 2007).

Furthermore, this method is particularly useful, especially when there is measurable and verifiable quantitative data available (Zheng et al., 2010). Another advantage of the Entropy approach is its ability to remove human involvement, thereby improving the accuracy of the findings (Mete et al., 2023). However, the Entropy method is highly sensitive to data quality and may often lean towards being too objective or too subjective in the evaluation of the data (Ouyang et al., 2013). The issue arises when the entropy values are close to one, resulting in a doubling of changes in the entropy weight. Consequently, this can lead to certain criteria being given weights that do not accurately match their relevance, hence affecting the reliability of the result assessments (Ouyang et al., 2013).

Table 1 presents an overview of previous research that has employed Entropy techniques to solve various MCDM methodologies.

Table 1. The application of the Entropy method

Author (s)	Methodologies	Application
Dehdasht et al. (2020)	Entropy–TOPSIS	Selection of key drivers for successful and sustainable lean construction.
Singh (2024)	Entropy–WASPAS–MACBETH	Performance optimization and selection of solar water heating system.
Neogi (2021)	Entropy–TOPSIS	Performance appraisal ranking of 20 nations in COVID-19 pandemic mitigation.

Source: Authors' compilation

The literature demonstrates that Entropy has been successfully integrated with multiple MCDM approaches in various practical scenarios. For instance, Dehdasht et al. (2020) applied the Entropy–TOPSIS technique to identify the key drivers for successful and sustainable lean construction. Empirical data were collected from 23 Malaysian construction experts, including contractors, supervisors, project managers, and academics, who rated 63 identified drivers across economic, social, and environmental sustainability dimensions using a 7-point Likert scale. Meanwhile, Singh (2024) applied the Entropy–WASPAS–MACBETH method to identify the most optimal solar water heating system based on three objective criteria, including Nusselt number, Friction factor, and Thermohydraulic efficiency. In addition, Neogi (2021) evaluated the early COVID-19 pandemic mitigation performance across 20 selected nations using the Entropy–TOPSIS method to appraise and rank national mitigation responses. The evaluation framework integrated seven objective criteria, comprising tests per million population, deaths per million population, case-fatality rate, tests per confirmed case, hospital beds per thousand population, highest level of stringency, size of populations (in Billion), and one subjective criterion representing public confidence in government responses and actions, evaluated on a 20-point scale.

Although the Entropy method is an objective weighting technique, it can be effectively applied to both objective and subjective criteria. Subjective responses are converted into quantitative data using numerical rating scales prior to calculating criteria weights objectively via Shannon's Entropy. In this paper, the

Entropy method is integrated with the MOORA method to evaluate and select the optimal pedestrian detection system.

2.2 MOORA Method

The Multi-Objective Optimization by Ratio Analysis (MOORA) method was introduced by Brauers and Zavadskas (2006) as one of the MCDM techniques for addressing complex and conflicting multi-objective problems (Singh et al., 2024). MOORA is a ratio-based system that evaluates each alternative and compares it to a denominator, which represents the square root of the sum of squared values for all alternatives under that objective (Brauers & Zavadskas, 2006). According to Andani et al. (2019), the MOORA approach calculation is relatively simple compared to other MCDM methods. The MOORA method simultaneously solves decision-making problems involving multiple criteria, in which the criteria can be divided into two categories, which are beneficial and non-beneficial criteria (Karande & Chakraborty, 2012).

This method can help decision-makers to evaluate multiple conflicting response parameters without requiring complex calculations of the alternatives (Dubey et al., 2021). Moreover, the MOORA method is known as a method that is simple to understand and adaptable in separating objects from the decision-weight criteria in the process of evaluation. This method also maintains the level of selectivity, proving that its effectiveness in distinguishing between conflicting objectives and criteria may help the process of making decisions (Cahyadi et al., 2022). Despite these advantages, the MOORA method must rely on the appropriate normalization of input data because inappropriate normalization may skew the results and lead to unreliable conclusions (Krishnan, 2022).

