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# Implementation of MCDM Methods in Road Safety Management: A Case Study of Dhule City

Dahihande kimaya[1], Parmar Sunil[2], Thube Aruna[3]
[1]*Student, COEP Pune*
[2] *Former Postgraduate student, SVNIT Surat*
[3]*Faculty, COEP Pune*

***Abstract-* National highways are vital for economic development and mobility, connecting major cities, industries, and underserved regions while supporting trade and transport. However, highways, especially in urban and semi-urban areas—are increasingly prone to motor vehicle crashes. Despite various safety measures, fatalities and serious injuries persist. Contributing factors include reckless driving, poor road conditions, faulty vehicles, and weak law enforcement, making national highways a significant safety concern.**

***To address this issue more efficiently, the factors that are the major contributors to crashes should be determined. For that purpose, in this study Multi-Criteria Decision Making (MCDM) methods are employed to analyze and prioritize the major causes of crashes.***

***A number of studies applied various MCDM methods, such as AHP, TOPSIS, FUCOM, and DEA, to assess road safety analysis or prioritize accident blackspots, however; such a study has not been conducted for the National Highway passing through urban area so far. Further, while AHP and SWARA have been employed separately in previous studies, there is limited comparative study between the two methods on the same dataset. This creates a knowledge gap on how various MCDM methods impact the output. Additionally, there are few studies that incorporate expert opinion and real crash data to result in useful insights that can be taken to the field for improvements toward reducing future crashes. This study seeks to fill those gaps by combining both AHP (Analytic Hierarchy Process) and SWARA (Step-wise Weight Assessment Ratio Analysis) methodology to NH-03 in Dhule.***

***In this study, the AHP and SWARA methods were selected as they integrate expert opinions and provide a structured approach to evaluating the importance of contributory factors in crashes. Comparison of their results contributes to the making of safer and more justified decisions to improve safety on this roadway section.***

***For analysis, crash contributors were grouped into five main categories: Driver Behavior, Road Condition, Vehicle Condition, Environmental Condition, and Traffic Control Measures. Road-related factors included road width, signage, dividers, curves, pedestrian crossings, and lane markings. Driver behavior covered helmet/seatbelt use, mobile phone use, wrong-side driving, and alcohol consumption. Traffic control measures involved CCTV surveillance, traffic signals, streetlights, and police patrolling.***

***Both methods identified driver behavior as the most influential factor. However, variations emerged: AHP ranked traffic control measures lowest, while SWARA placed them second, suggesting expert opinions vary by method. In road characteristics, AHP emphasized road width and shoulder condition, whereas SWARA prioritized signage visibility. For driver behavior, AHP highlighted helmet and seatbelt use, while SWARA gave top rank to wrong-side driving. Street lighting was consistently ranked highest by both methods.***

***The conclusions of this study suggest that AHP is more organized approach to evaluate decision-making, whereas the SWARA permits subjective judgment based on experience. Combined, the two provide a more vivid picture of where the greatest attention should be on making roads safer, especially for NH-03 corridor passing through Dhule city.***

***Index Terms* Multi-criteria decision making, Road safety management, Factor Prioritization, Analytic Hierarchy Process (AHP), Stepwise Weight Assessment Ratio Analysis (SWARA).**

## I. INTRODUCTION

In recent decades, with rapid growth of economy and population, the motorization of transportation sector has been rapidly grown. It is expected that the transportation sector will continue fast expansion in the next decades. This accelerated expansion in the transportation sector has led to new challenges such as road traffic and accidents. Road accidents have become a global problem for societies due to imposing irreparable financial and human life losses. In fact, the issue of road traffic fatalities and injuries has been known as public health and socioeconomic challenge in almost all societies.

