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Article

Weighing and Prioritizing Noise Control Methods Using the Delphi Technique and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) in an Iranian Tire Manufacturing Factory

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Abstract: Undoubtedly, noise has become a major hazardous issue in today's industrial world, with a lot of people suffering from exposure to excessive noise in their work environments. This study was conducted to weigh and prioritize noise control methods in an Iranian tire manufacturing complex in Iran. The Delphi method and the Technique for Order Preference by Similarity and an Ideal Solution (TOPSIS) were utilized for this purpose. This cross-sectional, descriptive study was conducted in the baking hall of an Iranian tire manufacturing factory in 2016. To weigh and prioritize noise control methods, Analytic Hierarchy Process (AHP) and TOPSIS were applied. In total, 4 criteria and 8 alternatives were examined. An AHP and TOPSIS questionnaire was then designed to prioritize noise control methods in the light of the objectives, criteria, and alternatives. Then, the collected data were fed into Expert Choise. V. 11 and Excel and data analysis was carried out using TOPSIS. The results of data analysis indicated that the inconsistency rate in all the cases was smaller than 10%, hence the consistency of the responses was verified. According to the TOPSIS results and experts' opinions about the criteria, implementation and maintenance cost (with a weight of 0.481) and method effectiveness and efficiency (with a weight of 0.046) had the highest and lowest priority respectively. Based on the weights TOPSIS, the appropriate methods for controlling noise in tire manufacturing are designing and manufacturing silencer, requiring people in charge to quickly fix the leaks and change baking press washers on time.

Keywords: Ranking; noise control methods; TOPSIS; delphi technique

1 Introduction

Noise pollution refers to unwanted and unpleasant sounds that cause physiological harms among people [1]. Noise is more likely to propagate in the environment in comparison to other occupational pollutants [2]. Exposure to excessive noise is a prevalent physical pollutant in various industries [3–6]. Over the past decade, the proportion of people exposed to noise levels above 65 dBA has increased from 15% to 26% [7]. Hearing loss is the major physiological complication of exposure to excessive noise. The National Institute of Occupational Safety and Health (NIOSH) has estimated that 1 out of every 4 workers over 55 years of age who are exposed to excessive noise (above 90 dB) will suffer from some degree of hearing impairment. It has introduced noise-induced hearing loss as one of the top 10 major work-related diseases [8]. In addition to hearing loss, noise exposure will cause other bad effects on human health [9]. In industrial environments, exposure to noise can lead to cardiovascular problems, sick absence, fatigue, and a wide array of other indices connected with physical health. Noise can also have an indirect impact on personnel's health like affecting their physiological responses (change in heart rate, blood pressure, adrenaline production, etc.) [10,11]. The intervention of secondary sources of noise production in work environments creates complicated audio fields. Some of these sources are airborne noise, structure-borne noise, noise refraction on the edge of machines, and noise reflection from the floor, wall, ceiling, and the surface of machines. Thus, noise generating sources should be identified and ranked prior to taking any controlling measures. Equipment and work environments can be modified to reduce noise production and isolated to prevent noise transfer to surrounding environments. Such measures are generally referred to as engineering control methods, which are typically more expensive and more effective than individual noise control measures and personal protective equipment [12]. Although controlling produced noise in work environments is a crucial enterprise, not all noise control measures can be implemented due to financial setbacks in various industries. Therefore, it is essential to prioritize noise control measures and implement the most effective ones. Multiple criteria decision making (MCDM) can be of great help in prioritizing/ranking noise control measures and reducing generated noise in different industries. Decision making entails the process of selecting the best option out of the available alternatives. MCDM refers to a situation in which various criteria are taken into account during the process of decision making. In this procedure, various criteria (rather than one criterion) are used to assess the efficiency of different measures. In MCDM, a decision tree is developed based on selecting, weighing, and ranking all relevant criteria [13]. Generally, MCDM procedures are divided into two types: multiple objective decision making (MODM) and multiple attribute decision making (MADM). MODM is commonly used for designing superior alternatives, while MADM is utilized for selecting the best options. The major distinction between MODM and MADM is that while the first one is defined based on continuous decision space, the second one is characterized in the light of discrete decision space [14].

