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Factors influencing unsafe acts in the automotive industry using grounded theory and fuzzy DEMATEL

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Occupational accidents are recognized as the cause of numerous severe injuries and fatalities worldwide. Unsafe Acts (UAs) and unsafe conditions are the two primary origins of accidents, dentifying and prioritizing them can help prevent accidents from occurring. So, the aim of this study was to identify and prioritize the factors influencing unsafe acts in the automotive industry using grounded theory and fuzzy DEMATEL. A conceptual model using accident reports and the grounded theory approach was created. This included steps such as data collection, open coding, axial coding, selective coding, and a model saturation test. The fuzzy DEMATEL was used to determiene intensity of the relationship between influencing factors. The 'Government policies' factor, with the highest value (D + R) of 1.49, stands out as a significant influence on workplace safety. As a criterion of the 'extra-organizational level,' it refers to factors outside the direct control of the organization but still influencing its operations. This factor's importance surpasses that of other factors in contributing to unsafe practices. Other crucial factors include the economic situation, foreign policy, social situation, and work environment, with values of (D + R) equal to 1.47, 1.35, 1.34, and 1.13, respectively. Among the cause groups, 'Organizational climate' had the maximum value (D – R), indicating its significant impact on unsafe practices. The 'Foreign policy' factor, with a value (D – R) equal to 0.77, was next in importance. This study's findings provide insights and actionable strategies for safety managers in the automotive industry. By understanding the causes of workers' unsafe actions and how human factors lead to accidents, they can formulate intervention strategies to prevent and control unsafe actions, empowering them to make a real difference in workplace safety.

Keywords Grounded theory, Fuzzy DEMATEL, Unsafe acts, Automobile industry

Occupational accidents are recognized as the cause of numerous severe injuries and fatalities worldwide. Based on the most recent International Labor Organization (ILO) estimations, over 395 million workers globally have sustained non-fatal work-related injuries. In addition, approximately 2.93 million workers have died because of work-related factors, which indicates an increase of more than 12% compared to two decades previously[1]. In Iran, work-related occupational accidents in 2022 totaled 7,800 accidents, with 711 resulting in deaths. Of these, 36% were related to industrial sectors.

Unsafe Acts (UAs) and unsafe conditions are the two primary origins of accidents. Reports suggest that about 70–95% of accidents occur due to UAs. This implies that UAs are more prominent in accidents than in unsafe conditions[2,3]. Some studies have explored the factors influencing unsafe behaviors. For instance, Aliabadi et al.[4] identified organizational weaknesses as the primary cause of accidents directly linked to workers' safety violations and errors. Liu et al.[5] demonstrated that the external environment, inadequate leadership, and organizational factors influenced workers' UAs. Furthermore, Fa et al.[6] identified external and organizational factors and inadequate supervision as the main contributors to unsafe behaviors. Using a fishbone diagram, Yu et al.[7] categorized the main factors affecting UAs among miners into five groups: individual factors, physical environment, safety leadership, safety management, and group factors. As whole, personal characteristics, safety climate, risk perception, stress, lack of safety awareness, job stress[8,9], and other organizational and economic

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factors are known as the most critical factors affecting UAs[10]. Researchers in Iran have reported the prevalence of UAs among workers to be between 40.37% and 54.76%[11]. A study in Iran identified the factors influencing unsafe behaviors as social factors, organizational factors, contractor-related factors, safety management and supervision, working conditions, and individual characteristics[12]. In addition, most studies conducted on UAs are quantitative and have focused solely on factors such as workers' perceptions. To better understand the factors influencing unsafe behaviors and reduce occupational accidents in work environments, it is crucial and necessary to examine these factors in depth[13].

The factors influencing unsafe behaviors have increased with the evolution of various accident and safety models. In previous literature, researchers often relied on analyzing accident reports or utilizing expert opinions through qualitative studies to determine the factors influencing UAs and accident occurrences[14–16]. Therefore, qualitative studies have been a valuable tool for discovering individuals' experiences in various situations and drawing realistic conclusions from their experiences in the real world. Qualitative research can deeply analyze the underlying factors behind accidents regarding behaviors, phenomena, or issues. Qualitative studies are carried out using various approaches, including grounded theory.

Grounded theory is an inductive method ideal for investigating the nature of research and allows concepts and categories to emerge with greater objectivity naturally. This theory has been effectively utilized across diverse fields[17,18]. For a better understanding of causal (cause-and-effect) relationships among criteria within a model, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method can be employed. This method utilizes graph theory and matrix tools to identify logical relationships among influential factors in complex systems. This approach constructs a matrix by analyzing the logical relationships among influential factors. Subsequently, the assessment parameters for each influential factor are derived by transforming the matrix to include the degree of influence, centrality, and causal degree[19].

The automotive industry in Iran plays a significant role in the national economy, contributing 18% to the total value added of industries and approximately 3.5% to the Gross Domestic Product (GDP). Within this industry, diverse processes and working conditions are observed where accidents occur with varying probabilities and intensities[20]. Shafei et al.'s[21] study, which aimed to determine the root causes of accidents in the automotive industry, indicates that deficiencies in management systems and organizational issues significantly impact occupational accidents in this sector. They believe that addressing approximately half of the risk factors makes controlling 80% of occupational accidents possible.

Since identifying factors influencing UAs based on the socioeconomic structure and characteristics of diverse processes in the automotive industry has not been conducted to date, and it need to investigate causal relationships among these factors to propose practical and effective safety risk management strategies. So, the aim of this study was to identify and prioritize the factors influencing unsafe acts in the automotive industry using grounded theory and fuzzy DEMATEL to prevent the occurrence of accidents.

Materials and methods

This qualitative research was conducted with the grounded theory approach. It relied on the primary dataset from the HSE department, a fundamental entity responsible for monitoring and ensuring occupational safety in the automotive industry. This 5-year report on accidents in the automotive industry, which includes all accidents resulting in lost workdays, served as the cornerstone of our research. In addition to this crucial dataset, we gathered supplementary information on the causes of these accidents through interviews with industry experts. Informed consent form and ethics approval was also presented in the Supplementary material. According to the general guidelines of ethics in medical science research with human subjects based on countriy regulations in all universites, the authers confirm that all methods were performed in accordance with the relevant guidelines and regulations.

A semi-structured interview with a grounded theory approach was conducted for data collection between December 2022 and June 2023. Five questions were designed by the research team based on industry accident data, pilot interviews and pervious studies. Then, In order to avoid bias in data selection and selecting appropriate questions for the semi-structured interview, two experts were independently used. Finally, a checklist containing questions for the interview was compliedThese questions facilitated participants' engagement with the research process. Using a snowball approach, targeted sampling was used to select interviewees based on their professional experience and knowledge relevant to the research questions. To prevent bias in data selection in the snowball approach, quotas were set based on work experience (at least 3 years), age (at least 30 years), and education (undergraduate and graduate). The expertise of the 21 individuals (comprising one manager, three supervisors, and 17 specialists) selected for interviews was instrumental in providing valuable insights. Before each interview, informed satisfaction was obtained, and the confidentiality of collected data was assured. Interviews were recorded with participants' permission, and notes were taken for verification and validation after each interview to enhance the credibility of the collected data. Each interview lasted between 50 and 70 min. Subsequently, interviews were meticulously transcribed and typed. Two research team members independently coded and analyzed the factors influencing accidents using MAXQDA software (version 10). The research roadmap and procedure are presented in Fig. 1.