The higher numbers of fatalities and injuries caused by road accidents across the India proposes that more realistic approach is required to better examine the factors influencing road accidents. Further, the necessity for supplementary evidence in various contexts is increasingly obvious because of insufficient data, such as the relative absence of information on non-fatal accidents, variances in findings, and the definition of accident severity with its associated factors. The detailed evaluation of accident-influencing factors may lay the foundation for road safety policies and strategies in the long run. Thus, it is mandatory to evaluate the severity of factors influencing road accidents by considering the fatalities and injury numbers.

## II. LITERATURE REVIEW

The literature review highlights the significant role of Multi-Criteria Decision Making (MCDM) methods in advancing road safety management. Over recent years, there has been a marked increase in the adoption of techniques such as Analytic Hierarchy Process (AHP), TOPSIS, FUCOM, SWARA, DEA, and hybrid models. These methods provide structured frameworks to systematically evaluate and prioritize the diverse factors contributing to road accidents, enabling more informed and transparent decision-making for accident prevention and safety improvements.

A variety of studies have demonstrated the effectiveness of MCDM approaches in ranking accident causes, assessing road safety performance, and identifying high-risk road segments. For instance, comparative analyses have shown that AHP is particularly effective in prioritizing suburban road safety indicators, while other research has introduced frameworks like Concordance Analysis and FUCOM-WASPAS to rank and validate the safety conditions of road sections. These studies underscore the methodological diversity and adaptability of MCDM techniques to different contexts and data types.

The integration of expert judgment and real-world data has become increasingly prominent in MCDM applications. Recent research incorporates expert linguistic assessments, group decision-making strategies, and hybrid fuzzy approaches to better capture the complexities of road safety challenges. For example, improved fuzzy SWARA methods allow for more nuanced weighting of criteria, accommodating equal weights where justified, and hybrid models such as BWM-TOPSIS and FD AHP-TOPSIS address uncertainties and validate rankings.

Context-specific analysis is emphasized throughout the literature, with studies from India, Iran, Serbia, Libya, and South Africa demonstrating the adaptability of MCDM frameworks to local road conditions, traffic characteristics, and user behaviors. This ensures that recommendations are both practical and tailored to the unique needs of different regions and policy environments.

Despite these advancements, a notable gap remains in comparative studies that apply multiple MCDM methods to the same dataset, especially within the Indian context. Few investigations integrate both expert opinion and real crash data to generate actionable insights for field implementation. Addressing this gap, the present research applies both AHP and SWARA methods to prioritize accident-contributing factors on NH-03 in Dhule, India, and compares their outputs to evaluate methodological impacts. By integrating expert surveys and real-world observations, the study aims to provide a comprehensive understanding of key factors influencing road safety and to support the development of targeted interventions.

## III. METHODOLOGY

The methodology adopted in this study is aimed at systematically evaluating the severity of various factors contributing to road accidents on the National Highway corridor passing through Dhule city. The research follows a multi-criteria decision-making (MCDM) approach by integrating both qualitative expert judgment and quantitative analysis. Two widely accepted MCDM techniques Analytic Hierarchy Process (AHP) and Stepwise Weight Assessment Ratio Analysis (SWARA) are employed to prioritize the identified accident factors based on their relative significance. The study involves a structured process that includes literature review, factor identification, expert data collection through questionnaires, matrix formation, and subsequent computation of factor weights using both AHP and SWARA. A comparative analysis of the results from the two methods is conducted to enhance the reliability of findings and provide comprehensive insights for road safety improvements.

### i Study Area Selection

National Highway (NH-03), formerly known as the Agra–Bombay Road, runs from Attari in Punjab to Mumbai in Maharashtra, covering approximately 1,626 km. It passes through key states like Punjab, Delhi, Madhya Pradesh, and Maharashtra, connecting major cities such as Amritsar, Agra, Indore, Nashik, and Mumbai. As part of the North-South Corridor under the NHDP, it plays a vital role in national connectivity.

