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An Applied Study on Integration Edges of Failure and TOPSIS to Educational Environment Safety Assessment: A Case Study

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ABSTRACT

A reliability and safety assessment for a bunch of listed schools can be challengeable for experts by the checklist system for safety reports. This paper aimed to respond to this challenge by merging the edges of failure 'EoF' and the technique for order of preference by similarity to ideal solution 'TOPSIS' to achieve an integrative approach for educational environment safety assessment. The qualitative assessment was implemented to detect safety faults in the case study area based on the results of the inspections. Then, the quantitative assessment was done to calculate critical points in edges of failure using the TOPSIS method. These points have been calculated for a bunch of listed schools that detected safety faults, and it also takes the form of the 'Jeopardous Pentagon' to calculate 'EoF Integration Mode'. It is an overall safety assessment to indicate performances region by region. This paper collected items of information about the twelve schools in Shahriar divided into three districts. Afterwards, a dangerous area is estimated to rank the existing options by the amount of achievement information. The first rank of the dangerous area between existence options is Shahriar two district. The most critical sides of the JP for first ranked reflect the human error 'RHE' and cultural governance 'CG' by values 0.989 and 0.989 for both intersection points. The combination of EoF and TOPSIS is recommended to apply for a physical and non-physical environment based on the safety checklist system.

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1. Introduction

A school is a complex place with a significant number of human capacities, and it also has the most exciting tendency to be a model as a system for such a place. Communications, details, humans, commitments, responsibilities, equipment, management of change, incident investigation, mechanical integrity, pre-startup safety review, training, etc., can be modelled as sub-systems for this system [1–3]. This paper evaluates the safety status of the Shahriar educational environment; for this purpose, embedded edges of failure and TOPSIS were applied to estimate "EoF Integration Modes" which is an integrated approach for selecting the high hazardous district by the checklist system for safety reports. Section 2 discusses edges of failure and dangerous areas in "Jeopardous Pentagon". Jeopardous pentagon algorithm and the way of estimation "EoF Integration Mode" is given in this section. Additionally, the methodology of the paper demonstrates in general. Section 3 collected dates by the checklist system for safety reports represent. Section 4 discusses the analyzed dates and prioritize districts in Shahriar by EoF Integration Modes. Section 6 gives an overview of the conclusions.

Because of the need for estimating the priorities of the dangerous areas of the schools selected and so that agile approach the strategy of Edges of Failure was selected by the investigation results in the other research item [1] related to solution design for the limitation of the checklist system. This study is an extended version of that item of research that covers the main concerns of management in the level of decision-making for stakeholders in Shahriar schools. The Risk-Zone map challenge was one of the big concerns for that area due to the investigation of the interconnection between the probability of the risks of the occurrence. This study is tried to draw a conceptual pattern for management to comprehend how the risks are connected by defined Edges of Failure. For this, it is needed to use TOPSIS for estimating EoF values for the reason why it is a solution that uses the best score with closeness to the ideal solution (there is more description in the methodology section of the article).

1.1. An overview of computational safety engineering problems

In this part, the gap of knowledge was detected as a concern of computational safety engineering problems for a group of schools' estimations. The real challenge was about formalizing a method of assessment for environmental safety to reveal critical gaps riskiness by novel computational informatics. To achieve this, some previous researches related to the matter of subject was reviewed to shape the basement theory and helped to formalize relations and functions in the case study.

It is a bit hard to select what kind of amplification and maturation of the managerial method to satisfy the aim of this research. Between the computational modelling methods, it is suggested to use Discrete Event Simulation (DES) for theoretical system modelling and some other computational methods for different computational areas, but it is not limited to the defined method [4]. Requirements and environmental functions determine which techniques independently or combinedly will be beneficial to scopes.

Faults and failures of a system have to take effect in computational modelling. It is because of the fails of a system which related to fault events [5]. Due to the nature of risk and environmental engagement, failures modes associated with each other in a system and risks connectedness result in failures [6]. Therefore, the role of risk in the model of computation should be clear through a mathematical computational solution.

There are some methods to apply to risk management like fuzzy and hybrid methods. However, the selection of the method depends on terms of the qualification and requirements affiliated with the environment. For example, the fuzzy Bayesian belief network or the usage of the credal network are methods for risk assessment under uncertainty [7]. On the other hand, a combination of practical methods must be used to achieve the intended goals in risk connected world.

1.2. An overall comparative look to applied algorithm

Two features requirement are addressed to illustrate the performance of the proposed method in terms of simplification of decision right and fast-tracked computation, respectively.

1.2.1. Simplification of decision right

Due to the nature of the safety management role in risk control, the decision makers and managers need to realize the identity of serious dangers and threats to a system. To comprehend the hazard and risk interconnectedness identity to decision makers and managers, the risky condition must be mapped as a practical method to convert the whole of output into an intelligible logic circuit. It is because decision makers need to have the items of information that are relevant to the context and their dynamic position [8]. Moreover, engineers try to give their functional solutions in simple patterns to be more practical illustrated for managers.

1.2.2. Fast-tracked computation

An engineering decision must be able to compute the right of use factors with the correct patterns in the cyclic process. The extracted value by the process results in the determination of conditional position that its specifications reveal the fact of the compatible function to use. It is clear that TOPSIS is able to choose the best ideal solution [9] and its computational algorithm is following a simple pattern for modelling in a computer-aided program. It is can be applied as an appropriate technique to non-dimension the distance between factors in each attribute [10]. The other ability of this technique is to help to achieve the optimal scheme by a specific performance approach [11] and the combination of TOPSIS to other methods results in a suitable integrated approach [12]. But generally, it is recommended to evaluate and select solutions as a computational strategy [13]. Therefore, TOPSIS can be used as a flexible solution for computation as a part of the algorithms for the estimation risk connectedness relationship.