Grounded theory

Grounded Theory comprises four stages: data collection, open coding, axial coding, selective coding, and model saturation testing[22] (Fig. 1). In open coding, researchers delve into deep analysis and coding of primary data[23]. Axial coding involves clustering categories formed during open coding and establishing correlations among different categories to create a larger category, namely the core category[24]. Selective coding builds on axial coding and involves a combination of relationships between main categories and the abstraction of core categories, which can summarize all categories and establish the relationships between core categories and subcategories in

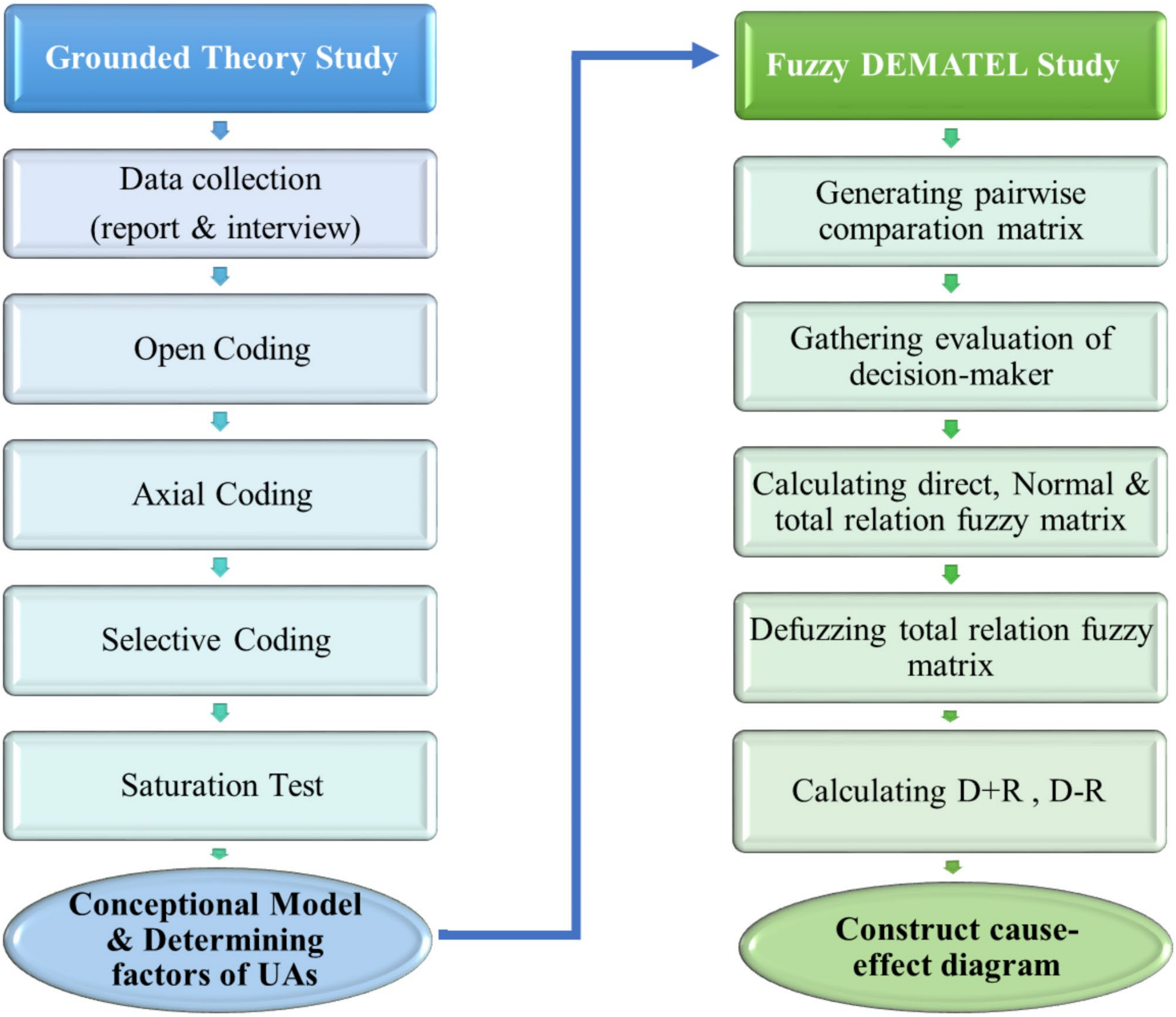

Fig. 1. Roadmap and Research procedury.

a clear pathway. Finally, the model is validated using saturation testing. For this purpose, new data are evaluated against the model. The thoroughness of the analysis process ensures that the core conceptual model is considered theoretically saturated when concepts or categories emerging from newly collected data merge with existing concepts or categories, and no new concept or category is generated[23,25].

After developing the conceptual model using accident reports and grounded Theory, we used the DEMATEL pairwise comparison method to determine causal relationships between criteria. Ten experts in the automotive industry applied this method, which allows for better decisions about the extent and intensity of relationships between criteria. They used a verbal questionnaire about the level and intensity of relationships between criteria. To integrate and clarify expert opinions in an uncertain environment, we employed the Fuzzy DEMATEL method[26].

Fuzzy DEMATEL method

The fuzzy DEMATEL method calculations were carried out in the following order:

1. Formation of direct relationship matrix: According to experts' opinions, relationships governing the connections between heads were determined, and ultimately, an n × n matrix of pairwise comparisons among factors was formed based on the experts' opinion (where aij denotes the influence degree of criterion ci on cj).

$$\tilde{E}^{k} = \begin{bmatrix} 0 & \cdots & \tilde{E}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{E}^{k}_{n1} & \cdots & 0 \end{bmatrix}, K = 1,2, \ldots, p \tag{1}$$

According to Table 1, initial direct matrix ($\tilde{E}$) was obtained from the average results of the experts' matrix to measure the relationship between different criteria[26,27].