Table 2 displays a summary of previous research involving the MOORA method and its extensions in various decision-making contexts. These studies demonstrate the flexibility of integrating the MOORA methodology and its extensions with different weighting methods. For example, Wang and Li (2025) applied the Fuzzy AHP-MOORA approach to evaluate the green maritime transportation aimed to reduce marine pollution. Besides that, Patnaik et al. (2020) conducted a study that employed a hybrid MCDM approach by combining the AHP and MOORA methods to identify the optimal alternative to polymer composite material for engineering applications. Additionally, De Paula et al. (2022) integrated the CRITIC-MOORA-3N approach to identify and select the most suitable Anchor Handling Tug Supply (AHTS) ships for offshore operations.

Table 2. The application of the MOORA method

Author (s)	Methodologies	Application
Wang and Li (2025)	Fuzzy AHP-MOORA	Green maritime transportation selection.
Patnaik et al. (2020)	AHP-MOORA	Polymer composite material selection.
De Paula et al. (2022)	CRITIC-MOORA-3N	AHTS ships selection for offshore operations.

Source: Authors' compilation

3. METHODOLOGY AND IMPLEMENTATION

In this research, the weights of the criteria was determined using the Entropy approach, a widely used weighting approach based on diversity, where the attribute weights were determined based on the variety of information between alternatives (Türegün, 2022). Alternatives with lower entropy provide more information and thus are considered more important (Khan et al., 2022). Let $i = 1, 2, 3, \dots, m$ alternatives and

$j = 1, 2, 3, \dots, n$ criteria; all the steps below were applied to adopt the Entropy method (Goswami et al., 2022; Manjate et al., 2021).

Step 1: Construct the decision matrix X by using:

$$X = (x_{ij}) = \begin{pmatrix} x_{11} & \dots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mn} \end{pmatrix} \quad (1)$$

Step 2: Normalize the decision matrix by using Equations (2) and (3), respectively, as follows:

For beneficial criteria:

$$D_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}} \quad (2)$$

For non-beneficial criteria:

$$D_{ij} = \frac{\left(\frac{1}{x_{ij}}\right)}{\sum_{i=1}^m \left(\frac{1}{x_{ij}}\right)} \quad (3)$$

Step 3: Calculate the entropy constant H by using:

$$H = \frac{1}{\ln(m)} \quad (4)$$

whereby m denotes the number of alternatives.

Step 4: Determine the entropy value E_j by using:

$$E_j = -H \sum_{i=1}^m D_{ij} \ln(D_{ij}) \quad (5)$$

Here, E_j ranges from 0 to 1.

Step 5: Calculate the weight of the criteria W_j by using:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^n (1 - E_j)} \quad (6)$$

Subsequently, the weights of the criteria were used as input in the MOORA framework to evaluate all the available alternatives. Several steps were applied to perform this method, which are as follows (Alinezhad & Khalili, 2019).

Step 1: Construct the decision matrix X as shown in Eq. (1).

Step 2: Normalize the decision matrix using:

$$K_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (7)$$

Step 3: Calculate the performance score M_i using:

$$M_i = \sum_{j=1}^g W_j K_{ij} - \sum_{j=g+1}^n W_j K_{ij} \quad (8)$$

with $j = 1, 2, \dots, g$ for the criteria to be maximized, $j = g + 1, g + 2, \dots, n$ for the criteria to be minimized, and W_j represents the weight of the criteria.

Step 4: Rank the alternatives.