A well known technique of MADM is the Technique for Order-Preference by Similarity to Ideal Solution (TOPSIS). TOPSIS mixes quantitative (e.g., Price, time, distance, etc.) And qualitative attributes (e.g., Relationship quality, quality assurance, reliability, etc.) To compare all available alternatives. Despite its advantages, TOPSIS does not present an exact alternative. In other words, following TOPSIS, the closest alternative to the ideal solution is the most appropriate one [15]. The ideal solution, in turn, originates from information about the available alternatives while one cannot be certain if the existing alternatives are in stable condition. Thus, TOPSIS is typically used to select one alternative from among the available ones without taking the suitability of the desired alternative into account [16]. Over the past decade, TOPSIS has been used in various areas such as supplier evaluation and selection, inter-company comparison, expatriate host country selection, risk assessment, facility location selection, robot selection, operating system selection, software outsourcing problems, partner selection, customer evaluation, weapon selection, performance evaluation, etc. [17].

Few studies in Iran and across the world have investigated noise control measures in tire manufacturing industries by adopting TOPSIS. Thus, the current study utilized TOPSIS in one of Iran's tire manufacturing complexes to achieve the following objectives:

- Assessment of the inconsistency rate
- Pairwise comparison of criteria using AHP
- Calculation of the weight of main criteria using AHP
- Assessment of the relative weight of the alternatives based on each criteria through adopting TOPSIS
- Assessment of the final weight of research alternatives using TOPSIS

2 Materials and Methods

2.1 Industry Selection

The study was conducted in a tire manufacturing complex in Iran. In this factory, 15 curing press machines were located in each row and there were 4 rows in total (hence the total number of machines was 60). Every two machines were 2 m apart and the hall had a length of 100 m, a width of 50 m, and a height of 9 m. The number of machines, the distance between them, and the hall volume all can play a part in the amount of generating noise. Furthermore, 30 twin PLC tire curing press machines, which were facing each other, were positioned in the middle of the hall. These machines applied direct heat under compressed air to cure tires. Additionally, 30 singleton OTR tire curing press machines were located on the two sides of the hall. These machines applied compressed air and vapor to manufacture 70 types/sizes of tires for cars, trucks, lightweight, semi-heavy, and heavy machinery, and agricultural machines.

Between 2000 and 2300 people worked in this factory. Sixty six of them worked in the curing hall in three work shifts (22 workers in each 8-hour shift, with the morning shift beginning at 8 AM). The curing hall had a total area of 5000 m^2, whereas the sandblast and trimming units occupied an area of 200 m^2.

2.2 Study Design

This cross-sectional, descriptive, analytical study aimed at prioritizing and ranking noise control measures in an Iranian tire manufacturing complex in 2016 by adopting TOPSIS. The following steps were taken in this study:

- **Delphi technique:** It was exploited to identify the criteria and alternatives of the study.
- **AHP method:** AHP decision matrix was used to conduct a pairwise comparison of the selected criteria and alternatives.
- **TOPSIS:** It was utilized to prioritize the constituent alternatives of the decision matrix.
- **Questionnaire development and assessment of the weight of noise control methods:** To prioritize and weigh noise control methods, the AHP and TOPSIS questionnaire was developed in the light of research objectives, criteria, and alternatives. The developed questionnaire was then submitted to noise control experts.

The detailed description of the four stages of the study is provided below.

2.3 The Delphi Technique

It was majorly developed by Dalkey et al. [18] at the Rand Corporation in the 1950s. It is an internationally acclaimed procedure for achieving opinion convergence with regard to real-world knowledge elicited from domain experts within a particular area. The Delphi technique is based on the rationale that "two heads are better than one, or… N heads are better than one" [19] and is based on a group communication process in which detailed examinations and discussions of a particular issue are conducted with the purpose of setting goals, investigating policies, or predicting future events [20–22].