1.3. Problem statement for case study

The school is a system that its components act over its life cycle. Due to its safety problems and riskiness status, this environment is required to take effect from the specific computational modelling method to estimate risky conditions and dangerous areas for the managers and stakeholders to make their decisions based on optimized opt. It's also needed to map hazards and situational risk interconnectedness for such an environment.

2. Literature review

One of the concerned topics for school safety is often related to the phenomenon of school violence. For example; school violence and disruption remained as a concern after the 1990s to 2010 [14], there was made a linkage between violent incidents and more general school safety [14–17], and it is still as one of the main concerns in Latin America countries [18]. In another study of the 5391 children surveyed, 26% were involved in bullying either as the victim, bully, or both (bully-victim) [19]. These were some examples of psychological aspects of risks in such an environment while there are non-physical and physical aspects for the educational environment to assess, as described in the 1.1.1 section of the article. But the concept of school safety in this article covers the reliable condition of a wide range of tasks to an educational environment.

A safe educational environment requires the systematic exploration of successful large-scale applications of evidence-based programs at the district, regional, and state levels that could inform theoretical paradigms, empirical databases, and practice [20–22]. Theoretical paradigms play an applied role in educational environment safety assessment. They are needed to more carefully outline how safety issues intermingle with the day-to-day internal social, and organizational patterns of schools [20,23]. More importantly, many schools listed in a district require a theoretical paradigm of a safe educational environment to assess dangerous situations.

2.1. A brief overview of school safety

The concept of school safety is defined in the previous section, but the risk is one of the most essential parts of school safety that needs to be addressed. This type of subject covers all types of threats to an educational environment such as a school. Risk management of school conditions may be the most effective solution for their environment. to achieve this purpose, some research addresses the following.

Reliability to an educational environment and making it safe are challenging issues for schools. A comparative study on the level of safety culture in the schools of highly hazardous seismic countries by reference to OCDE school safety assessment found that a safety management system is required to implement for such a place. In fact, by using a safety management system, the educational environment welcomes safety and reliability [24–26].

The tendency of students and all staff engagement of Shahriar educational environment is about designing an effective safety management system for the schools located there, and the results of the study indicate no satisfaction of safety by design in place. More and more critical is that perceptions of safety do not define as well for the managers, and there is an ambiguity effect that causes them to react as sub-minimal safety activities in place[27].

The checklist system for safety reports surveyed schools' safety status to discover disadvantages and advantages. According to the paper results, the researcher found that the checklist system is an excellent system to cover disadvantages of safety in an educational environment. In this way, it is recommended to survey schools' safety status by the edges of failure, and it is better to integrate OSHA 1910.11.2 checklist into the previous sample [1,28,29].

The routine maintenance of schools requires the definition of strategies for effectively allocating the available financial resources. To achieve this, applying the seismic VISUS methodology in a pilot project sponsored by UNESCO to assess the safety situation of 100 schools in El Salvador. The outcomes and the lesson learned were the basis for the VISUS methodology to a multiple-hazards perspective [30]. The VISUS is adaptable to different local contexts and needs, and it could be used as an effective decision-making tool for planning actions in risk mitigation at a regional scale following a rational approach [31].

There are some considerations to enhance school safety and security for school key stakeholders. For example, conduct school risk assessment regularly, know and follow school security and safety measures, create a good school climate, orient learners and staff about safety and security, etc. The author of the paper emphasized that safety and security should be understood before implementation [32,33]. On the other hand, the risk involved in an educational environment categorizes in various types by different types of religions.

According to the report on school crime and safety indicators, in 2019–20, there were a total of 75 school shootings with casualties, including 27 school shootings with deaths and 48 school shootings with injuries only [34]. But threats in an educational environment in a country like Iran are different from the point of American views; for example, natural disasters like the earthquake and others are some top concerns [35]. Therefore, please note that this issue is right about the communication in the context neither of an organization nor about the method or the way of assessment condition.

Designed systems aim to incorporate communication of details in a system component. But sometimes, the connection between sub-elements of a system doesn't occur. This means faults in the systems need to be detected to improve existence weaknesses and help the system develop. The faults of the ICS were detected by the FTA method. Then, a novel way of management in the context of safety and sustainability represent [23]. This novel model of ICS covers all faults detected to prevent the consequences of an accident.

3. Methodology

3.1. Edges of failure (EoF) method

This method is an output model with vital leading factors (LFs) in failures for an educational environment [1]. The educational environment includes some top main concerns with high potential risks (Edges of Failure). But the way of detecting failures in such an environment sometimes is hard to reach. For detecting failures, there need to investigate the sub-factors of LFs in Failure modes. To achieve this approach, it is required to follow LFs in Edges of Failure (EoF) to detect safety faults and educational environment mal-functions or mis-uses in safety by design. Jeopardous pentagon indicates in Fig. 1.

Fig. 1. Jeopardize Pentagon: Dangerous Area by Edges of Failure.

It is emphasized that this pattern of detected Edges of Failure called Jeopardize Pentagon is founded by an investigation into the faults of safety in Shahriar district referenced to the mentioned above article. The LFs include the below components in order of estimation the critical point called "EoF Integration Mode". It is an integrated approach for selecting the best choice with a highly reliable condition by merging TOPSIS and the EoF method.

3.2. Equipment and protective systems

It is essential to control dangerous occurrences by devices intended to protect the occupant. Equipment and protective systems performance lead to reduce the consequences of a disaster, and some of them act as an active warning in the case of emergency. Sometimes embedded systems with intelligent capabilities can sense and detect hazards in real-time. So, selecting what systems or equipment to use in an environment to protect is a requirement [36].

3.2.1. Reflection of the human error

Human error commonly refers to failures in the planning and execution stage of a task. In the educational environment, there will be no balance between the human factors and the safety culture if mistakes, violations, slips, and lapses, or other failures occur in such an environment, indicating a sign of critical safety [37,38].