In this research, data from an experienced expert were collected from the traffic system technology provider to illustrate the application of the Entropy-MOORA method in evaluating the pedestrian detection systems. Only one decision-maker was involved in the study, as a single individual is directly responsible for evaluating and selecting the pedestrian detection system within the organization under study. The decision-maker has 38 years of professional experience and extensive expertise in traffic systems technology, making them well qualified to evaluate the pedestrian detection systems. Three types of pedestrian detection systems were evaluated: a standard push button (A1), a smart pedestrian push button (A2), and a Wireless Vehicle Detector (WVD) in the pedestrian system (A3). Meanwhile, seven criteria were identified from the interview session with the decision-maker, which included cost (C1), detection accuracy (C2), response time (C3), reliability (C4), maintenance (C5), safety (C6), and user-friendliness (C7). All the criteria were selected based on their effect on pedestrian safety and the efficiency of traffic flow and were subsequently classified as either beneficial or non-beneficial criteria. Detection accuracy (C2), reliability (C4), safety (C6), and user-friendliness (C7) were categorized as beneficial criteria, which positively contributed to the effectiveness, usability, and safety of the system. In contrast, cost (C1), response time (C3), and maintenance (C5) were classified as non-beneficial criteria due to their negative impacts on performance levels, resulting in increased expenses and the service needed. A set of questionnaires was developed and subsequently reviewed by the decisionmaker, who has expertise in traffic systems technology, to ensure the validity and reliability of the evaluation.

The first evaluation criterion, cost (C1), refers to the purchase price of the single sensor used in the pedestrian detection system. Lower costs are preferable as they reduce the financial burden. The scale was rated as 1 for very low (RM1,000–RM1,500), 2 for low (RM1,501–RM2,000), 3 for moderate (RM2,001–RM2,500), 4 for high (RM2,501–RM3,000), and 5 for very high (RM3,001–RM3,500). C1 was treated as a non-beneficial criterion, where a lower score indicates a more desirable alternative.

For the second evaluation criterion, detection accuracy (C2) measures how effectively the system can identify pedestrians in real-world traffic environments. A system with high accuracy ensures that pedestrians are detected consistently, even in varying conditions such as weather changes or crowded areas. To prevent any accidents, it is important to have high accuracy in a detection system. Improved accuracy minimizes the chance of false detection and reduces the risk to pedestrians. The scale was rated as 1 for very poor performance (0–40%), 2 for poor performance (41–60%), 3 for moderate performance (61–80%), 4 for good performance (81–90%), and 5 for very good performance (91–95%). The data provided were in the form of a scale to reduce the uncertainty arising from different testing conditions and environments.

Therefore, C2 was considered a beneficial criterion, where higher scores indicate better detection performance.

The third evaluation criterion, response time (C3), indicates how quickly the system activates after detecting a pedestrian. The scale was rated as 1 for a very fast response (0–2 seconds), 2 for a fast response (3–4 seconds), 3 for a moderate response (5–6 seconds), 4 for a slow response (7–8 seconds), and 5 for a very slow response (9–10 seconds). Due to the system configurations, the decision-maker was unable to provide the exact numerical data since it was difficult to obtain. When the systems responded promptly to changing situations, this resulted in lower waiting times for pedestrians and reduced risk of traffic accidents. Systems with faster response times provided smoother traffic flow and better protection for pedestrians. Since a quicker response was desirable, response time was categorized as a non-beneficial criterion.

The fourth evaluation criterion, reliability (C4), reflects the ability of the system to perform well for long-term use, including its ability to withstand severe weather conditions, technical faults, and even vandalism. A highly reliable system can operate in nearly every situation without significant failure and minimal need for replacement. The scale was rated as 1 for very poor, 2 for poor, 3 for moderate, 4 for good, and 5 for very good. Reliability was considered a beneficial criterion, as higher reliability contributes to better long-term system usability.

The fifth evaluation criterion, maintenance (C5), represents how often the system needs maintenance to remain fully operational. A system requiring less maintenance will get a lower score. The scale was rated as 1 for very low maintenance requirements (service rarely needed), 2 for low requirements (service once per year), 3 for moderate requirements (service every six months), 4 for high requirements (service every one to two months), and 5 for very high requirements (daily or weekly service). Since higher maintenance needs are undesirable, this criterion was considered a non-beneficial criterion.