From a theoretical viewpoint, the Delphi process can be continuously iterated till consensus is achieved. Nonetheless, Ludwig et al. [22–24] and Custer et al. [25] argue that typically the required information can be collected and consensus can be achieved through three iterations. The following guideline provides a detailed description of how four iterations can be carried out to collect the necessary data and achieve consensus.

Round 1: The Delphi process begins with an open-ended questionnaire, which is used to elicit information from the Delphi participants [25]. The data collected through this questionnaire will in turn be converted into a well-structured survey, which is used in the second round of data collection. Extensive review of the existing literature shows that a structured questionnaire is also used in the first round of the Delphi technique, as a modification to the original four-step process. As pointed out by Kerlinger [26], the modified Delphi process is appropriate if basic information concerning the target issue is available and usable.

Round 2: Delphi participants will receive a second questionnaire, which is developed based on the respondents' ideas in the first round items. The Delphi panelists are invited to "rank-order items to establish preliminary priorities among items. As a result of round two, areas of disagreement and agreement are identified" [24]. On some occasions, the panelists are required to express the rationale behind their ratings. In this second round, consensus begins to form and the actual outcomes are evident in the panelists' responses.

Round 3: In this round, each Delphi panelist receives a questionnaire including the items and ratings of the previous round summarized by the investigators. The panelists are invited to revise their judgments or "to specify the reasons for remaining outside the consensus" [27]. This provides an opportunity for further clarification of the provided information in the previous round. A slight increase of consensus can be observed in comparison with the previous round [28–30].

Round 4: In this round, the list of remaining items, their ratings, minority opinions, and items on which a consensus has been achieved are given to the panelists. A final opportunity is presented to the panelist to revise their judgments. The number of Delphi iterations may range from three to five and largely depends on the degree of consensus that the investigators are seeking [24,31].

2.4 AHP Method

A typical decision method decomposes the multi-criterion complex into a hierarchy construction [32]. As a measurement theory, AHP prioritizes the hierarchy and consistency of judgment data presented by a panel of decision makers. It incorporates the assessments of all experts' ideas into a final decision in an objective way [33]. Sinuany used AHP to find the best location for a hospital in a rural area [34]. Generally, AHP is a scoring method to convert a complicated decision problem into a simple hierarchical process and give weight to various elements in the hierarchy of conducting pairwise comparisons and assessing the relative importance of decision criteria, attributes, and alternatives [35]. AHP modeling entails four phases: structuring the decision problem, developing measurement techniques, collecting data, and assessing the normalized weight of and synthesizing solutions [36].

In the current study, this four-phase process was utilized to select the best noise control methods.

AHP has been successfully used to solve different decision making problems. The following steps are used in the AHP process:

Establishment of pairwise comparison matrix A; Let C_1, C_2, …, C_n denote the set of elements, while a_{ij} represents a quantified judgment on a pair of elements C_i, and C_j. The relative importance of the two elements was examined using a scale with the values 1, 3, 5, 7, and 9, where 1 means "equally important", 3 denotes "slightly more important", 5 is defined as "strongly more important", 7 represents "demonstrably more important", and 9 denotes "absolutely more important". These scales yield a n × n matrix A as follows [37]:

$$A = [a_{ij}] = \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}.$$

$C_1, C_2, \ldots, C_n$ where $a_{ij} = 1$ and $a_{ij} = 1/a_{ij}, i,j = 1,2\ldots,n$. In matrix A, the problem becomes one of assigning a set of numerical weights $W_1, W_2, \ldots, W_n$ to the n elements $C_1, C_2, \ldots, C_n$ reflecting the recorded judgments.

Saaty suggested that the largest eigenvalue λ_{max} in Eq. (1) would be

$$\lambda_{max} = \sum_{j=1}^{n} a_{ij} \frac{W_j}{W_i}. \tag{1}$$

And then Saaty proposed utilizing consistency index (CI) and consistency ratio (CR) to confirm the consistency of the comparison matrix. CI and CR are defined as follows in Eqs. (2) and (3):

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{2}$$

$$CR = \frac{CI}{RI} \tag{3}$$

Here, the RI indicates the average consistency index over numerous random elements of same order reciprocal matrices. If CR $\leqq$ 0.1 indicated that the matrix reached consistency.

