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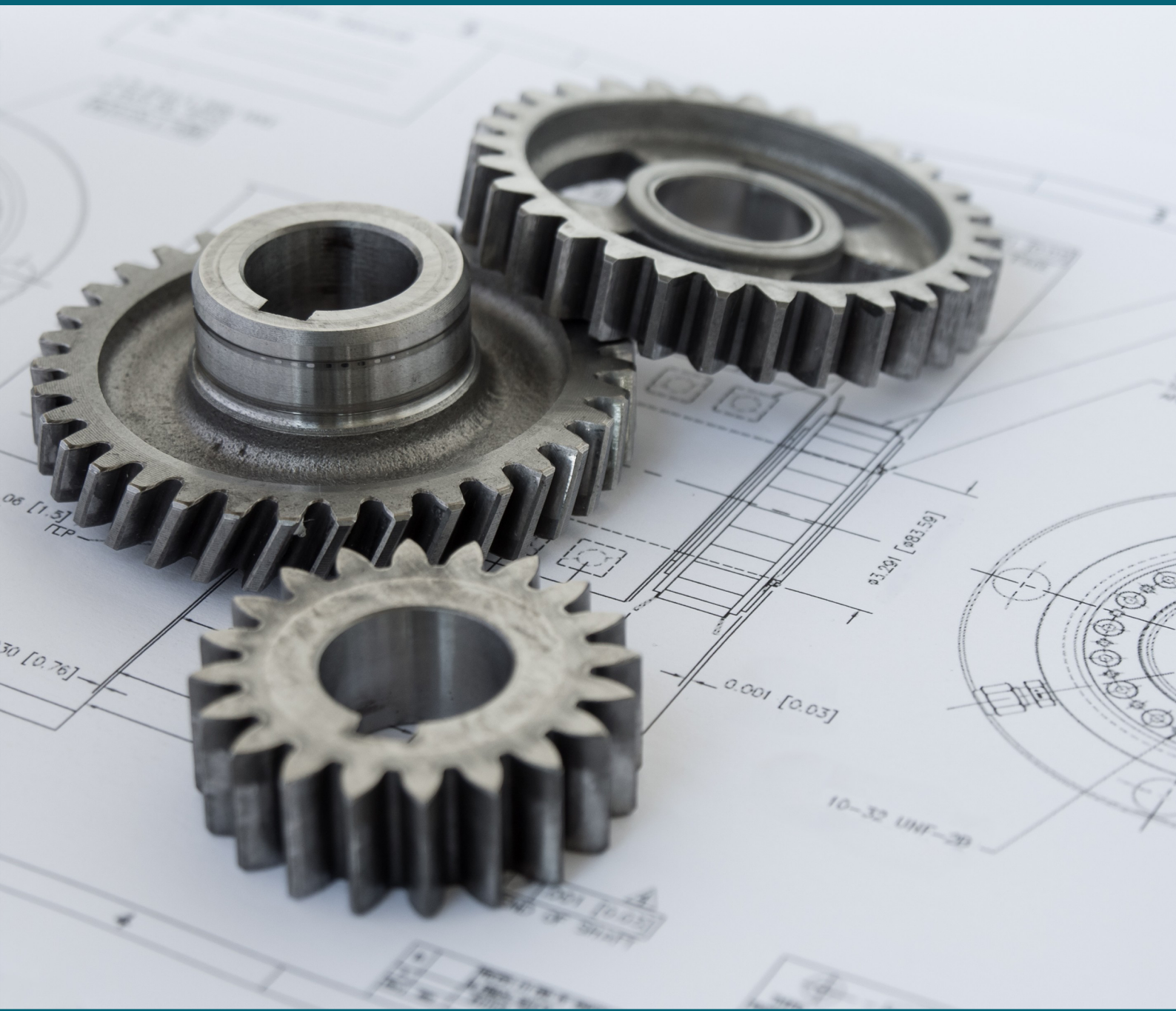

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Determinants of Job Satisfaction among the Employees of Aluminum Industries in Rajshahi City of Bangladesh: a Cross-Sectional Study

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Abstract

Job satisfaction of the employees is a concerning issue, accelerates the productivity of any organization. Higher job satisfaction among the employees means the higher chance of profitability of the employers. An effective understanding of factors associated with job satisfaction of the employees is precious to push organizational development. This study based on the data collected from three aluminum industries inRajshahi cityofBangladesh during January 21, 2016 to March 20, 2016 to identify the determinants of job satisfaction among the employees. In this study, age, sex, education, work experience, satisfaction with salary, workplace environment and workplace management system are revealed as the determinants of job satisfaction. For instance, higher aged respondents in more likely to satisfy with job than lower aged (Odds Ratio (OR): 1.30 [0.48-3.57]). Female are more likely (OR: 1.90 [1.03-3.51]) to satisfy with their job than the male. Higher educated employees are less likely (OR: 0.97 [0.56-1.70]) to satisfy with their job than the lower educated employees. Respondents with 15 & above years of experience are more likely (OR: 1.05 [0.33-2.15]) to satisfy with their job than those have less than 5 years of experience. Satisfaction with salary (OR: 1.97 [1.14-3.41]), workplace environment (OR: 1.62 [0.59-6.51]), management system (OR: 1.24 [1.25-3.98]) are significantly associated with job satisfaction of the employees. As the first study, it provides the determinants of job satisfaction among the employees in aluminum industries in Rajshahi city of Bangladesh. Relevant authorities are suggested to consider the study's findings and recommendations to create new policies regarding job satisfaction.

Keywords: Salary, Workplace environment, Management, Logistic regression, Job satisfaction.

1 | Introduction

Bangladesh has made some noteworthy development in the economic growth and reduction ofpoverty since the early 1980s [1]-[2] and the industries remain the heart of such progresses. Expansion of industrial sector has accelerated the job markets of the country and reduced the unemployment rate of the nation as well. The active and continuous efforts of employees help to run the development wheels continuously. Hence, it is imperative to ensure the satisfaction of the employees with their work. Job satisfaction is widely viewed as the attitudes of employees towards their working conditions and working environments [3]-[5] and positive emotional response to their jobs and work performances [6]-[8]. Job satisfaction is broadly researched topic [9] due to the reality that most individuals spend a large part of their work life at work. Some factors are very much important for the job satisfaction of the employees. However, there are some mark differences

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between the factors related to job satisfaction of low skilled and high skilled employees especially in physical labour-based industries where financial benefits and services are the main motivational and satisfaction factors for the employees. Additionally, they are not so much eager for social affiliation, self-esteem, rewards and recognition for their performance [10].