The sixth criterion, safety (C6), reflects the ability of the system to protect pedestrians and reduce the risk of accidents at crossings. The scale was rated as 1 for very poor safety performance (high accident risk remains), 2 for poor performance (multiple risks remain), 3 for moderate performance (some risks are reduced but limitations persist), 4 for good performance (most users are protected under normal conditions), and 5 for very good performance (effective protection in all conditions, including for vulnerable groups like children, the elderly, and persons with disabilities). As pedestrian safety is the main purpose of pedestrian detection systems, safety was classified as a beneficial criterion.

Finally, the seventh evaluation criterion, user-friendliness (C7), evaluates the ease of use and accessibility of the pedestrian detection system for diverse pedestrians. To represent all the different groups among the pedestrians, a 10-point rating scale was employed. The scale ranged from 1 as for very poor usability (extremely difficult to use), 2 for poor usability (hard for many users), 3 for low usability (mistakes and misuse are common), 4 for fair usability (somewhat easy but not suitable for all users, like elderly or persons with disabilities), 5 for moderate usability (most people can use it but not effortlessly), 6 for good usability (easy for most pedestrians), 7 for high usability (intuitive and simple for nearly everyone), 8 for very high usability (very easy, requires minimal effort), 9 for excellent usability (almost universal usability, even elderly and children can use it confidently), and 10 for perfect usability (fully user-friendly and accessible to all, including visually or hearing impaired users). As a result, user-friendliness was classified as a beneficial criterion.

In this research, all measurement scales for all evaluation criteria were derived directly from the expert's knowledge and professional experience in traffic systems technology. The data collected were analyzed using Microsoft Excel. Table 3 below presents the evaluation data used in this analysis.

Table 3. The data

Alternative/criterion	C1	C2	C3	C4	C5	C6	C7
A1	1	2	5	1	4	3	9
A2	2	3	3	4	3	4	10
A3	4	5	2	5	2	5	10

Source: Authors' primary data collected through a questionnaire completed by a traffic systems technology expert with 38 years of professional experience

4. RESULTS AND DISCUSSION

This section contains the results and discussion of the weights and rank of the criteria, as well as the rank of alternatives.

4.1 Weight and the Rank of the Criteria

In this research, the Entropy approach was utilized to determine the weights of each criterion. The data were collected from an expert serving as a senior project supervisor with 38 years of professional experience and expertise in traffic systems technology. Seven criteria were identified and used in selecting the appropriate pedestrian detection system. Table 4 depicts the weights of the criteria using the Entropy method and the decision-maker's preferences. By using the Entropy method, the ranking order for the criteria was $C4 > C1 > C2 > C3 > C5 > C6 > C7$. Notably, the findings showed that the ranking produced by the Entropy method and the preferences of the decisionmaker were consistent.

Table 4. Weight and ranking for criteria by using the Entropy method

Criteria	Entropy Weight	Criteria ranking	Decision-maker's preferences
Cost (C1)	0.2889	2	2
Detection Accuracy (C2)	0.1394	3	3
Response Time (C3)	0.1305	4	4
Reliability (C4)	0.3139	1	1
Maintenance (C5)	0.0823	5	5
Safety (C6)	0.0426	6	6
User-friendliness (C7)	0.0024	7	7
Sum	1		

Source: Authors' Entropy-weight calculations

It was observed that reliability (C4) had the highest weight value because of the variability of data. This is because the Entropy method evaluates the value by measuring the degree of differentiation. Therefore, the higher the degree of variation of the measured value, the higher the degree of differentiation of the index, and more detailed information may be obtained (Zhu et al., 2020). Vulnerable road users such as pedestrians and cyclists have a higher chance of being involved in crashes with motor vehicles and are more likely to cause severe injuries or fatalities (Sengupta et al., 2024). Therefore, a reliable pedestrian detection system needs to be installed at road intersections and crossings to reduce the probability of accidents happening. A reliable pedestrian detection system ensures that the technology can be used under various kinds of real-world conditions such as bright sunlight, heavy rain, and nighttime surroundings. The system must be built to provide consistent detection performance even when environmental conditions change. Reliable long-term performance is the most important criterion for pedestrian detection systems

because a system that fails to operate under various circumstances can affect the safety of pedestrians or cyclists. This situation shows that a suitable and reliable detection system is needed to ensure the safety of pedestrians.