2.5 TOPSIS

It was initially proposed by Chen et al. on the premise that the selected alternative must have the shortest distance from the ideal solution and the furthest distance from the negative-ideal solution [38].

A positive solution maximizes the benefit criteria/attributes and minimizes the cost criteria/attributes. In contrast, e negative ideal solution maximizes the cost criteria/attributes and minimizes the benefit criteria/attributes. The six steps are followed in TOPSIS [39]:

Step 1: The normalized decision matrix is calculated. The normalized value r_{ij} is calculated as follows in Eq. (4):

$$r_{ij} = x_{ij}\sqrt{\sum_{i=1}^{m} x_{ij}^2} \quad i = 1,2,\ldots,m \text{ and } j = 1,2,\ldots,n. \tag{4}$$

Step 2: The weighted, normalized decision matrix is calculated based on the following Eq. (5):

$$v_{ij} = r_{ij} \times w_j \quad i = 1,2,\ldots,m \text{ and } j = 1,2,\ldots,n. \tag{5}$$

where w_j is the weight of the j^{th} criterion or attribute and $\sum_{j=1}^{n} w_j = 1$.

Step 3: The ideal (A*) and negative ideal (A^-) solutions are calculated based on Eqs. (6) and (7):

$$A^* = \{(\max_i v_{ij} \,|j \in C_b), (\min_i v_{ij} \,|j \in C_c)\} = \{v_j^* \,|j = 1, 2, \ldots, m\} \tag{6}$$

$$A^- = \{(\min_i v_{ij} \,|j \in C_b), (\max_i v_{ij} \,|j \in C_c)\} = \{v_j^- \,|j = 1, 2, \ldots, m\} \tag{7}$$

Step 4: The separation measures are calculated using the m-dimensional Euclidean distance. Eqs. (8) and (9) are used to calculate the separation measures of each alternative from the positive ideal solution and the negative ideal solution respectively:

$$S_i^* = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^*)^2}, j = 1, 2, \ldots, m \tag{8}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2}, j = 1, 2, \ldots, m \tag{9}$$

Step 5: The relative closeness to the ideal solution is calculated. Eq. (10) is used to calculate the relative closeness of the alternative A_i with respect to A*:

$$RC_i^* = \frac{S_i^-}{S_i^* + S_i^-}, i = 1, 2, \ldots, m \tag{10}$$

Step 6: The preference order is ranked.

The value of the relative closeness of the alternative (RC_i^*) ranges from 0 to 1. The higher the value of this index, the higher the efficiency of the alternatives. The alternatives are prioritized using this index.

In TOPSIS, to minimize the distance from the ideal positive solution and maximize the distance from the ideal negative solution, the selected alternative should have the highest RC_i^* value [40–42].

2.6 Questionnaire Development and Assessment of the Weight of Noise Control Methods

To design the questionnaire, a list of all criteria (10 criteria) and noise control methods (16 alternatives) was initially developed. The criteria and alternatives were then put together in a questionnaire, which was subsequently submitted to 15 domain experts in the tire industry and occupational health experts who had carried out research on noise control. Based on these experts' opinions, 4 criteria and 8 alternatives were selected for prioritizing noise control methods. Each criteria/alternative of the questionnaire should be rated based on a Likert scale (Tab. 1). The responses then underwent TOPSIS to prioritize noise control methods. The Delphi technique was utilized to determine the criteria and alternatives of the study.