3.2.2. Cultural governance

One of the biggest safety threats is ambiguity. The ambiguity in safety information means to put obstacles in the path. This is because the decisions are the heart of the cultural governance for safety implementation, and it directly relates to the structure and process of well-articulated safety policy and philosophy. Cultural governance helps to improve such mis conflict or other close examples, and it helps to update old conducted ways to the novel solutions for more effective feedback of such environment, and its helps to a culture improvement by the making right decisions [39].

3.2.3. Structural integrity and failure

The building is constructed as a safe place for a specific application, but it isn't true while it's vulnerable to serious hazards. In this way, the building is a place as null-meaningless. Unexpected failure modes or a combination of causes may be led to a collapse or structural failure [40,41]. These will be occurred due to natural disasters such as earthquakes, floods, rain or heavy snow, hurricanes, cyclones, and fires. Sometimes the sign of the hazard reveals the structure like the crack and other symptoms in the structure of the building [42,43].

3.2.4. Ecotoxicology and environmental safety

Health and safe students and teachers would be served in the society for the future, and they wouldn't be exposed to the harmful environment. The educational environment may have some detrimental effects on users' health by exposure to the toxic chemicals in the labs or the environment. One of the examples is the love canal's environmental impact. The canal families didn't know that they were being exposed to poisonous chemicals or that chemical wastes were being dumped in the rivers, soil, and air. There are more other examples like this that you can find on the internet, but more importantly, it is the way of assessment and protection. Some of the kinds of threats for the educational environment consisted of; air pollution, wastewater, noise source, dust, fumes, hazardous wastes, diseases, risk of radio and telecommunication waves, etc [44,45].

3.3. Estimation of EoF integration mode

3.3.1. Find critical points by TOPSIS

TOPSIS is a component of compensatory decision rules. It also compares a set of alternatives by calculating the geometric distance between each alternative and the ideal one [46,47]. And this is a mechanism to select the best score in each criterion. On the other hand, in TOPSIS (Technique for Order Performance by Similarity to Ideal Solution), the alternatives are evaluated according to their distances from the optimal solution [48,49]. For this, first, it is required to create an evaluation matrix for each sub-factor. Then, the normalization method is used to form the matrix as normalized, calculate the weighted normalized decision matrix, and follow the steps below [50,51].

Step 1:

Identify the positive-ideal solution and the negative-ideal solution A^{-} :

$$A^{+} = (V_1^{+}, V_2^{+}, ..., V_n^{+}) \tag{1}$$

$$A^{-} = (V_1^{-}, V_2^{-}, ..., V_n^{-}) \tag{2}$$

Where V_j^{+} and V_j^{-} calculate by the following formula,

$$V_j^{+} = \left(\overset{MAX}{\underset{i}{}} V_{ij}, j \in j_1 or \overset{MIN}{\underset{i}{}} V_{ij}, j \in J_2 \right); \forall_J = 1,2,3,...,i \tag{3}$$

$$V_j^- = \left(\overset{MIN}{\underset{i}{}} V_{ij}, j \in j_1 or \overset{MAX}{\underset{i}{}} V_{ij}, j \in J_2 \right); \forall_J = 1,2,3,...,i \quad (4)$$

Then in calculation uses upper bound for the positive-ideal solution A^+, and lowest bound for and the negative-ideal solution A^- . in contrast, for V_j^- uses lowest bound for the positive-ideal solution A^+, and upper bound for and the negative-ideal solution A^-.

Step 2:

Calculate Euclidean distances from the positive ideal solution A^+ and the negative one A^- of each alternative:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left(d_{ij}^+\right)^2} \quad (5)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(d_{ij}^-\right)^2} \quad (6)$$

Where d_{ij}^+ and d_{ij}^- calculate by the following formula,

$$d_{ij}^+ = V_j^+ - V_{ij};\ \forall i = 1,...,m,\ \text{j=1,2,...,n.} \quad (7)$$

$$d_{ij}^- = V_j^- - V_{ij};\ \forall i = 1,...,m,\ \text{j=1,2,...,n.} \quad (8)$$

The way of calculation for V_j^+ and V_j^- is represented in step one.

Step 3:

Calculate the relative closeness for each alternative rc_i concerning to positive ideal solution reference to below formula. The parameters include d_i^+ and d_i^- in the formula for each alternative are calculated. These distances are used to compute the closeness index (rc_i) to the ideal solution:

$$rc_i = \frac{d_i^-}{d_i^+ + d_i^-}; \forall \text{i=1,2,...,m.} \quad (9)$$

The rc_i varies between 0 and 1, and the alternative with the highest rc_i value is selected as the best alternative [52].

3.3.2. Jeopardous Pentagon Algorithm

Step 1:

Calculate the dangerous area of an irregular pentagon by given items of information in Table 1. This table indicates the vector components, which are essential to calculate a Jeopardous Pentagon's area.

Table 1
Vector Components of Jeopardize Pentagon.

Edges of Failure (LFs)	Y-Direction General Constant	TOPSIS Rank	X-Direction (TOPSIS Out-Put)
EPS	1	1st	x_1
RHE	0.8	2nd	x_2
CG	0.6	3rd	x_3
SIF	0.4	4th	x_4
EES	0.2	5th	x_5

According to the vector components information in Table 1, it is possible to calculate EoF Integration Mode using the formulas 10, 11, and 12.

$$Y_x = (0.2\times x_2) + (0.4\times x_3) + (0.6\times x_4) + (0.8\times x_5) \tag{10}$$

$$X_y = (1\times x_4) + (0.8\times x_3) + (0.6\times x_2) + (0.4\times x_1) \tag{11}$$

$$\text{EoF Integration Mode} = \frac{Y_x - X_y}{2} \tag{12}$$

EoF Integration Mode consequence as a number between 0 and 1, and the option with the highest value is the one with high-risk and selected as the dangerous area. The value closeness to 0 means that the option reaches the safe zone.