Many organizations/industries fail to realize the importance of job satisfaction of their employees that is critical for industrial/organizational productivity [11]-[14]. Employees are the fundamental component in the process of achieving the industrial/organizational mission and vision [15]. Job satisfaction is a complex matter and generally can be explained as a sense of comfort and positive experience of an employee related to his job [16]. Satisfaction of employees is an indispensible intention for any organization to reach [17] as the increase level of job satisfaction of the employees will definitely leads to more return to the organization.

The application of aluminum products in our daily life has dramatically increased over the last few decadesand this has resulted in the quick expansion of aluminum industries certainly. A number of people are working in these industries. In Bangladesh, this sector definitely creates a huge number of job opportunities forits population. It is considered as one of the growing sectors that have specific participation in national development of the country. As a physical labour oriented industry, ensuring enough job satisfaction should be the concerning matter of aluminum industry. The main depositing fact of this study is to identify the most influential factors that affect the job satisfaction of the employees in aluminum industries. The appropriate policy responses at the industrial level can only be initiated by knowing the influential factors. Although there are studies on the determinants of job satisfaction around the world [11], [14], [18]-[22], in Bangladesh, extant literature has not paid particular focus of job satisfaction among the employees of aluminum industries. For example, job satisfaction of the employees has been studied in almost all the sectors including private companies [23], banking sectors [24], non-government organization sectors [25], educational sectors [21], readymade garments industries [26]-[27] except the aluminum industries. Thus, due to the lack of research on job satisfaction among the employees in aluminum industries, this study set the aim to identify the determinants of employee's job satisfaction in aluminum industries in Bangladesh. Considering the sector of the study (i.e. aluminum industries), it can be said as an innovative study. It is believed that findings ofthe current study will be more helpful for Bangladeshi policy makers in formulating active policies and creating strong measuresalong with revising the existing policies and programmesto encourage the respected authorities in ensuringjob satisfaction among the employees in aluminum industries in Bangladesh.

2 | Methods

2.1 | Data

The study is based on the primary data came from the project titled "determinants of human resource development in industrial sector in Rajshahi city: a micro-survey study", under the department of population science and human resource development, university of Rajshahi, Bangladesh. In brief, data for the project were collected from three aluminum industries in Rajshahicity of Bangladesh. In order to select these industries, firstly all the industries of that industrial area (locally called Bangladesh Small and Cottage Industries Corporation (BSCIC) area) are classified according to the number of employees. Based on the number of employees and the reality of the industries in the study area, the industries are categorized as: category one (the number of employees is less than 100); category two (the number of employees is 100-200); and category three (the number of employees is more than 200). Then, one industry from each of the category is randomly selected and finally the data were collected randomly from the employees ofthose three industries between January 21, 2016 and March 20, 2016.

About 70 percent employees from the industry of each category are the respondents of this study. Specifically, 70 employees form the industry under category one; 142 employees form the industry under category two; and 205 employees form the industry under category three. Finally, the data from 417

employees were collected from the selected industries. A well-structured questionnaire was administered face-to-face to 417 employees.

2.2 | Outcome Variable

As we think all the employees are satisfied with their job in very general context is the research question or hypothesis of this study. Job satisfaction (however, relative issues but considered in this study as the verbal consent of the respondents) of the employeesis considered as the outcome variable, which is dichotomized by assigning "1" if anemployeeis satisfied with his/her job (based upon their opinion) and "0" for otherwise. Here, the job satisfaction is considered as the aggregate of salary/wage satisfaction (income from their job), satisfaction with workplace environment (includes heat, light and space at their working place) and management system (training, overtime payment, rewards and promotion) of the corresponding industry.

2.3 | Explanatory Variables

A wide range of respondent's characteristics, reported to be associated with job satisfaction of theemployees in previous studies [15], [28]-[30], were included in the current study. These characteristics include respondent's current age (classified as <30, 30-39, 40-49 or 50 & above years), sex (classified as male or female), education (categorized 0 to 5 years of schooling as below secondary, 6 to 10 years of schooling as secondary, or 11+ years of schooling as higher secondary & above), work experience (categorized as < 5, 5-9, 10-14 or 15 & above years), satisfaction with salary/wage (classified as no or yes), satisfied with workplace environment (categorized as no or yes), satisfied with management system (categorized as no or yes).

2.4 | Statistical Analysis

After performing descriptive statistics of the study sample, chi-square tests were used toidentify the differences in the percentage of employees by the explanatory variables (detailed above). All variables significant inchi-square tests at level $p<0.20$ wereincluded in regression analysis. Moreover, multicollinearity in the logistic regression analysis was checked by examining the standard errors for the regression coefficients. A standard error larger than 2.0 indicates numerical problems such as multicollinearity among the explanatory variables [31]. No evidence of multicollinearity was observed in the current study. Finally, a binary logistic regression model was used to identify the factors that are influentialin job satisfaction of the respondents. The statistical significance of all analysis was set at$p<0.05$. No sampling weights were provided with the data as such we do not apply sampling weights in the analyses. The entire statistical analysis of the study was performed with SPSS version 16.0 for Windows (SPSS Inc., Chicago, IL, USA).

3 | Results

Table 1 represents the basic characteristics of the study respondents. The average age is 38.5 years. Among the participants, 22.8 percent are less than 30 years, 26.9 percent are 30-39 years, 31.7 percent are 40-49 years and 18.6 percent are 50 and above years old. Approximately, 80 percent respondents are male while 19.9 percent are female. Average year of schooling is 5.9, and majority of the respondents (61.6 percent) are with secondary level of education. Also, 26.2 percent are below secondary level while only 12.2 percent are higher secondary and above level.Average work experience of the respondents is 13.2 years where majority of the respondents (43.9 percent) are working for 15 and above yearswhereas, work experience less than 5 years consists only 15.6 percent. Overwhelming majority of the respondents (80.1 percent) is not satisfied with their salary/wagewhile only 19.9 percent are provided their opinion that they are satisfied with their salary/wage. On the other hand, 68.6 percent respondents are not satisfied with their workplace environment and only 31.4 percent are satisfied with that. Also, 75.3 percent respondents are not satisfied

with the management system of their respective industry and only 24.7 percent are satisfying with the same context.

Table 1. Basic characteristics of the respondents.