In Maharashtra, NH-03 passes through Dhule, Malegaon, Nashik, and ends in Mumbai. The Dhule section is a strategic junction where NH-03 intersects NH-52 and NH-60, with a four-lane bypass diverting traffic away from the city. The Avdhan Toll Plaza near Dhule manages highway traffic, which is typically moderate to heavy. This stretch has several accident-prone zones due to mixed traffic, high speeds, and limited pedestrian infrastructure, making it an important area for road safety research and highway planning.

The stretch chosen for the research is 17.3 km starting from Topline Resort ending at Nagaon Bari Junction at NH 03.

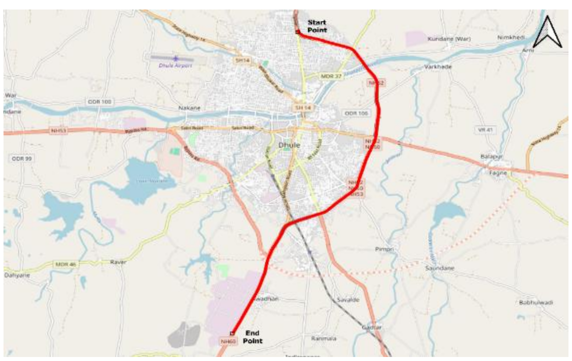


Figure 1 : Location of Study Area

### ii IDENTIFICATION OF FACTORS INFLUENCING ROAD ACCIDENTS

The identification of major factors that influence road accidents was carried out through a detailed review of published research studies related to Road Safety Analysis (RSA) and Multi-Criteria Decision-Making (MCDM) methods. Several national and international journals, case studies, and government reports were studied to understand which factors are most commonly responsible for accidents, especially on highways in Indian conditions.

From the literature, it was observed that most studies classified accident causes into a few broad categories. After carefully analyzing these studies, five major factors were finalized for this research work:

1. Driver Behavior
2. Road Condition
3. Vehicle Condition
4. Weather/ Environmental measures
5. Traffic control measures

These main parameters are further classified as follows:

1. Driver behavior:
   a) Helmet/ Seatbelt usage
   b) Mobile phone usage while driving
   c) Wrong side driving
   d) Alcohol usage
2. Road condition:
   a) Road width, shoulder condition
   b) Signage visibility and condition
   c) Medians/ dividers presence and condition
   d) Horizontal / vertical curves
   e) Presence of pedestrian crossing / Service roads
   f) Lane markings
3. Traffic control measures:
   a) CCTV surveillance
   b) Presence of traffic signal
   c) Street light availability at accident spots
   d) Police patrolling

### iii DATA COLLECTION

surveys were conducted using specially designed questionnaires. These were shared with professionals who have experience in road safety and highway management. The traffic police officers, road safety auditors, and civil engineers who have good knowledge and experience in road safety and traffic management. A total of around 10 experts participated.

Two types of responses were collected:

For the AHP method, the experts were asked to compare every two factors (like driver behavior vs. road condition) and give their judgment using a 1 to 9 scale. This information was used to form a pairwise comparison matrix.

For the SWARA method, the same experts were asked to rank the factors in order of importance and to rate how much more important one factor was compared to the next.

### iv Methodological Framework

#### 1. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty, is a decision-making method used to tackle problems involving multiple criteria. It effectively combines both qualitative and quantitative data by breaking down complex decisions into a clear, hierarchical structure of goals, criteria, sub-criteria, and alternatives. Through pairwise comparisons, AHP helps decision-makers systematically evaluate and prioritize factors, especially when subjective judgments are involved. This approach simplifies complex problems, making them easier to understand and ensuring more consistent and transparent decisions. The application of AHP can be broken down into six steps and is given in

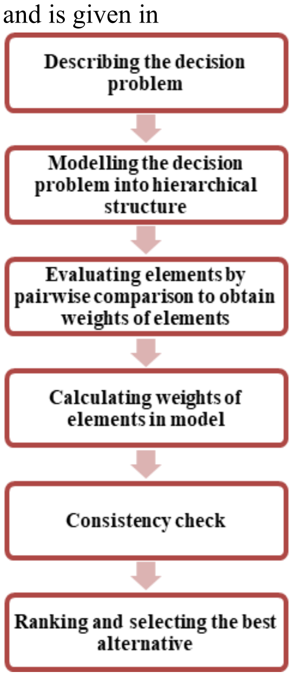


Figure 2: Flowchart of AHP

The first step in the Analytic Hierarchy Process (AHP) involves clearly defining the decision problem and identifying relevant criteria and sub-criteria through literature review and expert consultation. This ensures the analysis reflects the actual decision environment.