Meanwhile, user-friendliness (C7) received the lowest-ranked criterion among all because the scores given by the decision-maker for C7 within all three systems are very similar. Under the Entropy method, a criterion receives greater weight only when there is significant variation in the data and the values show big differences between each alternative. Because all pedestrian detection systems have been designed to be user-friendly, the decision-maker's evaluation does not vary significantly. Standard buttons were familiar; smart buttons were still easy to press; and wireless detection did not require user action. Additionally, user-friendliness was considered a basic requirement for a detection system and did not affect the possibility of an accident happening. It also does not affect technical performance as strongly as other criteria, such as cost, detection accuracy, and response time. Hence, user-friendliness became the least important criterion and appeared as the last-ranked criterion in the Entropy weight result.

4.2 The Ranking of Alternatives

Table 5 presents the ranking of alternatives obtained using the Entropy-MOORA method and the decision-maker's preferences. The Entropy-MOORA method ranked the alternatives as $A3 > A2 > A1$, which is consistent with the decision-maker's preferences.

Table 5. The ranking of performance scores for each alternative and the decision-maker's preferences

Alternative	Performance score	Rank	Decision-maker's preferences
Standard push button (A1)	-0.1170	3	3
Smart pedestrian push button (A2)	0.0517	2	2
Wireless Vehicle Detector (WVD) in the pedestrian system (A3)	0.0617	1	1

Source: Authors' Entropy-MOORA calculations

The Wireless Vehicle Detector (WVD) in the pedestrian system (A3) achieved the highest performance score (0.0617) and was ranked first. This finding shows that A3 performs the best in the majority of the evaluation criteria, such as detection accuracy, response time, reliability, maintenance, safety, and user-friendliness. According to Baniyas et al. (2018), wireless sensor technologies can reduce human interactions and make it easier to maintain the system compared to standard push button devices. The decision-maker also mentioned that A3 is fully automatic detection, and pedestrians do not need to press any button to activate it. It can sense the presence of humans in real time with the help of sensors, even in poor weather conditions, and it is safe, especially for people with disabilities, children, and the elderly. This system eliminates physical contact and reduces maintenance by relying on automated sensor detection to identify pedestrians. These factors may explain why this system remains the most preferred detection option, despite the higher cost of a single set.

Meanwhile, the standard push button (A1) had the negative performance score (-0.1170) and was ranked third. This system is the most basic and manually operated, requiring a pedestrian to push a button on a pole to enable the crossing light to activate the detection system. This poor performance may be caused by lower detection accuracy, higher response time, lower reliability, maintenance requirements, less safety, and less user-friendly compared to A2 and A3. The decision-maker also stated that this system has low detection accuracy and a high potential for misuse, such as pedestrians forgetting to press the button or the button failing due to vandalism. According to Sulmicki (2016), the standard push button can be considered a form of discrimination towards some pedestrians since this system requires an effort for a wheelchair user

to move into the right position and stop to press the button on the pole. Furthermore, the system is programmed to provide no faster green light when the button is pressed. The button only makes the pedestrian green light appear, but it does not speed up the waiting time, especially during the daytime.

4.3 Sensitivity Analysis

Sensitivity analysis evaluates the rankings' stability and reliability under many scenarios (Więckowski & Sałabun, 2023). In this paper, 15 scenarios were considered to assess the sensitivity of the ranking result by applying changes in the criteria weights. For the first scenario, the original weights were used to determine the alternative ranking. Scenarios 2 to 8 involve increasing the weights of Criteria 1 to Criteria 7 by 20%, and the remaining weights were adjusted so that the total weight is equal to 1. Similarly, in Scenarios 9 to 15, the weights of Criteria 1 to Criteria 7 decreased by 20%, while the remaining weights were also adjusted to keep the total weight equal to 1.