Variables	Frequency	Percent
Age group (in years)		
<30	95	22.8
30-39	112	26.9
40-49	132	31.7
50 & above	78	18.6
Average age (SD)	38.5 (10.6)	
Sex		
Male	334	80.1
Female	83	19.9
Education		
Below secondary	109	26.2
Secondary	257	61.6
Higher secondary & above	51	12.2
Average year of schooling (SD)	5.9 (3.4)	
Work experience (in years)		
<5	65	15.6
5-9	95	22.8
10-14	74	17.7
15 & above	183	43.9
Average work experience (SD)	13.2 (8.1)	
Satisfaction with salary/wage		
No	334	80.1
Yes	83	19.9
Satisfaction with workplace environment		
No	286	68.6
Yes	131	31.4
Satisfaction with management system		
No	314	75.3
Yes	103	24.7

Notes: SD indicates Standard Deviation.

Table 2 analyzes the bivariate association between job satisfaction and basic characteristics, and shows the variation in percentage. A significant association between job satisfaction and age group was found; percentage of the respondents who are satisfied with their job is higher among the lower age group and lower among the higher age group ($p<0.001$). Respondent's sex is significantly associated with the job satisfaction, where female are more satisfied with their job than their counterparts ($p<0.001$). A significant association is alsofound between respondent's education status and job satisfaction where higher percentage of satisfied respondents have higher education than other education categories ($p<0.001$). Also, higher work experience of the respondents consists lower percentage in considering their job satisfaction and the association is significant ($p<0.001$). Respondents who are satisfied with their salary/wage, workplace environment and management system are more likely to satisfy with their job than their counterparts.

Table 3 shows the results of binary logistic regression model that yields the odds of being job satisfaction by categories of explanatory variables. The likelihood of being satisfied with the job decreases with the age except 50 & above years. The odds of being satisfied with job for those in age group 30-39 years is 0.89 times (95 percent confidence interval: 0.69-2.80), for those in age group 40-49 years is 0.93 times (95 percent confidence interval: 0.39-2.23) and for those in age group 50 & above years is 1.30 times (95 percent confidence interval: 0.48-3.57) than those in age group less than 30 years. Female are more likely (1.90 times) to satisfy with their job (95 percent confidence interval: 1.03-3.51) than their counterparts. The odds of being satisfied with their job for the respondents in the secondary education level is 1.68 times (95 percent confidence interval: 0.72-3.91) and for those in higher secondary & above education is 0.97 times (95 percent confidence interval: 0.56-1.70) than those in below secondary education. Respondents with work experience 5-9 years are 1.63 times more likely (95percent confidence interval:

1.03-4.54), 10-14 years are 1.34 times more likely (95 percent confidence interval: 0.56-3.22) and 15 & above are 1.05 times more likely (95 percent confidence interval: 0.33-2.15) to satisfy with their job than the reference category. Respondents who are satisfied with their salary/wage are 1.97 times (95 percent confidence interval: 1.14-3.41) more likely to satisfy with their job than those are not satisfied with their salary/wage; also, who are satisfied with the workplace environment (1.62 times and 95 percent confidence interval: 0.59-6.51) and management system (1.24 times and 95 percent confidence interval: 1.25-3.98) are more likely to satisfy with their job than theircounterparts respectively.

Table 2. Percentage of respondents by job satisfaction.

Variables	Job Satisfaction of the Employee	
	Number	Row Percentage
Age group (in years)		
<30	61	35.8
30-39	68	39.3
40-49	103	22.0
50 & above	54	30.8
p–value	<0.001	
Sex		
Male	243	27.2
Female	43	48.2
p–value	<0.001	
Education		
Below secondary	67	38.5
Secondary	189	26.5
Higher secondary & above	30	41.2
p–value	<0.001	
Work experience (in years)		
<5	48	26.2
5-9	49	48.4
10-14	48	35.1
15 & above	141	23.0
p–value	<0.001	
Satisfaction with salary/wage		
No	244	26.9
Yes	42	49.4
p–value	<0.001	
Satisfaction with workplace environment		
No	243	21.7
Yes	90	31.9
p-value	<0.001	
Satisfaction with management system		
No	255	18.9
Yes	79	23.3
p-value	0.04	

Notes: The p values of chi-square tests.

4 | Discussion

To the best of my knowledge, this is the first study that reveals the determinants of job satisfaction among the employees in aluminum industry. The small scales cross-sectional data show that majority of the employees are not satisfied with their job in the aluminum industries of Rajshahicity. The determinants of job satisfaction among the respondents include age, sex, education, work experience and satisfaction with salary/wage, workplace environment and management system.

Table 3. Determinants of job satisfaction

Variables	Odds Ratio	95 percent Confidence Interval
Age group (in years)		
<30®	1.00	-
30-39	0.89	0.69-2.80
40-49	0.93	0.39-2.23
50 & above	1.30	0.48-3.57
Sex		
Male®	1.00	-
Female	1.90*	1.03-3.51
Education		
Below secondary®	1.00	-
Secondary	1.68	0.72-3.91
Higher secondary & above	0.97*	0.56-1.70
Work experience (in years)		
<5®	1.00	-
5-9	1.63	1.03-4.54
10-14	1.34	0.56-3.22
15 & above	1.05*	0.33-2.15
Satisfaction with salary/wage		
No®	1.00	-
Yes	1.97**	1.14-3.41
Satisfaction with workplace environment		
No®	1.00	-
Yes	1.62*	0.59-6.51
Satisfaction with management system		
No®	1.00	-
Yes	1.24*	1.25-3.98

Notes ®: Reference Category; Level of significance: **: p<0.01; *: p<0.05.

Higher age, particularly 50& above years are associated with higher likelihood of job satisfaction among the respondents in this study which is in line of previous studies [32]-[34]. This might be due to the fact that, in Bangladesh, majority of the people are losing their physical strength from the age of 50 & above and they tend to become an elderly population. It is well known to them that, they are well behind than their younger due to their age, physical limitation and constricted job market as a resultthey arefacing difficulties to manage a job. So, respondents with higher age are satisfied with their job by considering that at least they have a job. Female contains the highest odds of job satisfaction in the current study as compared to male. In previous studies, gender is also found as one of the determinants of job satisfaction, where female is more likely to satisfy with their job than male [35]-[37]. In conservative Bangladeshi society, female is still engaging onlyin the domestic work. Hence, as an employee, earning money from the work remains dream to them. When they are able to earn money, they are satisfied with that and their work and this might be true for the result of the present study.