Next, the decision problem is structured into a hierarchical model. The top level represents the overall goal, followed by levels for main criteria, sub-criteria, and finally the alternatives or options being evaluated.

Pairwise comparisons are then used to assess the relative importance of elements at each level. Experts rate the importance of each pair of criteria using the Saaty Scale, which provides a standardized scale for judgments. These ratings are arranged in a square pairwise comparison matrix.

Weights for each criterion are calculated by normalizing the matrix and averaging the rows. The normalized matrix is created by dividing each element by the total of its column, and final weights are obtained by taking the average of each row.

To ensure the reliability of these judgments, a consistency check is performed. This involves computing a consistency vector and determining the largest eigenvalue (λ_max), from which the Consistency Index (CI) and Consistency Ratio (CR) are derived. If the CR is $\leq 0.1$, the matrix is considered consistent. Otherwise, judgments need to be revised.

Finally, the weights from all levels of the hierarchy are combined to calculate the overall priority of each alternative. The alternative with the highest final weight is considered the best choice.

#### 2. Stepwise Weight Assessment Ratio Analysis (SWARA)

The Step-wise Weight Assessment Ratio Analysis (SWARA) is a widely used Multi-Criteria Decision-Making (MCDM) technique that supports expert-based evaluation, particularly when judgments are expressed in qualitative or linguistic terms. It is valued for its simplicity and efficiency in addressing decision problems in strategic and policy-level applications.

The SWARA method involves the following steps: initially, the criteria are ranked in descending order of importance by domain experts. From the second criterion onward, the relative importance of each criterion compared to the one ranked above it is evaluated. This is represented as SjS_jSj.

The coefficient Kj for each criterion is calculated as:

Kj=Sj+1 for j>1

Using these coefficients, the recalculated weights qj are determined as:

$q_1$=1 = qj=qj−1/Kj for j>1

Finally, the normalized weights, which represent the relative importance of each criterion, are calculated using:

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j}$$

These weights provide a quantitative basis for comparing and prioritizing the decision criteria, enabling a more transparent and rational decision-making process.

## IV. DATA ANALYSIS

For this study, two separate Google Forms were created, one for the SWARA method and one for the AHP method. These forms were shared with experts to understand their opinions about the factors that cause road accidents in Dhule city, especially on NH-03. The survey was filled out by traffic police officers, road safety auditors, and civil engineers who have good knowledge and experience in road safety and traffic management. Using different forms for SWARA and AHP helped collect the right type of information needed for each method. This made the analysis clearer and more accurate.

All the ten expertise expressed their opinion about the road safety parameters and ranked the parameters based on their experience and knowledge.

For ease of analysis and ranking, the main parameters influencing road accidents were abbreviated as follows:

Driver Behavior (P1), Road Condition (P2), Vehicle Condition (P3), Weather/Environmental Condition (P4), and Traffic Control Measures (P5). These were further classified into sub-parameters. Under Driver Behavior (P1), the sub-factors included Helmet/Seatbelt Usage (D1), Mobile Phone Usage While Driving (D2), Wrong Side Driving (D3), and Alcohol Usage (D4). Road Condition (P2) included Road Width and Shoulder Condition (S1), Signage Visibility and Condition (S2), Medians/Dividers (S3), Road Curvature (S4), Presence of Pedestrian Crossings or Service Roads (S5), and Lane Markings (S6). For Traffic Control Measures (P5), the sub-parameters were CCTV Surveillance (T1), Presence of Traffic Signals (T2), Street Lighting at Accident Spots (T3), and Police Patrolling (T4).