2. Calculating normalized direct-relation fuzzy matrix($\tilde{F}$): The normalization coefficient equals the maximum sum of rows and the maximum sum of columns of the average matrix (Eq. 2). By dividing the direct relationship matrix by the normalization coefficient, the normalized direct relationship matrix ($\tilde{F}$) is obtained.

$$\tilde{E} = \frac{\tilde{E}^{1} + \tilde{E}^{2} + \ldots + \tilde{E}^{P}}{P} \tag{2}$$

$$\tilde{F} = \begin{bmatrix} 0 & \cdots & \tilde{F}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{F}_{n1} & \cdots & 0 \end{bmatrix} \tag{3}$$

$$\tilde{e}_{ij} = (l_{ij}, \ m_{ij}, \ u_{ij}) \tag{4}$$

3. Calculation total-relation fuzzy matrix ($\tilde{T}$): matrix $\tilde{F}$, which is the criterion matrix of total influence, is calculated using the following equation.

$$\tilde{F} = \frac{\tilde{E}}{\gamma} \tag{5}$$

$$\gamma = max \sum {}_{j=1}^{n} u_j \tag{6}$$

$$\tilde{F} = \begin{bmatrix} \tilde{F}_{11} & \cdots & \tilde{F}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{F}_{n1} & \cdots & \tilde{F}_{nn} \end{bmatrix} \tag{7}$$

$$\tilde{f}_{ij} = \frac{\tilde{e}_{ij}}{\gamma} \left(\frac{l_{ij,}}{\gamma}, \frac{m_{ij,}}{\gamma}, \frac{u_{ij}}{\gamma} \right) \tag{8}$$

4. Calculating total-relation fuzzy matrix (T˜): A total relation matrix is computed would be represented with as shown below equations.

$$T = \begin{bmatrix} t_{11} & \cdots & t_{1n} \\ \vdots & \ddots & \vdots \\ t_{n1} & \cdots & t_{nn} \end{bmatrix} \tag{9}$$

$$\mathrm{t}_{ij} = (l'_{ij} + m'_{ij} + u'_{ij}) \tag{10}$$

$$Matrix \left[l'_{ij} \right] = F_l \times (1 - F_l)^{-1} \tag{11}$$

$$Matrix \left[m'_{ij} \right] = F_m \times (1 - F_m)^{-1} \tag{12}$$

$$Matrix \left[u'_{ij} \right] = F_u \times (1 - F_u)^{-1} \tag{13}$$

5. De-fuzzification: Converting total-relation fuzzy matrix (T˜) into non-Fuzzy total-relation matrix (T).

Linguistic variable	Fuzzy number
No influence	(0,0.1,0.3)
Very low influence	(0.1,0.3,05)
Low influence	(0.3,0.5,0.7)
High influence	(0.5,0.7,0.9)
Very High influence	(0.7,0.9,1)

Table 1. Fuzzy number according to linguistic variable.

$$\mathrm{t}_{ij} = \frac{1}{4}(l'_{ij} + 2m'_{ij} + u'_{ij}) \tag{14}$$

$$T = \begin{bmatrix} t_{11} & \cdots & t_{1n} \\ \vdots & \ddots & \vdots \\ t_{n1} & \cdots & t_{nn} \end{bmatrix} \tag{15}$$

6. Cause-and-effect diagram drawing: Initially, the values of tij were obtained using the sum of each row (Di) and the sum of each column (Rj).

$$D = \sum\nolimits_{j=1}^{n} \mathrm{t}_{ij},\ (1{,}2, \ldots , \mathrm{n}) \tag{16}$$

$$R = \sum\nolimits_{j=1}^{n} \mathrm{t}_{ij},\ (1{,}2, \ldots , \mathrm{n}) \tag{17}$$

Each row sum (Di) indicates the level of penetration and effectiveness of the criteria, and each column sum (Rj) indicates the susceptibility and impact level of criterion i. Then, values (Di + Rj) and (Di-Rj) were calculated, determining the intensity of interaction and effectiveness of a specific factor used in constructing the cause-and-effect diagram. After drawing this diagram, an average threshold was first calculated from the elements of matrix T to simplify the relationships between criteria and their directions of influence. Then, only relationships between each pair of factors that exceed the threshold in matrix T were considered, and the direction of each criterion's influence on another criterion was depicted as an arrow. The results can be utilized to propose solutions and recommendations for reducing accidents in the automotive industry and enhancing safety.

Results

This study used grounded theory to analyze accident reports as primary data. After screening, 40 accident reports from 2017 to 2021 were selected. The accidents primarily involved body-object collisions, person-object collisions, entrapments between objects, falls to non-level surfaces, and falls to level surfaces. Table 2 shows 213 expressions related to relevant concepts identified during the open coding phase. Subsequently, 146 initial concepts were screened and clustered. Based on their correlations, 47 open codes emerged independently, including government policies, economic situation, and Financial resources, as shown in the second column of Table 2. The primary conceptual categories were classified into 19 UA categories through axial coding. Systematic comparisons and clustering of these 19 categories resulted in identifying 4 core concepts, as indicated in the fourth column of Table 2. In the selective coding phase, the primary categories were grouped to obtain principal categories of factors influencing accidents in the automotive industry. A conceptual model of risk factors for unsafe behaviors among automotive industry workers was developed by summarizing the results of accident report coding and interview records, categorized into four primary levels: meta-organizational, organizational, supervisory, and operational factors.

Finally, a saturation test was conducted to evaluate the validity and integration of the conceptual model. This test was performed several weeks after the model's creation by another research team member to remove any researcher bias.The model was validated using the data of 10 accident reports of the automotive industry. The results of the test indicated that no new concepts needed to be included in the model. In addition, logical relationships were revealed after testing the three coding processes in grounded theory, indicating that the factors influencing UA were investigated, leading to a saturated theoretical model.

According to the results obtained from qualitative analyses using a grounded theory approach in Table 2, the conceptual model of the factors influencing accidents in the automotive industry is shown in Fig. 2.

Based on the model illustrated in Fig. 2, the results obtained from the criteria sourced from grounded Theory were utilized to determine the connections between the criteria. Following experts completed the relevant questionnaire regarding the effect of the criteria on each other, the average opinions were gathered by forming the direct relationship fuzzy matrix. The next step involved normalizing the direct relationship matrix and forming the total relationship matrix (Appendix A). The values of each row of the total matrix were employed to determine the D value, and each column's values were utilized to determine the R-value (columns 7 and 8 of Table 2). Ultimately, with the D and R values, the interaction of the criteria (D + R) and the influence (D - R) were established in Table 2. As shown in the model in Fig. 3, the criteria were classified into four levels. In the total matrix (Appendix A), the mean values of the criteria at each level were specified as the value of that level, with the values of (D + R) and (D - R) for each level presented in columns 4 and 5 of Table 3. Moreover, based on the ordered pairs (D + R) and (D - R) of the 3criteria in Table 2, the causal diagram was depicted as illustrated in Fig. 3.

Based on the results presented in Table 3, the factor' Government policies' has the highest (D + R) value which is 1.49. As depicted in Fig. 5, as one of the criteria at the 'meta-organizational level,' this factor holds greater importance than other factors in influencing UAs. The other important factors include 'economic situation,' 'foreign policy,' 'social situation,' and 'work environment factor' with (D + R) values of 1.47, 1.35, 1.34, and 1.13, respectively. As presented in Fig. 5, the 'organizational climate' factor is less important than the other factors in influencing UAs.