Consistent with previous literature [38], the current study also finds lower job satisfaction among the higher educated respondents. Several factors might be responsible for that as the scarcity of job in the country and the expectations of the higher educated employees from the employers are not often met. The employees believe their educational qualification did not match with their current position. Higher work experience also exerts the higher odds of job satisfaction among the employees in this study, which is in a line with the previous study [39]. The main reason behind this might be the fact that the adaptation power within their existing work environmentof the respondents increase with the increase of their work experience.

Some previous studies have shown that the job satisfaction of employees influenced by their level of income [40]-[42]. The current study also finds the higher likelihood of job satisfaction among the respondents who are satisfied with their salary/wage. It is quite evident that, especially in Bangladesh, satisfaction with income is more or less represents the satisfaction with job among the employees. Job satisfaction is also largely influenced by the workplace environment as some previous literatures have shown [43]-[44], in this study satisfaction with workplace environment exhibits the higher likelihood of

job satisfaction. Generally, people want to get a suitable workplace environment, where they are bound to spend at least eight hours per day. Satisfaction with the workplace environment of the respondents definitely acceleratestheir satisfaction with the job and the present study shows the same. Consistent with previous studies [45]-[46], the current study also finds the higher likelihood of job satisfaction among the respondents who are satisfied with management system of their industry as compared to those are not satisfiedwith that. The possible reason for such result is that, due to the lack of employees' friendly management system, dissatisfactionamong the employeesregarding their job always works within their minds.

5 | Conclusions

In entirety, asthe first study, it provides the determinants of job satisfaction among the employees of aluminum industries in Rajshahi city of Bangladesh. Based on the upstairs results anddiscussion, carefully planning should be made to accelerate the job satisfaction of the employees, since job satisfaction of the employees is considered asthe main instruments of industrialprogresses. Without ensuring the job satisfaction of the employees, industrial/organizational profitability remains distant dream. Relevant authorities may consider the following five recommendationsin revising and redrawing the existing policies along with creating new effective policiesto ensure job satisfaction among the employees. The recommendations are: 1) need to establish a comprehensive rights based job market for all, 2) ensure that access to employment opportunities is fair and equal without discrimination, 3) need for inflationary adjustment with the salary/wage (i.e. increase in the salary of the employees on regular basis) of the employees, 4) need to ensure secured and safety workplace (tolerable light and sound in the workplace)environment for the employees, and 5) friendly industrial management should be established for the employees as well as for the industry.

Limitations

The current study has some limitations. Being a cross-sectional study, it does not permit casual association of the explanatory variables with the outcome variable. The data come from aluminum industry in Rajshahi Industrial Area of Rajshahi city, and thus may not be generalizable to all the entire industries in Bangladesh. Despite the limitations, as the pioneer study in this sector, it demonstrates a detail analysis of various determinants of job satisfaction of the employees in aluminum industries, which is generalizable to all the industries of Rajshahi district in Bangladesh.

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Conflict of Interest

The author declares no potential conflicts of interest with respect to this research, authorship, and/or publication of this article.

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Prioritization of Earthquake Relief Using a Hybrid Two-Phase Approach

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Abstract

One of the stages of crisis management is planning and initial preparation to deal with the crisis. During natural disasters, one of the main activities is the logistics of relief groups and the activities of relief teams to save the lives of the victims of the accident. A review of past events shows that the chances of rescuing the injured decrease and that a quick and correct decision is important in this situation. This paper presents a two-phase hybrid approach to decision-making and prioritization of affected regions to send relief teams. In this approach, multi-criteria decision-making methods in two phases are used to consider different indicators in achieving the optimal solution. In the first phase, with the help of the primary decision matrix, the AHP, TOPSIS and AHP-TOPSIS methods are used. And in the second phase, according to the results obtained from the first phase, the secondary decision matrix is created. With the CoCoSo method's help, one of the newest methods in this field, areas are prioritized for relief. In order to implement the proposed approach, the city of Amol has been studied.

Keywords: Crisis logistics, Decision making, Crisis management, Relief.

1 | Introduction

Iran is among the ten countries prone to disaster and is ranked sixth in the world in terms of earthquakes. Although disaster damage is irreparable in many ways, it can be minimized by taking appropriate precautions as well as developing programs to deal with the effects of such disasters. Therefore, the supply chain in crisis situations is a necessary and vital issue in supply chain management [1], [2]. Natural phenomena have unique features and characteristics that knowledge of earthquake-associated phenomena, recognition of faults and their types is important in determining the seismic pattern and seismic regime of different regions [3]. The lack of pre-determined programs to deal with post-earthquake crises in some countries has increased the damage rate of this natural phenomenon. Therefore, there is a special need to provide an optimal plan for sending relief teams and deciding on the priority of relief to the affected regions [4].

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Unfortunately, there is little research in the field of prioritization and response to demand points before and during the accident (two stages), which we review in *Table 1* of some of these similar studies. Many types of researches have been done in the field of crisis management. An important part of the research conducted in this field is in line with the earthquake crisis, which has been studied from different perspectives, such as prioritizing post-earthquake relief, locating relief centers, routing relief vehicles, etc. [5]. Some of these problems can be seen in *Table 4*.

Table 1. The research in the field of crisis management.