Table 1: Rating the criteria and alternatives based on a Likert scale

Positive Criterion	Very low	Low	Moderate	High	Very high
	1	3	5	7	9
Negative Criterion	Very low	Low	Moderate	High	Very high
	9	7	5	3	1
	Numbers 2, 4, 6, and 8 can be used as mediator values on the Likert scale				

Table 2: The procedure used for introducing criteria in TOPSIS

Criteria	Representing symbol	Type of criterion	Very high	Very low
Implementation and maintenance cost	C_1^-	Negative	1	9
Method applicability	C_2^+	Positive	9	1
Method effectiveness and efficiency	C_3^+	Positive	9	1
Intervention in the process	C_4^-	Negative	1	9

Table 3: The procedure used for introducing alternatives in TOPSIS

Alternatives	Representing symbol
Reducing individuals' noise exposure time	A_1
Designing and installing sound isolation chamber for operators	A_2
Using earmuffs and earplugs simultaneously	A_3
Changing processes or operating procedures in machinery with excessive noise generation	A_4
Forming noise control engineering teams	A_5
Requiring people in charge to quickly fix the leaks and change baking press washers on time	A_6
Using acoustic panels in the ceiling and walls	A_7
Designing and manufacturing silencer and nuzzle for the steam and compressed air outlet of baking press machinery	A_8

Tabs. 2 and 3 illustrate the procedure through which the criteria and alternatives were introduced in TOPSIS.

3 Data Analysis

The questionnaire data collected from noise control experts and technical specialists were fed into Expert Choice. V11 and Excel [43].

4 Results

Examining the completed questionnaires and developing the group decision matrix by the use of geometric mean indicated that the inconsistency rate was 0.024. After assessing the consistency rate, the following results were obtained for prioritization of noise control methods:

4.1 Pairwise Comparison of Criteria Using AHP

Tab. 4 displays the pairwise comparison of criteria obtained through the geometric mean method.

4.2 The Weight of Each Criterion Obtained Through the AHP

The results of weighing each criterion are illustrated in Tab. 5.

It is observed that implementation and maintenance cost has the highest importance, whereas method effectiveness and efficiency has the smallest significance.

4.3 The Rating Mean Scores of Alternatives in Each Criterion Obtained through TOPSIS

Tab. 6 shows the rating mean scores of alternatives in each criterion obtained through TOPSIS.

Table 4: Pairwise comparison of criteria

Number	Numbers ranging from 1 to 9 were used	C_1^-	C_2^+	C_3^+	C_4^-
1	C_1^-	1	1	8.930	8.930
2	C_2^+	1	1	9	4.121
3	C_3^+	0.112	0.111	1	0.524
4	C_4^-	0.112	0.243	1.910	1

Table 5: The weight of the major criteria based on decision makers' view

	Criterion	Factor weight
C_1^-	Implementation and maintenance cost	0.481
C_2^+	Method applicability	0.397
C_3^+	Method effectiveness and efficiency	0.046
C_4^-	Intervention in the process	0.077

Table 6: The rating mean scores of alternatives in each criterion using TOPSIS

Criterion Alternatives	C_1^-	C_2^+	C_3^+	C_4^-
A_1	2	2	7	1
A_2	4	4	7	2
A_3	3	7	3	8
A_4	1	2	8	8
A_5	9	9	3	8
A_6	1	6	7	8
A_7	7	9	7	7
A_8	2	7	8	4

4.4 The Non-Scale Decision Matrix of Alternatives in Each Criterion Obtained through TOPSIS

The results of non-scale decision matrix of alternatives in each criterion obtained through TOPSIS are illustrated in Tab. 7. Based on the importance factor of the criteria and the obtained weights for each alternative, the highest non-scale value (0.701) in the first criterion (C_1^-: implementation and maintenance cost) was registered for A_5 (forming noise control engineering teams). The highest value for the second criterion (C_2^+: method applicability) was recorded for A_5 (forming noise control engineering teams) (0.503) and A_7 (using acoustic panels in the ceiling and walls) (0.503). Also, the greatest value in the third criterion (C_3^+: method effectiveness and efficiency) was registered in A_4 (changing processes or operational procedures in machinery with excessive noise generation) (0.433) and A_8 (designing and manufacturing silencer and nuzzle for the steam and compressed air outlet of baking press machinery) (0.433). Finally, the highest values in the fourth criterion (C_4^-: intervention in the process) were observed in A_3–A_6 (using earmuffs and earplugs simultaneously, changing processes, forming noise control engineering teams, and requiring people in charge to quickly fix the leaks) (0.443).