3.3.3. Draw jeopardous pentagonal diagram

Calculated five points based upon results of TOPSIS (EPS, RHE, CG, SIF, and EES) are the intersection between the sides in "Jeopardous Pentagon". Therefore, it is evident that there is one direction of the vector 'X direction' for drawing a JP. Another direction of the vector 'Y direction' contains a general constant for a prioritized rank of the calculated points. It is used to a general constant for 'Y direction' for why it is a requirement to shape a JP with these numbers [21,46,51]. So, there needs to be a generally constant number from top to zero to take the form JP, as you can see in Fig. 2.

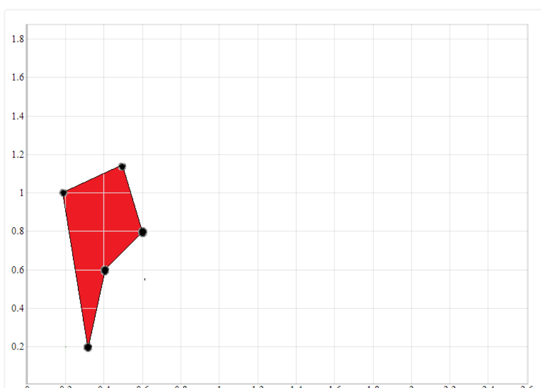

Fig. 2. Sample diagram: Uncover Dangerous area of Jeopardous Pentagon' JP' by specifying Edges of Failure.

The red area in the above example JP indicates a dangerous area where an integrative communication between edges of failure exists and may lead to higher potential risk. As a result, it makes a paradigm called *'The higher the value of JP makes the higher the risk*'. This is an applied principle to the *Edges of Failure* 'EoF' to track the whole steps in achieving a logical, comparative overview.

3.3.4. Specify EoF integration modes' EoF IM'

Prioritized results of the EoF Integration Modes by Jeopardous Pentagon algorithm create a ranking table. An example of a ranking table in Table 2 includes selected options with their ranks, as you can see in it.

Table 2
prioritized dangerous area by the EoF Integration Modes.

Rank	EoF Integration Mode	Option
1	I_1	N_1
2	I_2	N_2
0	0	0
0	0	0
n	I_n	N_N

3.3.5. Select the safe zone

As the amount of the pentagon area decreases, the risk value reduces by the same amount. Therefore, the safety value and reliability of the environment increase. In other words, because EoF Integration Mode has estimates based upon LFs and safety faults, which determine the value of EOF Integration Mode. The achievement value highlights the proportion of unreliability to an educational environment. Calculating how much is close to zero is essential because the safe zone is something like a dot in a cartesian coordinate system, and a dot means the change from a two-dimensional JP by its area to one dimension in a line, and continually there is another change to a dot with non-dimension. Then it concludes with one dimensionless parameter that eliminates the risk dimension 'detected risks in an environment and their communications'. So, choosing the lowest number of EOF Integration Modes is required between other existing options to select one safest zone among other options. According to the ranks of the options, the highest rank is as a chosen non-safest zone with an integrated approach.

4. The checklist system data

Collected data from the checklist system analyze by the sample pattern in Table 4. It indicates that quantitative assessment rises from qualitative one. This sample of inspection results is modified by the edges of failure to take a matrix form to evaluate intersection points in the Jeopardous Triangle. Intersection points in JP where are the edges of failure break the meet. To achieve a JP and specify its intersection points, it is required to specify the school groups by their region or district categorization. The table below indicates three options related to the regions of schools and the number of schools gathered in a group.

In Table 4, you see the way of quantity assessment by the qualitative output data from the checklist system for safety reports. The table below is a sample of Golshan's school's checklist results that indicates how the edges of failure detected many safety faults. This aims to achieve items of information for TOPSIS input. It needs to identify values for the intersection of edges in failure to estimate dangerous conditions and draw a JP.

Table 3
Division of the case study district.

Option	Distinct	Name of schools	Number of schools
1	Shahriar 1	Golshan, Ghiam, and SHAHID-SAMAIE	3
2	Shahriar 2	Emam-Khomeini, Alavi, Sadat, Arman, and Cheshmey-e-Noor	5
3	Shahriar 3	Azin, Haaftkhanegy, Isargaran, and Paayam-e-Noor	4

Table 4
Sample of Inspection results for safety faults in GOLSHAN school by the checklist system for safety reports.

<table>
<tr><th></th><th>Edges of Failure</th><th>Number of Detected Safety Faults</th><th>Safety Faults</th><th>Failure Mode</th><th>Inspection Results by the checklist system for safety reports</th></tr>
<tr><td rowspan="18">GOLSHAN</td><td rowspan="6">EPS</td><td rowspan="6">4</td><td>(1) Air conditioning and smoke evacuation systems</td><td>No installation</td><td>✓</td></tr>
<tr><td>(2) Fire detection and alarm systems</td><td>No installation</td><td>✓</td></tr>
<tr><td>(3) Firebox, wet and dry fire protection systems</td><td>No installation</td><td>✓</td></tr>
<tr><td>(4) Fire sprinkler system</td><td>No installation</td><td>×</td></tr>
<tr><td>(5) First-aid box</td><td>No installation</td><td>×</td></tr>
<tr><td>(6) Emergency power system</td><td>No installation</td><td>✓</td></tr>
<tr><td rowspan="3">RHE</td><td rowspan="3">0</td><td>(7) Safety principles in the installation of heaters, heating systems, or equipment</td><td>Fail to observe</td><td>×</td></tr>
<tr><td>(8) Safety principles in the design and implementation of roof wall retaining system</td><td>Fail to observe</td><td>×</td></tr>
<tr><td>(9) Chimney height rules, and 'H' Cowl control</td><td>Fail to observe</td><td>×</td></tr>
<tr><td rowspan="2">CG</td><td rowspan="2">1</td><td>(10) The safety training courses by the students and teachers</td><td>No pass</td><td>×</td></tr>
<tr><td>(11) Stair safety signs</td><td>Non-use</td><td>✓</td></tr>
<tr><td rowspan="3">SIF</td><td rowspan="3">0</td><td>(12) Emergency exit stairs and fire escape</td><td>Non-use</td><td>×</td></tr>
<tr><td>(13) Suitable and durable materials in the facade</td><td>Non-use</td><td>×</td></tr>
<tr><td>(14) Stairs Guard and Terrace Guard</td><td>Unsafe</td><td>×</td></tr>
<tr><td rowspan="4">EES</td><td rowspan="4">2</td><td>(15) Electric switchboard and electrical wiring system</td><td>Non-standard</td><td>×</td></tr>
<tr><td>(16) Manual Fire Extinguishing Equipment</td><td>No installation</td><td>✓</td></tr>
<tr><td>(17) Safe distance with telecommunication facilities and antennas, pressure reduction stations and electrical substations</td><td>Fail to observe</td><td>✓</td></tr>
<tr><td>(18) Arriving the fire and rescue vehicles to the building at accident tense</td><td>Inaccessibility</td><td>×</td></tr>
</table>