Author (Year)	Problem	Method	Case Study
Yariyan et al. [6]	Earthquake risk assessment	Integrated Fuzzy Analytic Hierarchy Process with Artificial Neural Networks	Sanandaj
Jahangiri et al. [7]	People's perspectives and expectations on preparedness against earthquakes	Cross-sectional study and a door-to-door survey	Tehran
Khalili et al. [8]	Relief supply location in post-disaster environment	Proposing a bi-objective nonlinear mixed integer and using Reservation Level driven Tchebycheff Procedure	Iran
Su et al. [9]	Classification method of emergency supplies	AHP and cluster analysis	Numerical instances
Boostani et al. [10]	Optimal location selection of temporary accommodation sites	Hybrid fuzzy multiple-criteria decision making	Iran
Fiedrich et al. [11]	Optimized resource allocation for emergency response after earthquake disasters	Mathematical modeling, Heuristics, Computer-based decision-support systems	Numerical instances
Salmerón and Apte [12]	Stochastic optimization for natural disaster asset prepositioning	A two-stage stochastic optimization model	Numerical instances
Rawls and Turnquist [13]	Pre-positioning planning for emergency response	Two-stage stochastic optimization	Southeastern America Storm
Gero et al. [14]	Dispositional Optimism and Disaster Resilience	Multiple logistic regression models	Japan
Ortuño et al. [15]	logistics of Humanitarian Aid	A lexicographical goal programming based decision support system	Nigeria
Bhandari et al. [16]	Disaster risk understanding of local people after the Earthquake	Histogram analysis, distribution analysis, bivariate correlations and independent sample t-tests	Pokhara City, Nepal
Abdollahian and Mahmoudzadeh [17]	Define and prioritize the criteria for locating accommodation and relief centers	TOPSIS	Sabzevar
Yarmohammadian et al. [18]	Investigation of the status of preparedness and crisis management restrictions	Descriptive-analytical	Hospitals of Isfahan University of Medical Sciences
Hallak and Pınar [19]	The Evaluation of Humanitarian Relief Warehouses	Fuzzy AHP and MULTIMOORA technique	Syria
Abazari et al. [20]	Prepositioning and distributing relief items in humanitarian logistics	Grasshopper Optimization Algorithm	Iran's flood
Sarma et al. [21]	Resource Allocation Model for Disaster Relief Operations	MCDM Approach	Numerical instances
Dachyar and Nilasari [22]	The Improvement of Disaster Relief Distribution	Internet of Things	Numerical instances

One of the problems in the field of earthquake crisis management is the prioritization of relief to earthquake-stricken areas, and various methods have been implemented to address this. In the reference [23], Shannon entropy and TOPSIS method have been used to rank residential areas against earthquake hazards. For this purpose, 8 criteria have been studied for 27 areas of Amol city, which include released energy, earthquakes of the last 20 years in terms of TNT, building quality, residential density, building

density, population density, network permeability, urban open space and groundwater depth are after construction. To rank the vulnerability, 5 categories of "very high", "high", "medium", "low" and "very low" were used and according to the city map, the vulnerability of Amol was prepared. The results showed that the central regions are very vulnerable.

Therefore, it is expected that the vulnerability of areas in the future construction of the city will be considered. Emergency logistics play a prominent role in reducing the consequences of disasters. The reference [24] evaluates the performance of emergency supplies based on the establishment of a comprehensive evaluation system that includes emergency preparation, response and recovery, and the TOPSIS-EW method. This study was used to evaluate the performance of emergency supplies in the Wenchuan earthquake and identified the five areas with the highest vulnerability. Finally, based on the results of the comprehensive evaluation, some specific management suggestions have been made to improve the capacity of emergency supplies. Relief logistics centers and the quality of their services become very important in the event of a natural disaster. In other words, choosing the right locations for relief logistics centers has a direct impact on operating costs and timely response to demands. The reference [25] provides a decision support system for prioritizing the locations of relief logistics centers in the event of a natural disaster.

Nyimbili et al. [26] considered the criteria of availability, risk, technical issues, cost and coverage at the location of relief logistics centers. In this paper, using the AHP method, the location of these centers has been done. In this paper, two methods of decision making, goal programming and two-stage logarithmic goal planning have been used. This paper has been reviewed for Tehran city data. Around the world, earthquakes and their resulting catastrophes have consistently had severely negative impacts on human livelihoods and have caused widespread economic and environmental damage. The severity of these disasters has necessitated a comprehensive effort to manage emergencies. In this regard, multi-criteria decision analysis methods are widely used by emergency managers to improve the quality of the decision process. In one study, integrated AHP and TOPSIS methods were used to generate earthquake hazard maps [26].

Istanbul city was surveyed and the five main criteria that have the greatest impact on earthquakes in the study area were identified, including topography, distance to the epicenter, soil classification, fluidization and fault-focal mechanisms. AHP was used to determine the weight of these parameters and these weights were given as input by the TOPSIS method to be used to produce earthquake hazard maps. The combination of decision-making tools has been used in various papers in which different methods such as simple average weighed, ε-constraint, response surface methodology, data envelopment analysis and AHP have been used [27]-[36]. As it has been observed, so far, TOPSIS, AHP and AHP-TOPSIS methods have been used separately in different papers in the field of selecting the location of the earthquake relief center. Each of these methods has many advantages and is very practical. However, no study has used all three of these methods simultaneously. In this paper, in the proposed two-phase approach, all three of these methods are implemented in the first phase, and in the second phase, the results of all three methods are combined to create the final result. Therefore, the most important advantage of the proposed two-phase approach is to use the advantages of all three methods, which will lead to more accurate results.

On the other hand, in the second phase, to integrate the results, one of the new and accurate methods in the field of multi-criteria decision-making (CoCoSo method) has been used. Due to the importance of selecting a relief center after the earthquake, the proposed two-phase approach for this problem has been implemented and the data of Amol city has been used for this purpose. In this paper, the factors affecting the priority of relief have been identified and then according to these criteria and the use of the proposed approach to the affected areas to send relief teams is prioritized.

In the following, first, the hybrid two-phase approach of the paper and the tools used in it are introduced. Then, the hierarchical structure of the problem and the criteria and options of the decision matrix for

selecting the relief center is examined. Finally, the proposed approach for the city of Amol will be implemented and the results will be presented.

2 | The Proposed Hybrid Two-Phase Approach

Multi-criteria decision-making methods are used in various areas of management and planning problems. In this paper, a proposed approach according to *Fig. 1* is presented. This proposed approach combines four multi-criteria decision-making methods, including AHP, TOPSIS, AHP-TOPSIS and the new CoCoSo method. In the first phase, using the initial decision matrix, AHP, TOPSIS and AHP-TOPSIS methods are used to prioritize the regions separately. The initial decision matrix contains information about the problem and different relief reigns are considered as alternatives and different relief parameters are considered as criteria. Then in the second phase, considering the different results of these three methods from the first phase, the secondary decision matrix is created. In this matrix, decision methods (AHP, TOPSIS and AHP-TOPSIS) are considered as criteria and relief reigns as alternatives. In fact, the secondary matrix data is created according to the findings of the first phase of the problem. In the second phase, the CoCoSo method, which is one of the newest decision-making methods, is used for the secondary decision matrix. Relief reigns are ranked with the help of the CoCoSo method and according to the best alternative, the most important reign for relief is determined. The selected reign will be used to establish a relief center.