The values of (D - R) were used to classify the factors based on the cause-and-effect group. Factors with positive (D - R) values belong to the cause group (influential factors), while those with negative (D - R) values belong to the effect group (affecting factors). Additionally, (D - R) values indicate the manageability level of each factor, reflecting the priority for management control over UAs. Cause group factors are root causes that are less

Item	Open coding	Axial coding	Selective coding
1	Sanction	Laws and regulations	Meta-organizational Level
	High cost of living	Government policies	
	High cost of purchasing equipment and parts	Foreign policy	
	Government imposed policies	Economic situation	
	Stress and social problems	Social situation	
	Currency fluctuationsCommand pricing		
2	Operating standards and procedures	Organizational process	Organizational Level
	Organization policies	Organizational climate	
	Organizational supervision	Resource management	
	Safety culture	Contractor and project management	
	Safety program and structure	Change management	
	Financial resources		
	Hardware and equipment resources		
	Recruitment procedures		
	Organizational promotion procedure		
	Management of contractors and projects		
	Change management		
3	Failure to obtain a work permit	Supervisory violation	Supervision Level
	Failure to use PPE	Inadequate supervision	
	Failure to provide proper equipment and PPE	Inappropriate operating plan	
	Inadequate supervision in the training program	Not correcting known problems	
	Inadequate monitoring of safe work practices	Supervision of contractors and projects	
	Inadequate supervision of PPE use		
	Inadequate monitoring of equipment PM		
	Lack of coordination of operators		
	Speed of operation		
	Inadequate supervision about work permit		
	Inadequate supervision of safety instructions		
	Failure to correct known issues		
4	Lack of proper teamwork	Individual factors	Operator level
	Poor planning	Physiological state	
	Inadequate training	Mental status	
	Use of tobacco and alcohol	Factor work environment	
	Failure to comply with work and rest requirements		
	Physical fatigue		
	Sickness		
	Mental exhaustion		
	Deficits in attention or lack of concentration		
	Stress		
	Poor attention and concentration		
	Inappropriate work tools		
	Poor quality parts		
	Worn and unsuitable equipment		
	Defects in equipment design and layout		
	Ambient light and noise		
	Weather conditions		

Table 2. Conceptual model of factors causing accidents in the automobile industry.

affected by other factors and are thus more manageable. Conversely, factors in the effect group are primarily influenced by various factors, and their control and improvement are challenging. Based on the findings in Table 3, factors such as 'organizational climate,' 'economic situation,' 'government policies,' 'social situation,' 'regulations,' 'laws,' and 'resource management' have positive (D - R) values and are classified under the cause group. Factors such as inadequate supervision, supervisory violation, and mental status have negative (D - R) values and are categorized under the effect group. Among the cause group factors, 'organizational climate' had the maximum (D - R) value, indicating its highest influence on UAs. Following that, the factor' foreign policy' with a (D - R) value of 0.77 had the next level of importance.

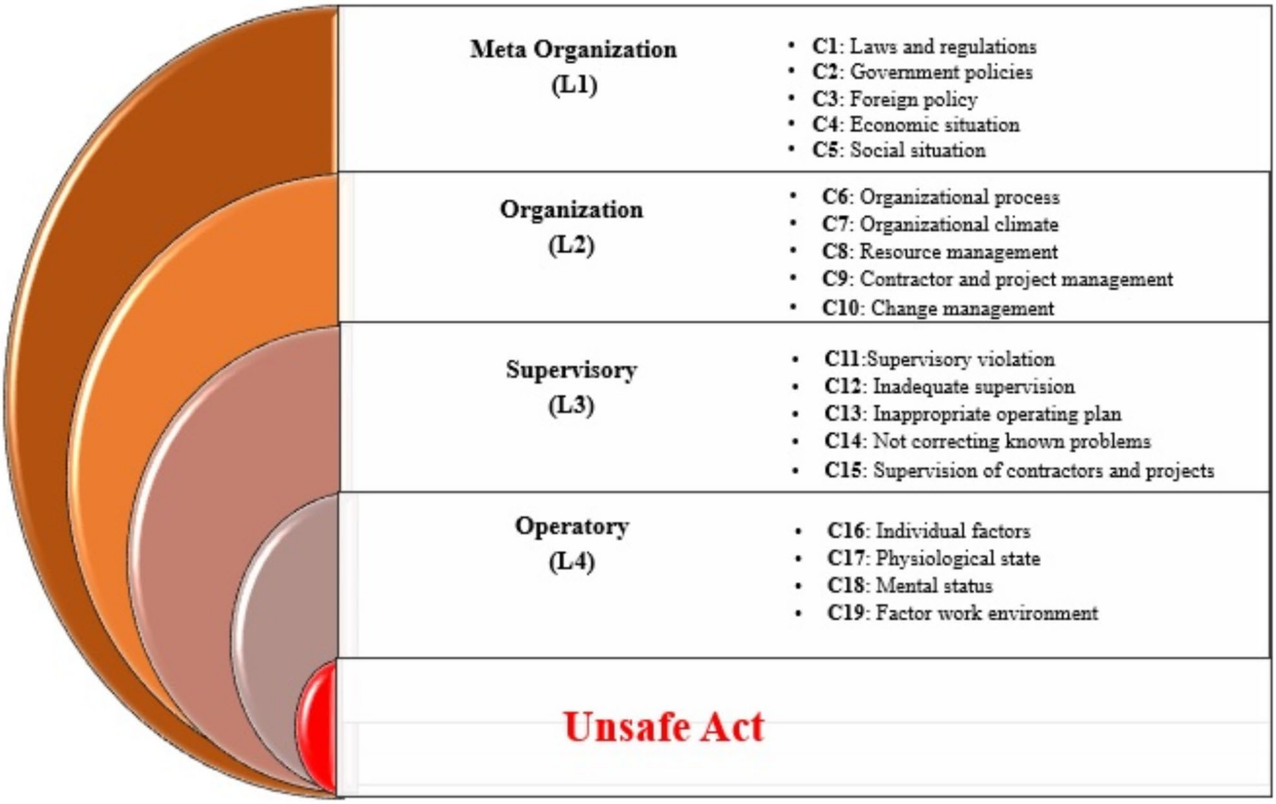

Fig. 2. Conceptual model of factors affecting the unsafe acts among the automotive industry employees.

Examining the factors in the effect group suggests that 'individual factors' and 'physiological state' are particularly critical factors significantly influenced by other factors.

In Fig. 3, factors were divided into four quadrants by determining the average D + R and creating Cartesian coordinates centered at (0, 1). The first group of cause factors (influential) includes all factors from the 'meta-organizational level' and one factor, 'contractor and project management' from the 'organizational' level. The first group of causal factors includes 'organizational process,' 'change management,' and 'inadequate supervision. The third and fourth groups pertain to affecting factors. Factors such as 'supervisory violation,' 'inappropriate operating plan,' 'not correcting known problems, and 'supervision to contractors and projects' are in zone 3, while factors like 'individual factors,' 'physiological status,' 'mental status' and 'factor work environment' are in zone 4. This means that the factors of areas 3 and 4 are affected by the factors of areas 1 and 2.

By setting a threshold equal to 0.026 in the complete T matrix and using the dataset (D + R and D-R), a causal relationship map among the factors was drawn, as shown in Fig. 4. Additionally, with the average of criteria from the regions related to the four levels extracted from the grounded theory in the T matrix and considering the threshold, a causal relationship map among the 'effective levels' in UAs for automotive industry workers is illustrated in Fig. 5.