The Above-represented information 'Table 4' outputs eighteen factors from the checklist system for safety reports integrated into edges of failure to specify critical edges for emergency response. It is consumed to take feedback from the risk condition of a bunch of listed schools categorizes in three options' Table 3'. It is an integrated applied approach in order of safety assessment for the educational environment region by region.

Based on the above pattern, safety faults categorize in edges of failure for each school. In this way, numbers of detected safety faults demonstrate what edges are the most critical and what others are the safest in each school. But, what about the group results in the region? Or, what about the method of prioritizing to estimate safety status for a bunch of schools listed by district?

To answer the questions, first, it has to collect data on an educational safety environment by the edges of failure like Table 5, and then it is required to check items of information in the checklist like Table 4 for each school.

Table 5
The edges of failure analyzed by the checklist system for schools.

Row	School Name	Edges of Failure	Safety Faults by Failure Mode based on the previous table	Number of Detected Safety Faults
1	**SADAT**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	-	0
		EES	(15), (16), (17)	3
				8
2	**Emam-Khomeini**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	(12)	1
		EES	(15), (16), (17)	3
				9
3	**Alavi**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	-	0
		EES	(15), (16), (17)	3
				8
4	**Cheshmeh-Noor**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	(12)	1
		EES	(16), (17)	2
				8
5	**Azin**	EPS	(1), (2), (3), (6)	4
		RHE	(7)	1
		CG	(11)	1
		SIF	(12)	1
		EES	(15), (16), (17)	3
				10

6	**Haft-Khanegi**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	(12)	1
		EES	(16), (17)	2
				8
7	**Isargaran**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	(12)	1
		EES	(16), (17)	2
				8
8	**Payameh-Noor**	EPS	(1), (2), (3), (6)	4
		RHE	(7)	1
		CG	(10), (11)	2
		SIF	(12)	1
		EES	(16), (17)	2
				10
9	**Ghiam**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	-	-
		EES	(16)	1
				10
10	**SHAHID-SAMAIE**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(10), (11)	1
		SIF	(12)	1
		EES	(16)	1
				7
11	**GOLSHAN**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	-	-
		EES	(16), (17)	2
				7
12	**Arman**	EPS	(1), (2), (3), (6)	4
		RHE	-	0
		CG	(11)	1
		SIF	(12)	1
		EES	(16), (17)	2
				8

Collected items of information in Table 5 indicate the ratio between alternatives and criteria for TOPSIS input data in order of fundamental risk analysis based on safety faults detection, and it also shows the quantitative assessment for these ratios. The ratios values are input-dates to create an evaluation matrix that helps calculate 'X Direction' points of the vector by TOPSIS, and then following edges of failure steps to draw JP and achieve EoF Integration Mode.

Furthermore, this assessment method is verified by T. Hartmann's procedure of computation modeling in systems engineering [4]. The computational evolvement problem in systems engineering and the system process's evolution reveals the algorithm obtained from the computational model in this study. It has also been compared with the proposed model in T. Hartmann's "Advanced Computing Strategies for Engineering" article because it indicates a hybrid of suggested computational methods in modeling systems engineering, which can be used to shape a practical algorithm to solve system engineering problems in safety issues of this study. Based on the problem statement of the case study, the hazards during the system's lifecycle have been identified. Two defined computational features, fast-tracked computation, and simplification of decision rights, have been included in this model.

5. Discussion

In this study, there are three districts referred to Table 3 and twelve school's inspection results uses from the checklist system for safety reports in Shahriar firefighting. This section of the paper is the next level of creating an evaluation matrix. Using the matrix, founded ratios of alternatives and criteria analyze with the TOPSIS method to indicate the ranks of each alternative. The results relate to option one shown in Tables 6, 7, and 8 in section 4.1. these tables information indicate TOPSIS results. The vector component to draw the JP for option one represents in Table 9. An overall assessment of the environmentally dangerous area calculates a value of 0.6626 EoF Integration Mode. It reveals a high probability of risks interference into an integrated area. Each point in this area can be a threatened risk to the environment. Tables 10, 11, and 12 indicate TOPSIS results, and based on founded information' Table 13' draws JP' Fig. 4' for option two. As the same process, Tables 14, 15, and 16 indicate results related to TOPSIS and the JP' Fig. 5' drawn by the vector component in Table 17.

5.1. Option one, "shahriar 1 district"

A dangerous condition in this option by the value 0.6626 'Table 9' is close to the value 0.6034 of 'Table 17' option three. But this is the option with an upper value compared to the last one. Reflection of the human error 'RHE' and structural integrity and failure 'SIF' by values 1 and 0.9 are critical intersection points in JP, as you can see in Fig. 3. X-direction of the vector values' Table 9' indicates TOPSIS output. The Y-direction of the vector values exhibits a general constant to form a JP. In fact, an audit process must be taken to reduce the TOPSIS output values to reach zero.