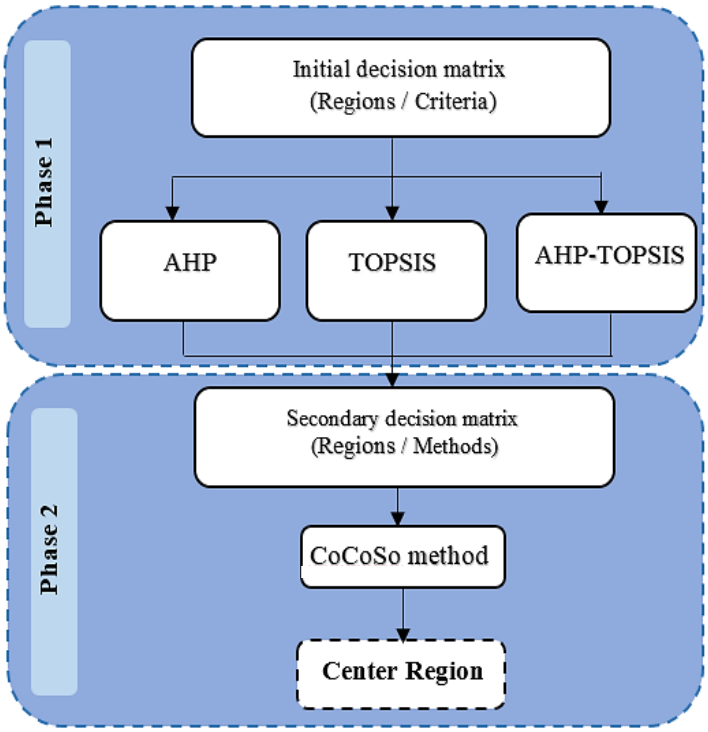

Fig. 1. The flowchart of the hybrid two-phase approach.

3 | Introduction of the Tools Used in the Proposed Approach

The AHP method was first introduced by Wind and Saaty in 1980 [37]. This method facilitates problem ranking by hierarchical structure and the use of pairwise comparisons. The hierarchical structure reduces the complexity of problem understanding and pairwise comparisons lead to more accurate information from the decision-maker. The AHP method has been used in various papers [38]-[40].

The word TOPSIS means the technique for order of preference by similarity to ideal solution. This model was introduced by Huang and Yoon in 1981 [41]. The logic of this method is to define the ideal

alternative (positive) and the ideal alternative (negative). A positive ideal alternative is one that increases the profit criterion and decreases the cost criterion. The optimal alternative has the shortest distance from the ideal alternative and, at the same time, the farthest distance from the negative ideal alternative. The TOPSIS method has been used in many papers to identify the best alternative, which can be referred to [39], [42]-[44].

CoCoSo method is one of the new multi-criteria decision-making techniques that was presented by Yazdani et al. [45]. This method provides a compromise combination solution for ranking alternatives. This method is an integrated model of simple weight addition method and multiplication model, the steps of which are given below.

Step 1 (formation the decision matrix). In fact, the first step in all multi-criteria decision-making methods is the formation of the decision matrix, which is given in the following. In this regard, (X_{mn}) is actually evaluating the (m) alternative based on the (n) criterion *Eq. (1)*.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}, \qquad i = 1,2,\dots,m, \qquad j = 1,2,\dots,n. \tag{1}$$

Step 2 (normalization of the decision matrix). Normalization occurs in almost all multi-criteria decision-making methods. In this step, based on *Eqs. (2)* and *(3)*, the decision matrix becomes normal.

$$r_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}, \text{For profit criteria .} \tag{2}$$

$$r_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}}, \text{For cost criteria.} \tag{3}$$

Step 3 (calculate the values of weighted sum and weighted multiplication). In this step, based on *Eqs. (4)* and *(5)*, the values of weighted sum (S) and weighted multiplication (P) for each alternative are calculated.

$$S_i = \sum_{j=1}^{n} \left(w_j r_{ij}\right). \tag{4}$$

$$P_i = \sum_{j=1}^{n} (r_{ij})^{w_j}. \tag{5}$$

Step 4 (determine the evaluation score of the alternatives based on the three strategies). In this section, the score of the alternatives based on the three strategies is obtained through *Eqs. (6)-(8)*. *Eq. (6)* expresses the arithmetic mean of the scores, while *Eq. (7)* expresses the relative scores compared to the best. *Eq. (8)* is a compromise between the previous two calculated scores. In this relation λ is determined by the decision-maker but in 0.5 mode it has a lot of flexibility.

$$k_{ia} = \frac{S_i + P_i}{\sum_{i=1}^{m}(S_i + P_i)}. \tag{6}$$

$$k_{ib} = \frac{S_i}{\min S_i} + \frac{P_i}{\min P_i}. \tag{7}$$

$$k_{ic} = \frac{\lambda S_i + (1-\lambda)P_i}{\lambda \max S_i + (1-\lambda)\max P_i}, 0 \le \lambda \le 1. \tag{8}$$

Step 5 (determining the final score and ranking the alternatives). In this section, the final score is calculated based on *Eq. (9)*. In fact, this relationship represents the sum of the geometric mean and arithmetic mean of the three strategies of the previous stage. The higher the score (k) of any alternative, the better it is.

$$K_i = (k_{ia}k_{ib}k_{ic})^{\frac{1}{3}} + \frac{1}{3}(k_{ia} + k_{ib} + k_{ic}). \tag{8}$$

4 | Determining the Priority Criteria of Relief Center to the Demand Points

There are always many restrictions in the event of an accident that prevents the delivery of relief to all points of demand with the best quality and quantity, some of these restrictions include the following: breakdown of relief centers due to the high severity of the accident, lack of rescue vehicles, lack of necessary knowledge of rescue forces, failure of rescue teams for reasons such as lack of knowledge of family or loss of relatives in the accident, weather and environmental conditions and so on. *Fig. 2* shows the relationship between these criteria and alternatives, which are given below the reasons for these relationships.