Discussion

Occupational accidents are identified as the leading cause of severe injuries in industries. UAs are acknowledged as the primary contributors to these accidents. Hence, it is essential to thoroughly examine these factors to understand unsafe behaviors better and reduce occupational accidents in work environments[12]. The aim of this study was to identify and prioritize the factors influencing unsafe acts in the automotive industry using grounded theory and fuzzy DEMATEL. The results revealed four levels of factors, meta-organizational, organizational, supervisory, and operational, as the primary causes of UAs in the automotive industry. Malakoutikhah et al.[16] have demonstrated that the highest incidence of unsafe behaviors in Iran occurs in the steel, petrochemical, refinery, and automotive sectors. The prevalence of unsafe behaviors in these industries is attributed to poor safety culture and inadequate supervision and enforcement of safety protocols[28]. Another study highlighted economic and social conditions, lack of risk awareness, working conditions, and inadequate legislative frameworks for reporting unsafe behaviors as significant contributors to unsafe behaviors among Iranian workers[29]. Mohammadfam et al.[30] found that in the automotive and steel industries in Iran, in addition to working conditions, insufficient safety training, organizational factors, workload, job stress[28], inadequate safety equipment, limited work experience, unsafe working conditions, fatigue, time pressure, and inappropriate work speed are significant reasons behind the occurrence of unsafe behaviors in these sectors[31,32]. Khosravi et al.[12], argue that communication, resource management, environmental conditions, management attitudes, and social

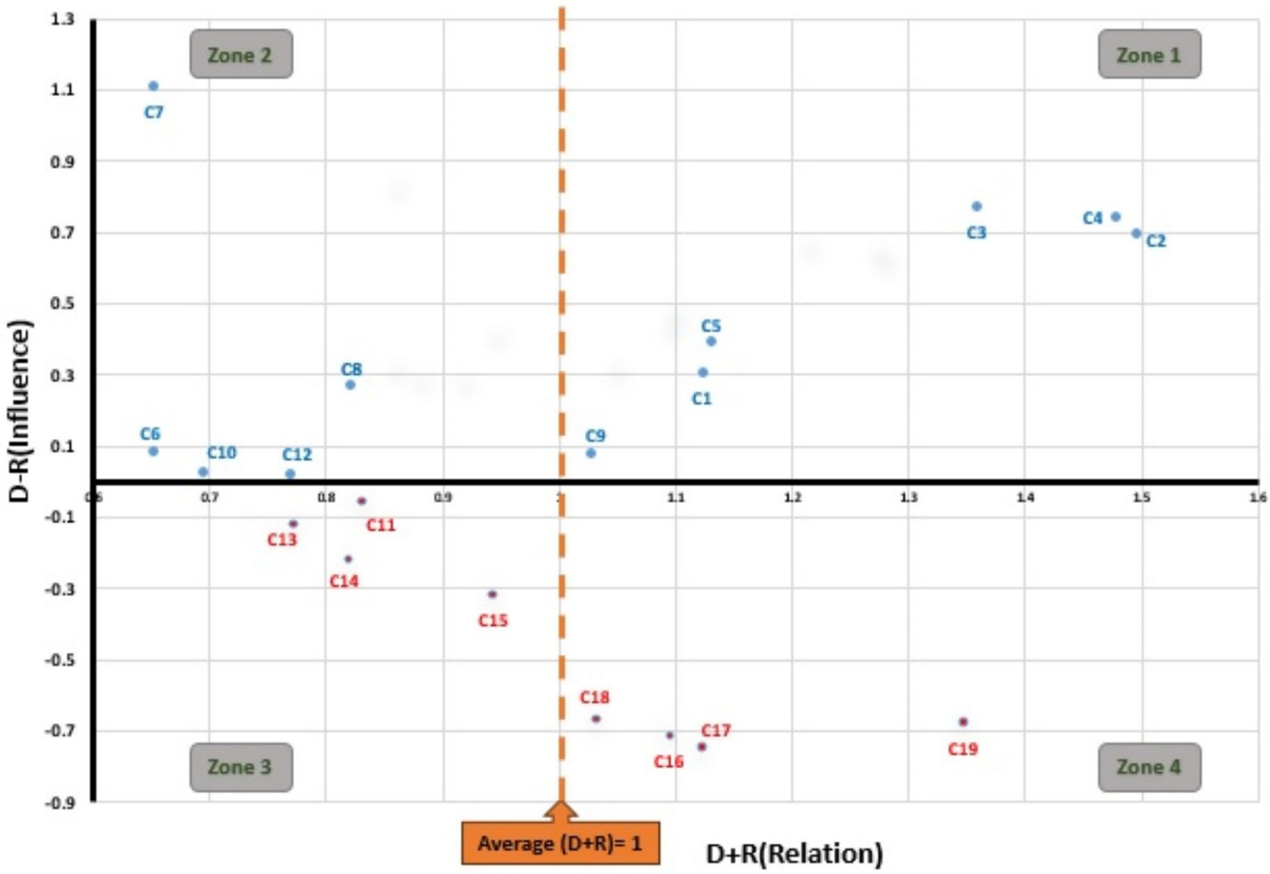

Fig. 3. Cause -effect relation diagram.

<table>
<tr><th></th><th>R</th><th>D</th><th>R+D</th><th>R-D</th><th></th><th>R</th><th>D</th><th>R+D</th><th>R-D</th></tr>
<tr><td rowspan="5">L1</td><td rowspan="5">0.07</td><td rowspan="5">0.2</td><td rowspan="5">0.27</td><td rowspan="5">0.13</td><td>C1</td><td>0.71</td><td>0.41</td><td>1.12(6)</td><td>0.31(6)</td></tr>
<tr><td>C2</td><td>1.09</td><td>0.39</td><td>1.49(1)</td><td>0.69(4)</td></tr>
<tr><td>C3</td><td>1.06</td><td>0.29</td><td>1.35(3)</td><td>0.77(2)</td></tr>
<tr><td>C4</td><td>1.11</td><td>0.65</td><td>1.47(2)</td><td>0.74(3)</td></tr>
<tr><td>C5</td><td>0.76</td><td>0.36</td><td>1.13(5)</td><td>0.39(5)</td></tr>
<tr><td rowspan="5">L2</td><td rowspan="5">0.08</td><td rowspan="5">0.10</td><td rowspan="5">0.18</td><td rowspan="5">0.02</td><td>C6</td><td>0.37</td><td>0.28</td><td>0.66(18)</td><td>0.09(8)</td></tr>
<tr><td>C7</td><td>0.45</td><td>0.36</td><td>0.65(19)</td><td>1.11(1)</td></tr>
<tr><td>C8</td><td>0.65</td><td>0.37</td><td>0.82(13)</td><td>0.27(7)</td></tr>
<tr><td>C9</td><td>0.39</td><td>0.31</td><td>1.02(10)</td><td>0.08(9)</td></tr>
<tr><td>C10</td><td>0.42</td><td>0.41</td><td>0.69(17)</td><td>0.027(10)</td></tr>
<tr><td rowspan="5">L3</td><td rowspan="5">0.10</td><td rowspan="5">0.08</td><td rowspan="5">0.18</td><td rowspan="5">-0.02</td><td>C11</td><td>0.35</td><td>0.41</td><td>0.83(11)</td><td>-0.05(12)</td></tr>
<tr><td>C12</td><td>0.36</td><td>0.34</td><td>0.76(16)</td><td>0.025(11)</td></tr>
<tr><td>C13</td><td>0.32</td><td>0.44</td><td>0.77(15)</td><td>-0.11(13)</td></tr>
<tr><td>C14</td><td>0.31</td><td>0.51</td><td>0.81(14)</td><td>-0.21(14)</td></tr>
<tr><td>C15</td><td>0.31</td><td>0.62</td><td>0.94(11)</td><td>-0.31(15)</td></tr>
<tr><td rowspan="4">L4</td><td rowspan="4">0.18</td><td rowspan="4">0.05</td><td rowspan="4">0.23</td><td rowspan="4">-0.13</td><td>C16</td><td>0.19</td><td>0.91</td><td>1.09(8)</td><td>-0.71(19)</td></tr>
<tr><td>C17</td><td>0.18</td><td>0.93</td><td>1.12(7)</td><td>-0.74(18)</td></tr>
<tr><td>C18</td><td>0.18</td><td>0.84</td><td>1.03(9)</td><td>-0.66(16)</td></tr>
<tr><td>C19</td><td>0.33</td><td>1.01</td><td>1.34(4)</td><td>-0.67(17)</td></tr>
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Table 3. The four influence level for each factor.