Table 7: Non-scale decision matrix of alternatives in each criterion obtained through TOPSIS

Criterion Alternatives	C_1^-	C_2^+	C_3^+	C_4^-
A_1	0.156	0.112	0.379	0.055
A_2	0.311	0.224	0.379	0.111
A_3	0.234	0.391	0.162	0.443
A_4	0.078	0.112	0.433	0.443
A_5	0.701	0.503	0.162	0.443
A_6	0.078	0.335	0.379	0.443
A_7	0.545	0.503	0.379	0.388
A_8	0.156	0.391	0.433	0.222

4.5 The Results of Weighted Non-Scale Decision Matrix of Alternatives in Each Criterion Obtained through TOPSIS

According to the obtained importance factors of the criteria and weights of the alternatives illustrated in Tab. 8, the highest weighted non-scale value in the first criterion (C_1^-: implementation and maintenance cost) was registered for A_5 (forming noise control engineering teams) (0.337). The highest values for the second criterion (C_2^+: method applicability) were recorded for A_5 (forming noise control engineering teams) (0.337) and A_7 (using acoustic panels in the ceiling and walls) (0.200). Also, the greatest value in the third criterion (C_3^+: method effectiveness and efficiency) was registered in A_4 (changing processes or operational procedures in machinery with excessive noise generation) (0.020) and A_8 (designing and manufacturing silencer and nuzzle for the steam and compressed air outlet of baking press machinery) (0.020). Finally, the highest values in the fourth criterion (C_4^-: intervention in the process) were observed in A_3–A_6 (using earmuffs and earplugs simultaneously, changing processes, forming noise control engineering teams, and requiring people in charge to quickly fix the leaks) (0.034).

Table 8: The weighted non-scale decision matrix of alternatives in each criterion obtained through TOPSIS

Criterion Alternatives	C_1^-	C_2^+	C_3^+	C_4^-
A_1	0.075	0.044	0.017	0.004
A_2	0.15	0.089	0.017	0.009
A_3	0.112	0.155	0.007	0.034
A_4	0.037	0.044	0.02	0.034
A_5	0.337	0.2	0.007	0.034
A_6	0.037	0.133	0.017	0.034
A_7	0.262	0.2	0.017	0.03
A_8	0.075	0.155	0.02	0.017

4.6 The Results of Prioritizing Alternatives through TOPSIS

As observed in Fig. 1, the first priority in the alternatives belongs to “designing and manufacturing silencer and nuzzle for the steam and compressed air outlet of baking press machinery” with a final weight of 0.828, while the last priority goes to “forming noise control engineering teams” with a final weight of 0.340.

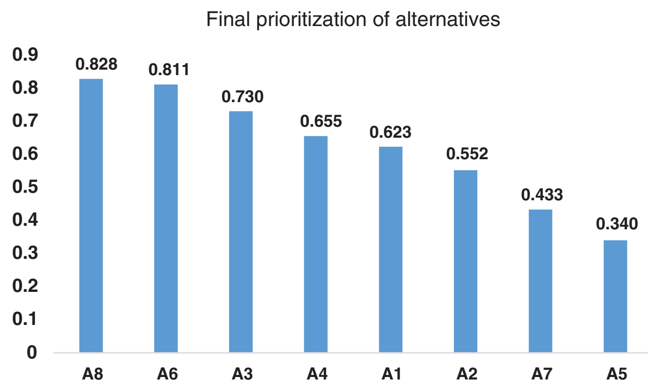

Figure 1: Prioritizing alternatives through TOPSIS

5 Discussion

This study sought to weigh and prioritize noise control methods using the Delphi technique and TOPSIS in an Iranian tire manufacturing factory in 2016. AHP was used in this study to assess the consistency rate, conduct pairwise comparison of criteria, and weigh each of the criteria. Then, to obtain the rating mean score of each alternative in every criterion, non-scale matrix and weighted non-scale matrix were used. Finally, TOPSIS was adopted to weigh and prioritize alternatives to select the best noise control methods.