Table 6
Weighted normalized decision matrix.

	C1	C2	C3
A1	0.228	0.377	0.307
A2	0	0.001	0.001
A3	0.057	0.094	0.077
A4	0.057	0.001	0.001
A5	0.057	0.094	0.153

Table 7
The positive-ideal solution and the negative-ideal solution for each criterion.

Criterion	A^{+}	A^{-}
C1	0	0.228
C2	0.001	0.377
C3	0.001	0.307

Table 8
The Similarity of alternatives compared to an ideal solution.

Option	Closeness to the ideal solution	Positive distance	Negative distance
A1	0	0	0.536
A2	1	0.536	0
A3	0.752	0.403	0.133
A4	0.9	0.514	0.057
A5	0.661	0.365	0.187

Table 9
Find the sides of the pentagon by the vector components and estimate EoF Integration Mode.

<table>
<tr><td colspan="4">Table 9. Vector Components of Jeopardize Pentagon</td><td>EoF Integration Mode</td></tr>
<tr><td>Edges of Failure (LFs)</td><td>Y-Direction General Constant</td><td>TOPSIS Rank</td><td>X-Direction (TOPSIS Out-Put)</td><td rowspan="6">0.6626</td></tr>
<tr><td>EPS</td><td>1</td><td>5th</td><td>0</td></tr>
<tr><td>RHE</td><td>0.8</td><td>1st</td><td>1</td></tr>
<tr><td>CG</td><td>0.6</td><td>3rd</td><td>0.752</td></tr>
<tr><td>SIF</td><td>0.4</td><td>2nd</td><td>0.9</td></tr>
<tr><td>EES</td><td>0.2</td><td>4th</td><td>0.661</td></tr>
</table>

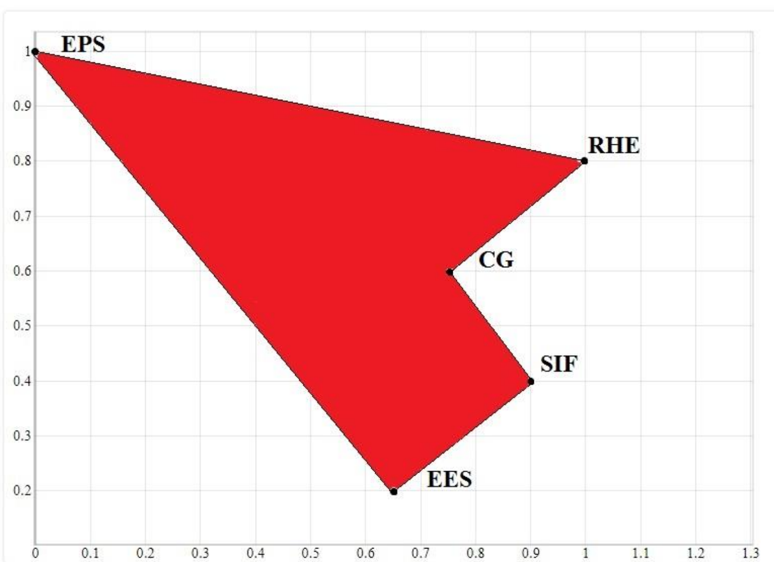

Fig. 3. Jeopardous Pentagon' JP' by specifying Edges of Failure: indicates dangerous area by the number of 0.6626.

5.2. Option two, "shahriar 2 district"

Among the existing schools, many listed schools in option two require an emergency procedure to prepare for hazards or reduce risks and a risk-mitigation plan. By the focus on EoF, a reflection of the human error 'RHE' and cultural governance 'CG' is critical to respond for why they are top-ranked in TOPSIS by values 0.989 and 0.989 'Table 12'which indicate the closeness to the ideal solution demonstrates essential points of intersection in JP. they also provide a major area of JP where is a high probability of collision in communication between risks. It means hazard occurrence. The overall assessment for the dangerous area can be seen in Fig. 4.

Table 10
Weighted normalized decision matrix.

	C1	C2	C3	C4	C5
A1	0	0	0	0.556	0.019
A2	0	0	0	0.006	0.019
A3	0	0	0	0.006	0.019
A4	0	0	0	0.556	0.013
A5	0	0	0	0.556	0.013

Table 11
The positive-ideal solution and the negative-ideal solution for each criterion.

Criterion	A^{+}	A^{-}
C1	0	0
C2	0	0
C3	0	0
C4	0.006	0.556
C5	0.013	0.019

Table 12
The similarity of alternatives compared to an ideal solution.

Option	Closeness to the ideal solution	Positive distance	Negative distance
A1	0	0	0.55
A2	0.989	0.55	0.006
A3	0.989	0.55	0.006
A4	0.011	0.006	0.55
A5	0.011	0.006	0.55

Table 13
Find the sides of the pentagon by the vector components and estimate EoF Integration Mode.