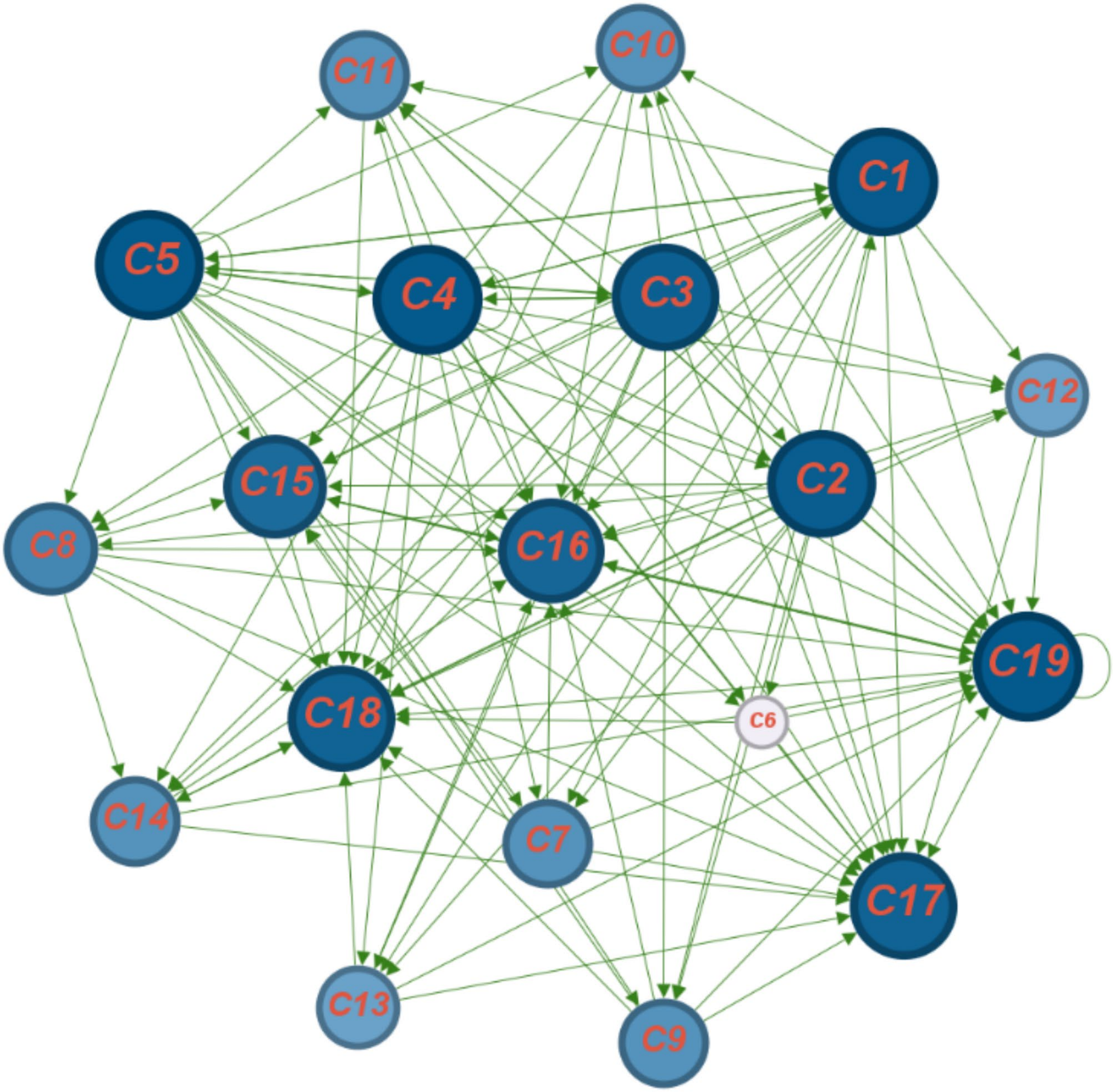

Fig. 4. Causal relations criteria map.

factors are the primary causes of UAs across major industries. Gordon et al.[33], examined the underlying causes of accidents in offshore industry processes based on accident report forms. The causes of unsafe behaviors were categorized into individual and job-related factors. In this study, we emphasize the significant impact of job-related factors, including meta-organizational and organizational aspects, supervision, and oprational aspests. According to Fig. 3; Table 3, meta-organizational factors has asignificant role in causing UAs in the automotive industry These factors, considered cause or influential variables in Zone 1, include 'government policies' that significantly impact UAs more than other factors. Socioeconomic factors, particularly economic instability during contract definition, also contributed significantly to UAs. Another study highlighted economic issues as a significant factor in unsafe behaviors[12], and due to economic instability, projects face financial fluctuations, which can lead to unsafe behaviors.

Similarly, Mullen et al.[34] emphasizes that inadequate resources (time and budget) can create pressure for managers and workers to prioritize safety and influence the adoption of safety procedures. In line with this, Malakoutikhah et al.[13] found that many safety experts attributed the lack of investment in safety to a lack of understanding of the direct and indirect costs of accidents and the economic value of safety measures. These findings are significant and should be of interest to all in the automotive industry. Compliance with 'laws and regulations' is another critical factor identified with the highest causal significance at the meta-organizational level in contributing to UAs. Naghavi et al.[35] also pointed out that the absence of "national standards" in the