### v AHP Analysis

The following is the example of AHP analysis of main parameters by expert 1

Table.1: Pairwise matrix for main parameters by expert 1

| Parameters | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| P1 | 1.00 | 3.00 | 7.00 | 5.00 | 3.00 |
| P2 | 0.33 | 1.00 | 3.00 | 9.00 | 7.00 |
| P3 | 0.14 | 0.33 | 1.00 | 9.00 | 7.00 |
| P4 | 0.20 | 0.11 | 0.11 | 1.00 | 3.00 |
| P5 | 0.33 | 0.14 | 0.14 | 0.33 | 1.00 |
| Total | 2.01 | 4.59 | 11.25 | 24.33 | 21.00 |

Table **Error! No text of specified style in document.**.2 :Pairwise matrix for main parameters by expert 1

| Parameters | P1 | P2 | P3 | P4 | P5 | Priority vector | Weighted Sum |
|---|---|---|---|---|---|---|---|
| P1 | 1/2 | 2/3 | 5/8 | 1/5 | 3/7 | 0.48 | 1.02 |
| P2 | 1/6 | 2/9 | 1/4 | 3/8 | 1.00 | 0.40 | 0.61 |
| P3 | 0.07 | 0.07 | 0.09 | 3/8 | 2.33 | 0.59 | 0.48 |
| P4 | 0.10 | 0.02 | 0.01 | 0.04 | 3 | 0.63 | 0.25 |
| P5 | 1/6 | 0.03 | 0.01 | 0.01 | 0.05 | 0.05 | 0.11 |

### vi SWARA ANALYSIS

The following is the example of SWARA analysis of main parameters by expert 1

Table.3: SWARA analysis by expert 1

| Expert 1 | | | | |
|---|---|---|---|---|
| MAIN CRITERIA(j) | Relative Significance $S_j$ | $K_j$ | $q_j$ | $W_j$ |
| P3 | | 1 | 1 | 31.72 |
| P2 | 0.3 | 1.3 | 0.77 | 24.40 |
| P1 | 0.35 | 1.35 | 0.57 | 18.07 |
| P5 | 0.2 | 1.2 | 0.47 | 15.06 |
| P4 | 0.4 | 1.4 | 0.34 | 10.76 |
| | | TOTAL | 3.15 | |

## V. RESULTS

The comparative analysis using AHP and SWARA methods revealed that driver behaviour is the most influential factor contributing to road accidents on the NH-53 section passing through Dhule city. However, the methods differed in the prioritization of other factors. The AHP method ranked helmet usage, seatbelt compliance, and road width as high-priority factors, reflecting its structured and consistency-based evaluation. In contrast, the SWARA method gave more importance to wrong-side driving, signage visibility, and traffic control measures, capturing expert perceptions based on local experience.

A key commonality between both methods was the high ranking of street lighting, indicating its universally recognized role in ensuring nighttime road safety. These differences and similarities provide a multi-dimensional understanding of the factors influencing road safety, allowing for more informed and balanced decision-making in highway management.

i AHP

| Main Parameters | Weight | Rank |
|---|---|---|
| Driver Behaviour (P1) | 4.57 | 1 |
| Road Condition (P2) | 2.55 | 2 |
| Vehicle Condition (P3) | 1.98 | 3 |
| Weather / Environmental Condition (P4) | 1.54 | 4 |
| Traffic Control Measures (P5) | 0.52 | 5 |

| Driver Behaviour | Weight | Rank |
|---|---|---|
| Helmet/ Seatbelt usage (D1) | 5.39 | 1 |
| Mobile phone usage while driving (D2) | 2.73 | 2 |
| Wrong side driving (D3) | 1.34 | 3 |
| Alcohol usage (D4) | 0.54 | 4 |