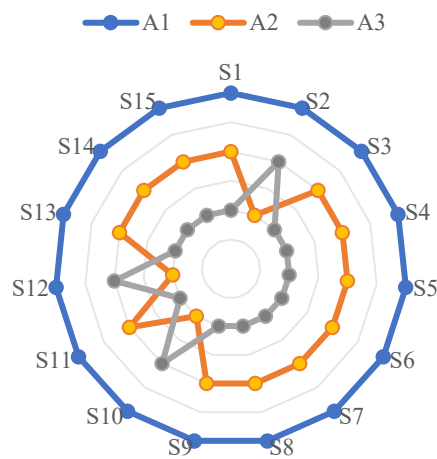


Fig. 1. The sensitivity analysis

Source: Authors' sensitivity analysis of Entropy-MOORA rankings across 15 scenarios

The radar chart depicted in Fig. 1 shows the stability of the final ranking for the three alternatives under 15 different scenarios. A3 maintained its ranking position in 12 out of 15 scenarios, showing that its ranking position is still stable and not easily affected by the weight adjustments. A2 also retained its ranking position in 12 out of 15 scenarios and remained in second place throughout all of them. While A1 remained in third place in all 15 scenarios, the result indicates that A1 did not outperform A2 and A3, even with changes in the weights. The consistency in the ranking across all 15 scenarios indicates that the relative positions of the alternatives do not change significantly, which confirms the stability of the final ranking. This stability suggests that the ranking is trustworthy, even when different weight variation scenarios are evaluated.

5. CONCLUSION

This research employed the Entropy-MOORA method to rank and select the most suitable pedestrian detection systems for application at road intersections and crossings. The Entropy technique was utilized to determine the criteria weights, while the MOORA method was applied to rank the pedestrian detection systems. Multiple alternatives were evaluated with several conflicting criteria. The determination of Entropy weights for each criterion and the MOORA evaluation was conducted using Microsoft Excel. The results identified A3 as the most favorable pedestrian detection system, whereas A1 ranked as the least favorable alternative. With that, the findings demonstrated that the Entropy-MOORA method provided an optimal solution for pedestrian detection system evaluation, which enables users to make accurate choices in actual deployment scenarios.

Future research should consider utilizing fully objective datasets to further improve evaluation accuracy. In addition, applying alternative objective and subjective weighting methods such as CRITIC or Analytic Hierarchy Process (AHP) may also be explored. Moreover, future studies are recommended to apply Fuzzy Entropy and Fuzzy MOORA to address the ambiguity and uncertainty in human judgments. These fuzzy methods, particularly Fuzzy Entropy, can address the vagueness and uncertainty of human judgments, thus enhancing the reliability of the decision-making results (Cardone & Di Martino, 2024). Furthermore, the proposed Entropy-MOORA approach may be extended to other MCDM applications, including material selection, location selection, supplier selection, and other selection-related problems, as this approach is effective in handling multiple criteria and producing reliable ranking results.

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7. CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare that are relevant to the content of this article.

8. AUTHORS' CONTRIBUTIONS

Muhammad Nasrullah Masri: Conceptualisation, methodology, formal analysis, investigation, and writing—original draft; Muhammad Hadi Abdul Razak: Conceptualisation, methodology, formal analysis, investigation, and writing—original draft; Nor Faradilah Mahad: Conceptualisation, supervision, writing—review and editing, and validation.

9. DECLARATION OF GENERATIVE AI IN THE WRITING PROCESS

During the preparation of this manuscript, AI generative tools were used to enhance the clarity, readability, and linguistic quality of the text. All content was subsequently reviewed, revised, and verified by the authors. The authors are solely responsible for the originality, accuracy, validity, and integrity of the work presented in this manuscript.

10. DATA AVAILABILITY/SUPPLEMENTARY MATERIALS

All data generated or analyzed during this study are included in this published article.

11. ETHICS STATEMENT

This study was reviewed and approved by the Universiti Teknologi MARA (UiTM) Cawangan Negeri Sembilan, Kampus Seremban Research Ethics Committee (Approval No: REC/1665/2025). Informed consent was obtained from the participant, and data anonymity was strictly maintained throughout the study.

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