Vector Components of Jeopardize Pentagon				EoF Integration Mode
Edges of Failure (LFs)	Y-Direction General Constant	TOPSIS Rank	X-Direction (TOPSIS Out-Put)	0.8
EPS	1	5th	0	
RHE	0.8	1st	0.989	
CG	0.6	2nd	0.989	
SIF	0.4	3rd	0.011	
EES	0.2	4th	0.011	

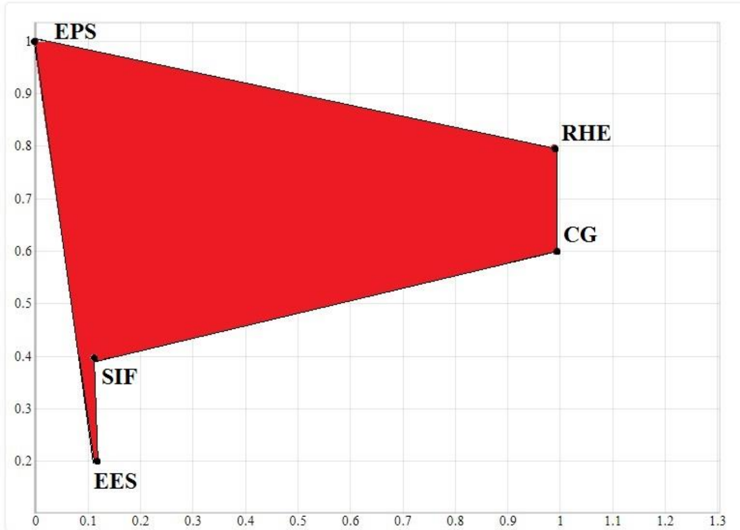

Fig. 4. Jeopardous Pentagon' JP' by specifying Edges of Failure: indicates dangerous area by the number of 0.8.

5.3. Option three, "shahriar 3 district"

Reflection of the human error 'RHE', Structural integrity and failure 'SIF', and cultural governance 'CG' are three critical edges for failure with intersection points by values 1, 0.764, and 0.756 referenced to the JP in Fig. 5. The value of 'EoF Integration Mode' for this option is 0.603, as shown in Table 17. Achievement values for each point are connected that it indicates their proportion with the length of the vector. The vector length is the same as the edge connected to the other one by an intersection point. To reduce risk or jeopardous areas, it needs active mitigation measures for each point. In this way, the periodic audit process results in a reduction in jeopardous areas. But if mitigation measures are implemented just for one point, their consequences are revealed as a change in values of two adjacent vectors leading to the intersection points.

Table 14
Weighted normalized decision matrix.

	C1	C2	C3	C4
A1	0.131	0.299	0.299	0.098
A2	0.033	0.001	0.001	0.024
A3	0.033	0.075	0.075	0.049
A4	0.033	0.075	0.075	0.024
A5	0.098	0.15	0.15	0.049

Table 15
The positive-ideal solution and the negative-ideal solution for each criterion.

Criterion	A^{+}	A^{-}
C1	0.033	0.131
C2	0.001	0.299
C3	0.001	0.299
C4	0.024	0.098

Table 16
The similarity of alternatives compared to an ideal solution.

Option	Closeness to the ideal solution	Positive distance	Negative distance
A1	0	0	0.439
A2	1	0.439	0
A3	0.756	0.335	0.108
A4	0.764	0.34	0.105
A5	0.497	0.219	0.222

Table 17
Find the sides of the pentagon by the vector components and estimate EoF Integration Mode.

Vector Components of Jeopardize Pentagon				**EoF Integration Mode**
Edges of Failure (LFs)	Y-Direction General Constant	TOPSIS Rank	X-Direction (TOPSIS Out-Put)	**0.6034**
EPS	1	5th	0	
RHE	0.8	1st	1	
CG	0.6	3rd	0.756	
SIF	0.4	2nd	0.764	
EES	0.2	4th	0.497	

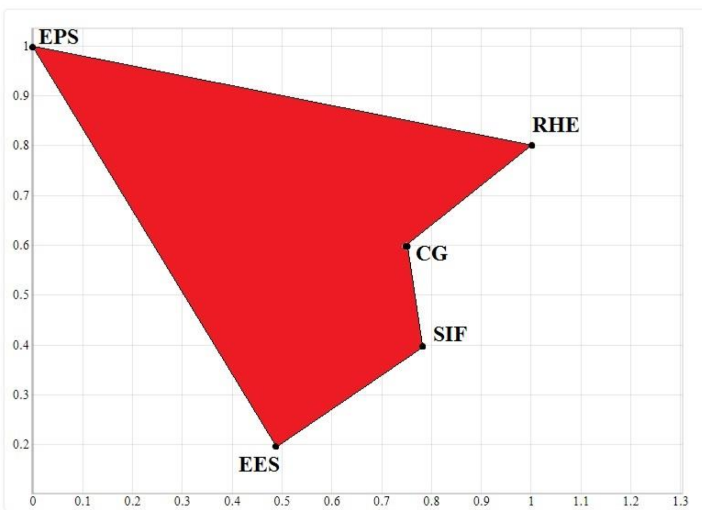

Fig. 5. Jeopardous Pentagon' JP' by specifying Edges of Failure: indicates dangerous area by the number of 0.6034.

Options prioritized with ranked EoF Integration Modes. According to the main principle of Edges of Failure, *'The higher the value of JP makes the higher the risk'*, higher value of the JP for option two dedicates 0.8 EoF Integration Mode. Then, to arrange them in order of priority, the values 0.6626 and 0.6034 are ranked in 2th and 3th. You can see the results in Table 18.

Table 18
Prioritizing districts by specifying the dangerous area.

Rank	EoF Integration Mode	Option
1	0.8	2
2	0.6626	1
3	0.6034	3

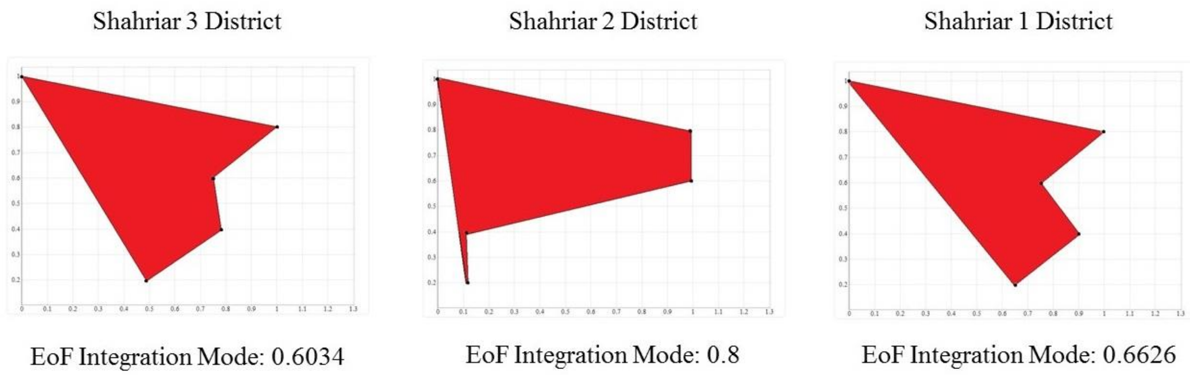

Fig. 6. A comparative look at different districts' risk condition.