| Traffic Safety Measures | Weight | Rank |
|---|---|---|
| CCTV surveillance (T1) | 5.16 | 1 |
| Presence of traffic signal (T2) | 2.74 | 2 |
| Street light availability at accident spots (T3) | 1.45 | 3 |
| Police patrolling (T4) | 0.65 | 4 |

| Road Condition Parameters | Weight | Rank |
|---|---|---|
| Road width, shoulder condition (S1) | 3.80 | 1 |
| Signage visibility and condition (S2) | 2.46 | 2 |
| Medians/ dividers presence and condition (S3) | 1.61 | 3 |
| Horizontal / vertical curves (S4) | 1.09 | 4 |
| Presence of pedestrian crossing / Service roads(S5) | 0.76 | 5 |
| Lane markings (S6) | 0.41 | 6 |

ii SWARA

| Criteria | Parameters | Weight | Rank |
|---|---|---|---|
| P1 | Driver Behaviour | 289.51 | 1 |
| P2 | Road Condition | 208.30 | 3 |
| P3 | Vehicle Condition | 192.13 | 4 |
| P4 | Weather / Environmental Condition | 84.79 | 5 |
| P5 | Traffic Control Measures | 216.87 | 2 |

| Criteria | Driver Behaviour Parameters | Weight | Rank |
|---|---|---|---|
| D1 | Helmet/ Seatbelt usage | 190.61 | 4 |
| D2 | Mobile phone usage while driving | 286.45 | 2 |
| D3 | Wrong side driving | 315.72 | 1 |
| D4 | Alcohol usage | 207.22 | 3 |

| Criteria | Traffic Control Measures | Weight | Rank |
|---|---|---|---|
| T1 | CCTV surveillance | 187.55 | 4 |
| T2 | Presence of traffic signal | 274.27 | 2 |
| T3 | Street light availability at accident spots | 321.00 | 1 |
| T4 | Police patrolling | 217.19 | 3 |

| Criteria | Road Condition Parameters | Weight | Rank |
|---|---|---|---|
| S1 | Road width, shoulder condition | 192.71 | 3 |
| S2 | Signage visibility and condition | 228.64 | 1 |
| S3 | Medians/ dividers presence and condition | 178.51 | 5 |
| S4 | Horizontal / vertical curves | 71.52 | 6 |
| S5 | Presence of pedestrian crossing / Service roads | 198.99 | 2 |
| S6 | Lane markings | 173.57 | 4 |

## VI CONCLUSION

This study focused on identifying and prioritizing the factors influencing road accidents on NH-03 passing through Dhule city using two MCDM methods: AHP and SWARA. Expert opinions were collected from traffic police, civil engineers, and road safety auditors through structured questionnaires.

Both methods identified driver behaviour as the most critical factor. However, there were differences in other rankings. AHP gave the lowest importance to traffic control measures, while SWARA ranked them second. In terms of road characteristics, AHP emphasized road width and shoulder condition, whereas SWARA prioritized signage visibility.

For behavioral sub-factors, AHP focused on helmet and seatbelt usage, while SWARA gave the highest weight to wrong-side driving. Street lighting was consistently ranked high by both methods, highlighting its role in accident prevention.

AHP offered a more structured and logical approach, whereas SWARA allowed subjective and experience-based judgment. Using both methods together provided a broader and more balanced understanding of the key accident-causing factors.

The results suggest that improving driver behaviour, signage visibility, and street lighting should be top priorities for enhancing safety along the NH-03 corridor in Dhule. Authorities can use these insights for more focused road safety planning.

This study is limited to expert opinion and a specific location. Future research can include accident data, expand to more regions, or apply additional MCDM techniques for deeper analysis.

REFERENCE

[1] Alizadeh A, Amini A, and Omrani H. 2020. "An integrated group best-worst method – Data envelopment analysis approach for evaluating road safety: A case of Iran." Measurement 152 (2020)107330.https://doi.org/10.1016/j.measurement.2019.107330 .