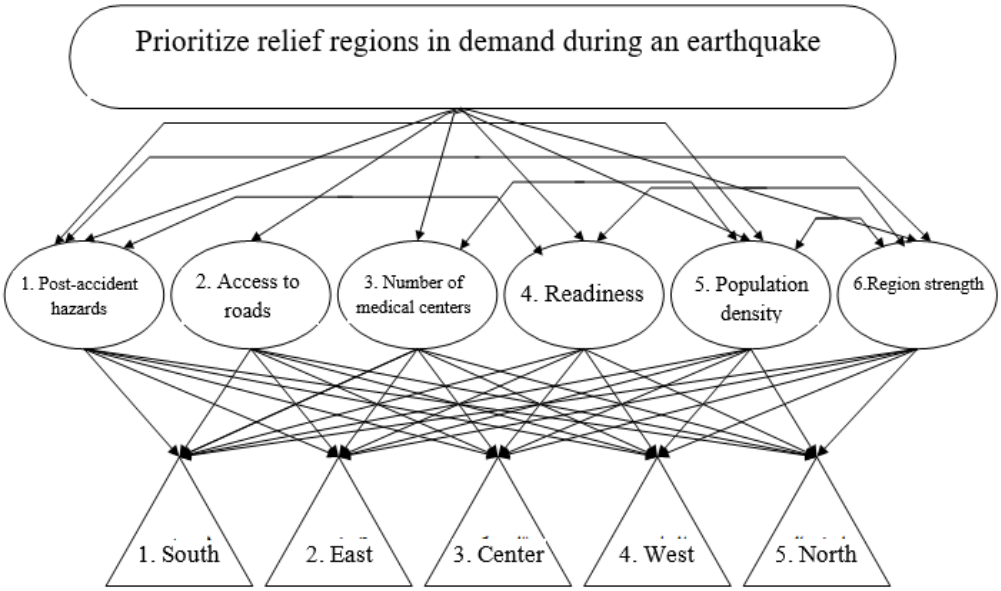

Fig. 2. Internal and external dependence of demand point prioritization network.

The stronger region and the number of buildings built according to the building standard; the more people are prepared for the accident. The higher the regional strength and the more standard the buildings, the lower the risk of post-accident hazards such as fire, explosion, drift, etc. The higher the population density, the more medical centers have been built in that region. As the population density increases, the likelihood of post-accident hazards will increase, especially in densely populated buildings. The greater the level of preparedness, the lower the risk of post-accident hazards. The higher the risk of post-accident risk, the lower the population density. Any region where the risk is greater is expected to be more prepared but, unfortunately, what is evident is that the preparedness is lower in such regions.

5 | Prioritize the Damaged Regions of Amol City Using a New Combined Approach

Mazandaran is one of the northern provinces of Iran, which is located near the Alborz mountain range and has a special location due to its location on the North Alborz fault. For this reason, Mazandaran province is considered as one of the earthquake-prone regions of Iran. Mazandaran is divided into three regions: east, west and center. Studies have shown that the central region has more faults than its two adjacent regions. In this study, the city of Amol, one of the central cities of Mazandaran province, is studied. Amol city is limited to Mahmudabad city from the north, Babol city from the east, Noor city from the west and Tehran province from the south and has a population of 376,056 people. Due to its proximity to Damavand Peak (the highest mountain in Iran and the Middle East and the highest volcanic peak in Asia), the city is always at risk of small and large earthquakes. The last deadly earthquake in this city is related to the village of Sangchal, which occurred in 1,336 with a magnitude of 6.7 Richter occurred, and about 133 people died and 260 people were injured. In this study, Amol city is divided into five regions, northwest, center east and south based on urban structure, which are numbered in *Fig.*

3, respectively. In this study, it is assumed that there is only one relief center in the city center and relief teams are sent from this center to the demand centers as a specified point. In the following, the proposed approach of the paper for the city of Amol is examined. The initial decision matrix that has been collected according to environmental information for the city of Amol is as shown in *Table 2*.

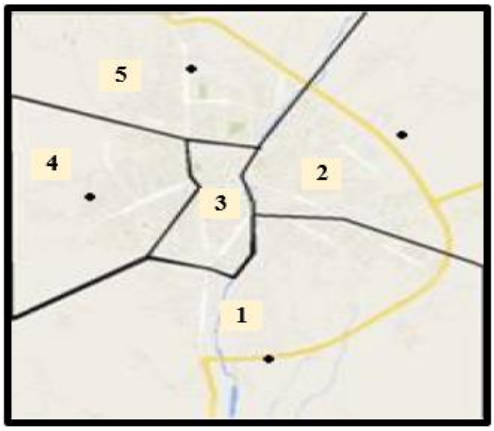

Fig. 3. Regions studied in Amol city to establish a relief center.

Table 2. Initial decision-making matrix.

Alternatives	Region Strength	Population Density	Number of Medical Centers	Post-Accident Hazards	Access to Roads	Readiness
South	0.66	0.5	2	0.4	0.8	0.5
North	1	1	1	1	1	1
East	0.33	1.5	2	1.2	1	1.25
West	1.33	1.75	3	1.61	0.5	0.75
Center	1	2.5	4	2	0.5	1.75

5.1 | The First Phase of the Proposed Approach

In this phase, the AHP method is first implemented on the problem, which is the solution process according to *Tables 4* to *6*. Paired comparison tables are based on collected data and expert preferences. Also, in order to grade the importance, the scoring of *Table 3* has been used. Since all matrices of pairwise comparisons are incompatible, in order to calculate the weights, special methods of this category must be used. In this paper, the approximate method of the geometric mean is used, which is one of the good methods in this category. Then local weights are calculated and finally used to calculate the total weights and scores of each region. In *Table 7*, the final results of the AHP method show the desirability of the northern region of the city for the construction of a relief center.

Table 3. Scoring of the importance.

The Degree of Importance	Very Low	Low	Medium	Much	Very Much
	1	3	5	7	9

Table 4. Matrixes of pairwise comparisons of regions based on: a. population density; b. region strength; c. readiness; d. number of medical centers; e. post-accident hazards; f. access to roads.

Population Density	West	South	Center	East	North
West	1	0.33	0.5	0.28	0.2
South	-	1	1.5	0.85	0.85
Center	-	-	1	0.57	4
East	-	-	-	1	0.7
North	-	-	-	-	1

a.

Region Strength	West	South	Center	East	North
West	1	2	1.33	4	1.33
South	-	1	0.67	2	0.66
Center	-	-	1	3	1
East	-	-	-	1	0.33
North	-	-	-	-	1

b.

Readiness	West	South	Center	East	North
West	1	0.4	0.5	0.66	0.28
South	-	1	1.25	1.66	1.71
Center	-	-	1	1.33	0.57
East	-	-	-	1	0.42
North	-	-	-	-	1

c.

Number of Medical Centers	West	South	Center	East	North
West	1	1	2	0.66	0.5
South	-	1	2	0.66	0.5
Center	-	-	1	0.33	0.25
East	-	-	-	1	0.75
North	-	-	-	-	1

d.