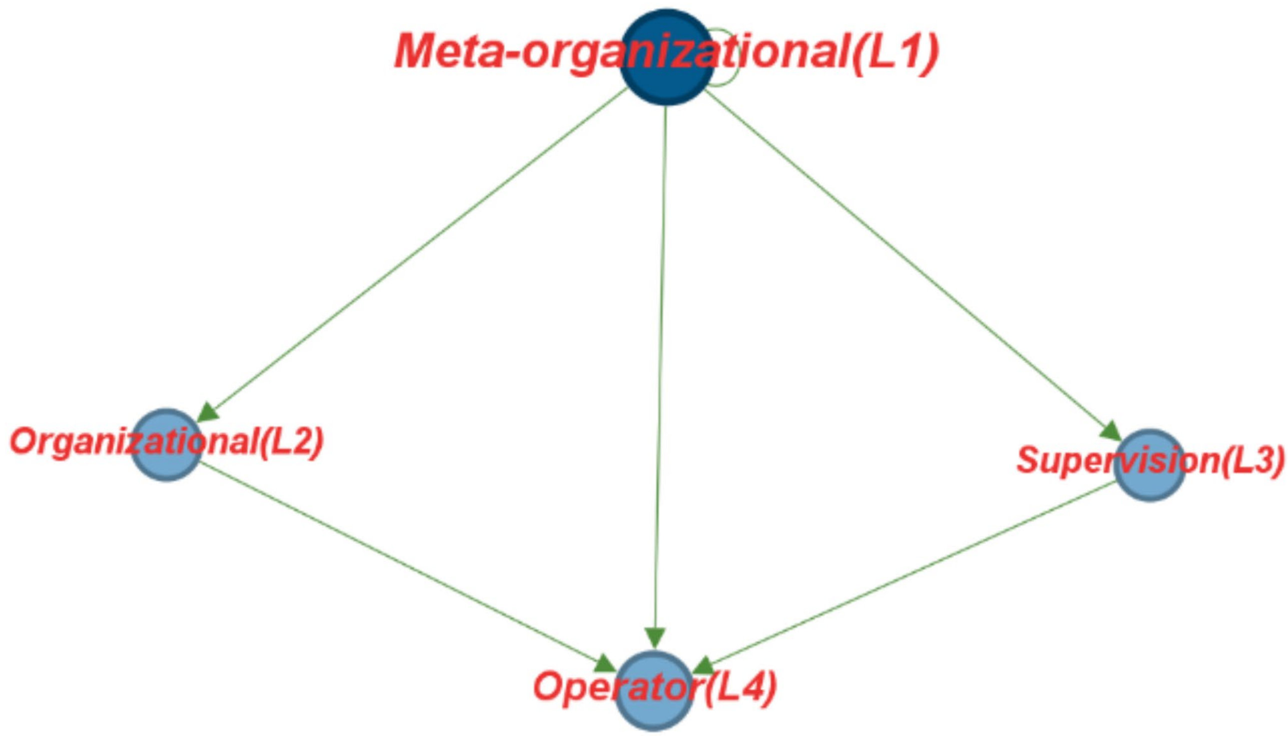

Fig. 5. Causal relations level map.

oil industry affects the behavior of employees. They argued that uniform safety protocols have been developed by the central safety departments in the Ministry of Petroleum, which all subsidiaries are expected to follow. management competence' was another important concept discussed in some studies. In fact, management competence wasidentified as a significant factor influencing unsafe behaviors, impacted by external factors such as laws and regulations[35–37].

After meta-organizational factors, organizational factors are variables that exert the most significant causal influence on the occurrence of UAs. These organizational factors are positioned in Zone 2 of causes/effects, which refers to the immediate factors within an organization that directly influence unsafe behaviors. The findings of this study demonstrate that among organizational factors, 'organizational climate' holds the highest degree of influence. A positive organizational climate, fostered by management's safety attitudes, prioritization, and regulatory oversight, is crucial in mitigating UAs. Understanding and implementing these findings could significantly improve workplace safety by allocating adequate equipment, budget, procedures, and conducive working conditions. Hannani et al.'s findings are consistent with those of the current study, which underscores the significant role of organizational factors in shaping the unsafe behaviors of coal miners[38]. Mohammadfam et al.[39] believe that organizational factors are the primary contributors to UAs compared to other factors, potentially influencing the entire system. Additionally, Oah et al.[40] identified poor leadership and inadequate safety climate as two organizational factors that significantly impact workers' cognitive perception of risks. This underscores the urgent need to address these issues to ensure a safe working environment. Another study highlights management style and safety culture as essential variables affecting workers' situational awareness[41]. Several other studies emphasizes the importance of organizational management style and leadership in shaping workers' risk perception and safe behaviors[42,43].This emphasis on the importance of management style and safety culture should make the audience feel the importance of these factors in shaping workers' risk perception. One of the critical organizational factors identified in the research by Zahiri et al.[44] is 'priority given to safety issues', closely linked to organizational management culture and thus considered a pivotal aspect in UAs. Organizational climate was another identified factor that received considerable attention from the interviewees[35]. The priority of production over safety in participants' statements was perceived as the most influential factor, especially in managerial positions. Thus, research emphasizes that managers create a safe climate and control motivations for compliance through rewards, incentives, and discipline[13]. Hence, responsible managers and decision-makers must clearly express their support for safety, align organizational priorities with safety regulations and ensure effective implementation of safety management systems[15]. Gourdon et al.[33], qualitative findings underscored the importance of contract management. The study revealed many participants attribute safety challenges to employment contracts and inadequate contractor management. Factors such as minimum-cost outsourcing strategies compel contracting companies to reduce costs by employing unskilled personnel, insufficient tools and equipment, delayed payments, and placing psychological pressure on contractual workers[45]. In addition, 'inadequate budget' and 'insufficient supervision' for projects within appropriate timeframes were identified as significant factors influencing safety and causing project delays[46]. In this study, 'contractor and project management' was identified as another crucial influencing factor on the causes of UAs alongside meta-organizational causes at level 1 of the variables.

Zone 3 variables, influenced by zone 1 and zone 2 variables, influence safety performance. In this study, several supervisory factors such as 'inappropriate oprating plan,' 'not corrected known probllms,' 'supervision of contractors and projects,' and 'supervisory violations' were among the organizational-level variables in this zone. Poor supervision is a primary cause of accidents in many industries, leading to worker dissatisfaction and reduced productivity. However, the study by Naghavi et al.[35] revealed that supervision was the second most significant influential factor in unsafe acts, offering a glimmer of hope for improvement. Moreover, this study highlighted the delegation of safety responsibilities as an influential factor in safety supervision. Rebitzer et al.[47] also reported that the multiple responsibilities of supervisors serve as barriers to adequate supervision, while inadequate assessment of supervisory performance and low commitment from supervisors were identified as influential factors in accident processes. In essence, supervising safety performance emphasizes safety importance, and conducting safety meetings to transfer information to individuals can be beneficial for adequate supervision[45]. Fabiano and Curro[48], inadequate supervision over permit-to-work (PTW) procedures was identified as a significant challenge. Since PTWs control specific types of potentially hazardous tasks, accidents were reported due to delegating permit issuance to inexperienced contractor employees who lack awareness of installation hazards[49]. Consistent with the present study, Jahangiri et al.[49] demonstrated that employing unskilled personnel in contractor companies, especially for key positions, can lead to accidents. They also attributed human errors in issuing PTWs to insufficient individual training, lack of experience, and procedural gaps. Hence, it can be inferred that PTWs, as a safety procedure, require effective management, particularly for outsourced activities or those conducted by organizations. Disregarding safety laws and regulations by managers and supervisors was perceived as an influential factor in compliance with safety regulations among subordinates[35].Therefore, it's hopeful to know that training strategies can be improved to focus on developing safety training and ensuring that safety guidelines and training initiatives emphasize the appropriate use of equipment and safety methods, offering a promising future for safety training[15].