[2] Khorasani G, Rahimi M, and Tatari A, and Yadollahi A. 2012. "Implementation of MCDM Methods in Road Safety Management." International Conference on Transport, Civil, Architecture and Environment engineering (ICTCAEE'2012) December 26-27, 2012 Dubai (UAE).

[3] Chen F, Li y, She L, Sun H, and Sun Z.2022. "Measuring road safety achievement based on EWM-GRA-SVD: A decision-making support system for APEC countries." Knowledge-Based Systems 252 (2022) 109373. https://doi.org/10.1016/j.knosys.2022.109373.

[4] Nenadic D. "Ranking dangerous sections of the road using the mcdm model." Decision Making Applications in Management and Engineering., vol. 2, no. 1, pp. 115–131, 2019.

[5] Cheni F, Cuid H, Dingb Y, Gaoe H, Guoc Y, Li Y, Lia Y, Zhouf Z, and Zhuh S. 2023. "An integrated decision model with reliability to support transport safety system analysis." ReliabilityEngineeringandSystemSafety239(2023)109540. https://doi.org/10.1016/j.ress.2023.109540.

[6] Dordevic M, Softić E, Subotić M, Stević Ž, Ponjavic M, and Vrtagić S. "Ranking Road sections based on mcdm model: New improved fuzzy swara (imf swara)." Axioms, vol. 10, no. 2, 2021. https://doi.org/10.3390/axioms10020092.

[7] Dr Mirmohammadi M, Dr Verki M, and Fazelpour S. 2013. "Investigation of Road Accidents and Casualties Factors with MCDM Methods in Iran." Journal of American Science 2013;9(7s). http://www.jofamericanscience.org/.

[8] Stevi Ž, Subotić M, Softić E, and Božić B. 2022 "Multi-Criteria Decision-Making Model for Evaluating Safety of Road Sections." Journal of Intelligent Management Decision. vol. 1, no. 2, pp. 78–87, 2022, https://doi.org/10.56578/jimd010201.

[9] Guido G, Haghshenas S, Haghshenas S, Vitale A, Gallelli V, and Astarita V. 2022. "Prioritizing the Potential Smartification Measures by Using an Integrated Decision Support System with Sustainable Development Goals (a Case Study in Southern Italy)," Safety, vol. 8, no. 2, https://doi.org/10.3390/safety8020035.

[10] Badi I. and Bouraima M. "Development of MCDM-based Frameworks for Proactively Managing the Most Critical Risk Factors for Transport Accidents: A Case Study in Libya." Spectrum of Engineering and Management Sciences, Volume 1, Issue 1 (2023) 38-47. https://doi.org/10.31181/sems1120231b.

[11] Zhou Na, Stevi Z, Suboti M, Das D, Kou G and Moslem S. 2024 "A novel interval rough model for optimizing road network performance and safety". Expert Systems with Applications 255 (2024) 124844. https://doi.org/10.1016/j.eswa.2024.124844.

[12] Trivedi P and Kalita K and Shah J. 2024. "A Hybrid Best-Worst Method (BWM)—Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Approach for Prioritizing Road Safety Improvements." IEEE Access · February 2024.

[13] Komasi H, Nemati A, Zolfani S and Taheri H. 2024. "Road safety evaluation in inner-city roads and suburban roads based on a novel-hybrid MCDM mode." Ain Shams Engineering Journal 15 (2024) 102796. https://doi.org/10.1016/j.asej.2024.102796.

[14] Alghazzawi D, Noor A, Alolaiyan H and Khalifa H. 2024. "A novel perspective on the selection of an effective approach to reduce road traffic accidents under Fermatean fuzzy settings." PLOS ONE: Selection of an effective approach to reduce

road traffic accidents 19(5): e0303139. https://doi.org/10.1371/journal.pone.0303139