The priorities obtained are included Shahriar 2 district, Shahriar 1 district, and then Shahriar 3 district. They are arranged in order of risk communication between scopes of defined Edges of Failure. This indicates Risk-Zone map to management and their stakeholders for making a better decision on designing an optimal condition based on better-allocated resources to safety. Each edge's scope lets the decision-makers know what is the value of risk compared to the ideal solution. The value calculated by the TOPSIS indicates to them what edges are critical to responding in order of priorities. By referring to Fig. 6, it is evident that risk communication by edges failure between districts one and 3 are similar. But district two is different from others in risk communication. The way of estimation for EoF Integration Mode for given items is explained in the previous section. In practice, Shahriar 2 District is communicated with more risks than the other and it means that some types of emergency actions are required for listed schools in that district compared to other districts. You can see that 3rd intersection point called cultural governance 'CG' and the last one ecotoxicology and environmental safety 'EES' are different in values.

It indicates that these two edges require a critical review. Because High differences between two or more LFs lead to increases in the area of communication between risks and it means audit on risk requirement to reduce the differences between items. This is an overview of the safety status of the Shahriar educational environment that can be used as a suitable management strategy for selecting high hazardous districts and specifying what edges of failures are critical to responding and audit-related risks. It needs to pay attention that this Edges of Failure which is defined in this study cannot be used for another district with a different environment. because defined Edges of Failure in this study are based on investigation of the case study and for another environment may be different from each other.

6. Conclusion

The result of the research gives a look at all aspects of risk-based upon edges definition. The more area involvement with faults detection exerts, the more threatened risk like the comparative look at different districts' danger in Fig. 6. There are two key points in this research results; method of safety assessment for a bunch of listed schools expand by an integrative approach to compensate the weakness of the checklist system, and the communication between existing risks in an educational environment can be seen in the form of a logical glimpse view in a JP diagram helps to prioritize districts by the dangerous area.

Two mentioned above key points indicate stakeholders of the schools how to allocate resources to safety and eliminate blame culture in place. It can serve as an alarm to enable the audit process and implement corrective actions. For example, Fig. 6 indicates an alarm for many listed schools in Shahriar 2 district to review the checklist items to enhance an educational safety environment for each school in the districts. But prioritization leads to being aware of selecting an emergency response.

A closer look at the computational evolvement problem and the evolution of the system process reveals that the algorithm obtained from this study compared with the proposed model called "Advanced Computing Strategies for Engineering" which indicates a hybrid of suggested computational modeling methods, showed noticeable performance and can be used to shape a practical algorithm as a solution for system engineering problems in safety issues of this study. Based on the problem statement of the case study, the hazards during the lifecycle of the system have been identified and two defined computational features fast-tracked computation and simplification of decision rights have been included in this model.

The combination of EoF and TOPSIS is recommended not only for the educational environment. Instead, it is recommended for any type of safety checklist system related to inspection of physical and non-physical condition for why it covers checklist system weakness about to use it for a wide range of environment in different districts. But it is required to determine edges and define alternatives and criteria to assess the intersection points.

The following context indicates the benefits of the combination Edges of Failure and TOPSIS method in an educational environment safety assessment, highlighting the expected output consequences.

1. Identification of highly potential risks to an educational environment by specifying categories.
2. Detecting communication of the risks and interpretation of the probabilities for hazard occurrence.
3. A glimpse looks over safety situations in an educational environment with physical and non-physical conditions.
4. Displaying a dangerous graphical area by JP.
5. Prioritization of the dangerous condition for groups of a bunch of listed schools in each district' region by region' by 'EoF Integration Modes'.
6. Indicating the emergency response by the rank of values closeness to the ideal solution 'TOPSIS'.

7. Limitations and future research opportunities

This research has certain limitations that future investigations may consider in their work. The analyzed samples of the case study belong to the items raised in the research, which are related to the educational environment. Thus, although this study introduced a case study project in the field of educational safety assessment and estimation of EoF IM, this approach cannot differentiate practical safety techniques in the place. In addition, the outcome of the current work can be used in other aspects of the environmental field or system safety analysis to determine dangerous conditions by considering edges.

It is suggested that developing the established method in engineering applications as a form of plug-ins for project safety management software or project management can be considered in the future studies. Besides, engineered risk modeling as EoF IM can be developed in three-dimensional form using mathematical methods in various representational modes.

The considering approach of this article to the safety assessment of the environment can be expanded by emphasizing the relationship of the interconnected risks and specifying a method of probability risk occurrence assessment in the form of interaction between risks in an environmental threat. Therefore, it's recommended that consider the probability of collision between high-probability risks. This phenomenon can reveal the uncertainties of the environment, a part of which has been done in this study.

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Conflicts of interest

The authors declare no conflict of interest.

Authors contribution statement

MR, NS: Conceptualization; MR, NS: Data curation; MR: Formal analysis; MR, NS: Investigation; MR, NS, HV: Methodology; JJ: Project administration; MR: Resources; MR, MR: Software; NS, HV, JJ: Supervision; NS, NS: Validation; MA: Visualization; MA, MR: Roles/Writing – original draft; MR, MR: Writing – review & editing.

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