Variables in zone 4 are factors influenced by variables in zones 1 and 2. Personal, physiological, mental, psychological, and environmental factors are among the variables in this zone. Personal factors refer to personality traits, competencies, and individual skills acquired throughout life. Fang et al.[50] found that older, married, or family-dependent workers perceive safety more positively than younger, single individuals with fewer family responsibilities. In other words, individuals tend to prioritize safety more as their social responsibilities increase. Aksorn et al.[51], the primary causes of UAs among construction workers were inadequate transportation and equipment handling conditions linked to the skills and training of the individuals involved. Also[40], highlight leadership style, inappropriate safety climate, and individual experience as influential in reducing UAs. Yeganeh et al.[52] identified knowledge and experience as the most influential variables in hazardous conditions and risk occurrence.

Consistent with these studies, Tang et al.[28] also attribute the lack of knowledge and awareness of risks to the absence of experience in encountering UAs. Therefore, it can be argued that contractual employees are vulnerable due to their lack of work experience regarding activities, insufficient knowledge in specific areas, limited experience, and inadequate training in facing accidents. Alongside individual factors, mental and psychological factors are also identified as the most significant influences. Further research indicates that fatigue and stress are the primary factors contributing to reduced awareness among individuals. Fatigue and stress are critical factors that play a key role in UAs[53,54]. Bonneville-Roussy et al.[55], believe that the operators' psychological conditions are rooted in stress and related factors such as anxiety, calmness, and motivation. Findings suggest that motivated individuals without mental concerns and stress tend to resolve issues. Various studies indicate that operators experience significant stress due to time constraints or work-related issues being identified as major causes. However, the potential for improvement in workplace safety is significant, with the continuous presence of supervisors and managers during work being identified as a key factor in problem-solving and stress management. Some studies argue that fostering motivation among employees, including operators, has empowered individuals to improve their skills and reduce errors[56]. In this context, some research has highlighted the motivational role as a psychological aspect of the Chornobyl disaster[57]. Generally, psychological and emotional conditions encompass certain traits such as calmness, high job demands, sufficient motivation, risk tolerance, operator alertness, and job-related stress, which are critical factors influencing UAs. Other factors examined in this study influence these conditions, including meta-organizational, organizational, and supervisory factors[15].

Environmental parameters include noise, lighting, indoor air quality, and others[58]. Noise exposure can act as a stress factor, increase mental workload, and ultimately disrupt cognitive function[59,60]. Noise can also result in fatigue[61] and significantly impact performance during complex tasks that require mental processing[59]. Moreover, appropriate lighting enhances awareness and cognitive performance[62], while inadequate lighting can contribute to depression, mental fatigue, and sleep quality issues[63]. Research indicates that indoor air quality in the workplace, including chemical pollutants such as particles and carbon dioxide, affects cognitive performance[64]. Workplace conditions such as job difficulty, equipment type and arrangement, and insufficient PPEs also play significant roles in industrial safety issues. The study by Malakoutikhah et al.[16] revealed that the most frequent UAs among Iranian workers involve non-use or incorrect use of PPEs (27.79%). Non-use or improper use of PPE has consistently been considered the primary cause of accidents[35]. Non-use of PPE has been identified as one of the top six causes of accidents in Iran from 1994 to 2003 [65]. A study of 500 construction accidents in the UK in 2001 also revealed that 80.29% of these accidents were attributed to unsafe behaviors, with a significant portion of these behaviors linked to the non-use or improper use of PPE[66]. In China, the second most common unsafe behavior among technical workers, following failure to comply with safety regulations, was reported as non-use or improper use of PPE, accounting for 24%[32]. Askaripoor et al.[67] identified non-use or improper use of PPE as the predominant cause of accidents in the automotive industry. Furthermore, poor-quality equipment, tools, and PPEs were cited as influential factors contributing to UAs[32]. Other studies in this context also cite potential workflow interruptions or environmental conditions, discomfort in using equipment[68], and absence of warning panel installations as factors contributing to unsafe behaviors[69].

This study identifies a four-level model consisting of 19 factors that are influential in unsafe behaviors. The model is proposed to offer qualitative insights into analyzing UAs. A qualitative approach empowers researchers to uncover interaction mechanisms among these factors, thereby aiding in formulating preventive actions by considering the interrelations. The findings underscore the prominent role of meta-organizational and organizational factors as fundamental causes of UAs in the automotive industry. However, it's important to note that this research, like others, has its limitations. One of the most important limitations is that this study was specifically designed to develop a model in an automotive industry and cannot be generalized to other similar industries. Therefore, it may require substantial effort to extrapolate these conclusions to other industries. It's crucial to emphasize the need for further research and validation of the findings across diverse work settings and among different personnel groups. Robust statistical models such as Structural Equation Modeling (SEM) should be employed to assess the causal relationships between these variables. The combination of DEMATEL and SEM methods could enhance the reliability of the findings.

Conclusion

This study aimed to identify influential factors on unsafe acts (UAs) as significant critical factors in occupational accidents in an automotive industry using the grounded theory approach and the fuzzy DEMATEL model. Grounded theory results identified 19 primary factors for UAs in the industry, indicating that managers must critically focus on these causal factors to control UAs. Among the most recognized factors in the automotive industry, those related to meta-organizational levels exhibited the most decisive influence and minor effect on UA occurrence. Despite its limitations, this study's findings will clarify the causes of unsafe behaviors in this industry, Considering the importance of UAs in industrial accidents. The fuzzy DEMATEL method is a valuable tool widely applicable across industrial sectors to address issues requiring group decision-making. Therefore, safety managers in the automotive industry can utilize this model to comprehend the causes of worker UAs and the human factors contributing to industrial accidents. This understanding provides a theoretical foundation for formulating intervention strategies to prevent and control UAs. These results can, after identifying and prioritizing the factors affecting unsafe practices, help managers control and prevent accidents. With prioritized factors in hand, managers can implement targeted interventions such as "enhanced training programs" improving worker competence and confidence in using safety equipment. Also, managers can use the model to complie comprehensive safety strategies such as prioritizing and allocating resources in interventionly safety programes.

Data availability

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

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Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
Ethical approval was obtained from ethics committees of Tehran university of Medical sciences, under ethical code IR.TUMS.SPH.REC.1401.082. In this line,informed consent was obtained from all subjects and/or their legal guardian(s).

Consent to participate
Due to conducting research in Iran, the authors obliged to comply with thegeneral guidelines of ethics in medical science research with human subjectsbased on the Islamic Republic regulations. Therefore, while maintaining theconfidentiality of the research units and audio recording with the permission of theparticipants, the code of ethics was also received with the number ofIR.TUMS.SPH.REC.1401.082. Informed consent form and ethics approval was alsopresented in the Supplementary material.

Consent to publish
Consent to Publish is not included in this study.

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