The main advantages of exploiting TOPSIS are as follows: “TOPSIS logic is rational and understandable”, “the computation processes are straightforward”, “the concept permits the pursuit of best alternative criterion depicted in a simple mathematical”, and “the importance weights are incorporated comparison procedures” [15].

The results of assessing the consistency rate of the criteria and alternatives using AHP indicated that the inconsistency rate was less than 10% of all cases. Thus, the prioritization of pairwise comparison of matrices was acceptable and the consistency of responses was verified. Therefore, the obtained coefficients were reliable, hence pairwise comparisons were conducted. The results of weighing different criteria indicated that implementation and maintenance cost had the highest weight (0.481), whereas method effectiveness and efficiency registered the smallest one (0.46) (Tab. 4).

The results of weighing and prioritizing alternatives through TOPSIS showed that the three alternatives with the highest priority were “designing and manufacturing silencer and nuzzle for the steam and compressed air outlet of baking press machinery” (0.828), “requiring people in charge to quickly fix the leaks” (0.811), and “using earmuffs and earplugs simultaneously” (0.730) in that order. On the other hand, “using acoustic panels in the ceiling and walls” (0.433) and “forming noise control engineering teams” (0.340) came last in terms of their priority (Fig. 1).

No similar study in Iran or across the world has tried to use TOPSIS to weigh and prioritize noise control methods in the tire manufacturing industry. However, a limited number of studies in Iran have utilized AHP to rank the priority of noise control methods in other industries. Therefore, in this section, the findings are justified in the light of the studies that have adopted AHP.

Sekhavati et al. [44] used AHP to prioritize noise control methods in a cement factory in Larestan by examining 8 criteria and 9 alternatives. They concluded that "initial investment cost" had the highest importance (with a weight of 0.247), while "satisfaction with method implementation" recorded the lowest one (with a weight of 0.035). Also, pairwise comparison of alternatives based on the objectives of using noise control methods indicated that "individuals' noise exposure time" had the highest priority (with a weight of 0.224), while "isolation of buildings" recorded the lowest weight (0.064). The results of the study carried out by Sekhavati et al. Indicate a conflict between their findings and the ones obtained in the current study. This contradiction can be attributed to the large number of proposed alternatives and criteria, which makes the prioritization and weighing process a difficult undertaking. Using AHP, Hwang et al. [45] sought to prioritize noise control methods in a glass factory in Hamedan. They focused on 4 criteria (i.e., Cost, efficiency, applicability, and lack of intervention) and 11 alternatives. The prioritization process of the study criteria proceeded in the light of assessing importance factors. The results showed that method applicability (with a weight of 0.277) and use of complete separation wall between the two main sections (with a weight of 0.133) had the highest priority. The findings of Eshaghi's study are therefore in line with the results of the current research.

Ahmadi et al. [46] exploited AHP to rank noise control methods in the Alam San'at Factory of Lamerd, Fars Province, Iran. Through conducting pairwise comparisons, they concluded that "method effectiveness and efficiency" had the highest importance (with a relative weight of 0.576), whereas "implementation cost" had the lowest priority (with a relative weight of 0.243). With regard to the noise control methods, they also found that "installing noise absorbing layers in the floor, ceiling, and walls had the highest priority" (with a final weight of 0.243), hence being the most appropriate method for noise control. On the other hand, "putting a noise wall between the worker and the machinery" was the least suitable method of noise control (with a final weight of 0.135). These findings are in conflict with the results of the present study, which can be attributed to the wide variety of proposed alternatives and criteria.

6 Conclusion

Out of different proposed criteria in this study, "implementation and maintenance cost" and "method effectiveness and efficiency" recorded the highest and lowest priorities respectively. On the other hand, considering the alternatives, the highest and lowest priorities belonged to "requiring people in charge to quickly fix the leaks and change baking press washers on time" and "using earmuffs and earplugs simultaneously" respectively.

This study further demonstrated how the best noise control methods can be selected by decision makers in the light of the obtained value of each criterion. Different approaches can be utilized to prioritize noise control methods. The results of the current study suggest that TOPSIS can be utilized as an effective approach in this regard. Thus, this approach can be followed for selecting the best noise control methods.

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