Post-Accident Hazards	West	South	Center	East	North
West	1	0.33	0.4	0.25	0.2
South	-	1	1.2	0.75	0.6
Center	-	-	1	0.62	0.5
East	-	-	-	1	0.8
North	-	-	-	-	1

e.

Access to Roads	West	South	Center	East	North
West	1	0.8	0.8	1.6	1.6
South	-	1	1	2	2
Center	-	-	1	2	2
East	-	-	-	1	1
North	-	-	-	-	1

f.

In the next step of the first phase, the TOPSIS method will be implemented on the problem. Given that there are six criteria in the problem and assuming the weights are the same for the criteria, the weight of each criterion will be equal to $\frac{1}{6}$. The final results of this method in *Table 8* show the desirability of the Amol city center region for the construction of a relief center.

Table 5. Matrixes of pairwise comparison of criteria: a. all criteria; b. post-accident hazards; c. Readiness; d. Population density.

Matrix of Pairwise Comparisons of Criteria	Region Strength	Population Density	Number of Medical Centers	Post-Accident Hazards	Access to Roads	Readiness
Region strength	1	5	3	1	5	3
population density		1	7	3	5	7
Number of medical centers			1	5	7	5
Post-accident hazards				1	9	7
Access to roads					1	5
Readiness						1

a.

Post-Accident Hazards	Region Strength	Population Density	Readiness
Region strength	1	4.5	1.8
Population density	-	1	0.4
Readiness	-	-	1

b.

Readiness	Region Strength	Post-Accident Hazards
Region strength	1	2
Post-accident hazards	-	1

c.

Population Density	Region Strength	Post-Accident Hazards
Region strength	1	0.25
Post-accident hazards	-	1

d.

Table 6. Calculation of local weights.

Criteria	Weight	Weights in Access to Roads		Weights in Post-Accident Hazards		Weights in Number of Medical Centers		Weights in Population Density		Weights in Region Strength		Weights in the Degree of Readiness	
Region strength	0.325814	West	0.25	West	0.0663033	West	0.155632	West	0.067981	West	0.272545	West	0.097861
population density	0.288027	South	0.25	South	0.218657	South	0.155632	South	0.252752	South	0.136272	South	0.243335
Number of medical centers	0.174951	Center	0.25	Center	0.131724	Center	0.0827188	Center	0.133146	Center	0.257247	Center	0.213429
Post-accident hazards	0.140492	East	0.125	East	0.263449	East	0.294753	East	0.266291	East	0.0766884	East	0.140891
Access to roads	0.041791	North	0.125	North	0.319867	North	0.311264	North	0.27983	North	0.257247	North	0.304484
Readiness	0.028925												

Table 7. The final results of the AHP method.

Regions	Results of AHP Method
West	0.158200757
South	0.192632352
Center	0.171763299
East	0.199564038
North	0.277838895

Table 8. The results of the TOPSIS method.

Regions	The Distance from the Negative Ideal	The Distance from the Positive Ideal	TOPSIS Score
South	0.136831	0.11513	1.115129805
North	0.118664	0.110051	1.110051464
East	0.097764	0.122019	1.122019064
West	0.107966	0.113771	1.113771319
Center	0.13033	0.130803	1.130803292

As the last part of the first phase, the AHP-TOPSIS hybrid method is implemented on the problem. The purpose of this method is to use the weights obtained for the criteria from the AHP method (the results of *Table 6*) and to apply the TOPSIS method. The results of *Table 9* show the superiority of the western region as a relief center.

Table 9. The results of AHP-TOPSIS hybrid method.

Regions	The Distance from the Negative Ideal	The Distance from the Positive Ideal	AHP-TOPSIS Score
South	0.187155	0.121959	1.121958517
North	0.168411	0.127946	1.127945977
East	0.096095	0.100761	1.100760816
West	0.181026	0.133384	1.133383686
Center	0.138982	0.123656	1.123656085

5.2 | The Second Phase of the Proposed Approach

Due to the different results of the three methods used in the first phase (*Fig. 4.*), the best center is examined using the new CoCoSo method and the secondary decision matrix of *Table 11.* Also, the weights required for this method are extracted from the paper of Sharma et al. [46]. In their paper, three methods AHP, TOPSIS and AHP-TOPSIS are compared. In the end, the best method was AHP-TOPSIS and the worst method was TOPSIS. Therefore, according to the results of this paper, the weights of *Table 10* are considered for each of them according to the superiority of the method. The CoCoSo method is implemented on the secondary matrix according to the steps mentioned and the final result of the second phase in *Table 12* shows the desirability of the center as a relief center.

Table 10. The weights of three methods AHP, TOPSIS and AHP-TOPSIS.

Method	AHP	TOPSIS	AHP-TOPSIS
Weight	0.335	0.225	0.44

Table 11. The secondary decision matrix.

Regions	AHP	AHP-TOPSIS	TOPSIS
South	0.192632352	1.1219585	1.11513
North	0.277838895	1.127946	1.110051
East	0.199564038	1.1007608	1.122019
West	0.158200757	1.1333837	1.113771
Center	0.171763299	1.1236561	1.130803

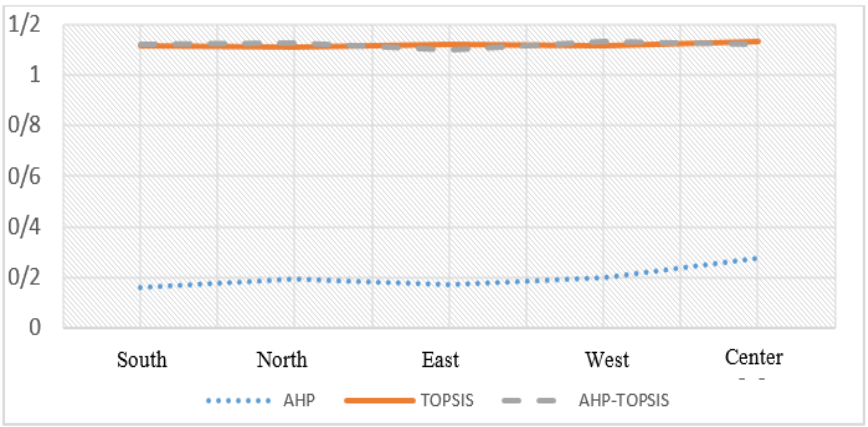

Fig. 4. Different results of the three methods used in the first phase.

Table 12. The results of CoCoSo method.

Regions	s_i	p_i	k_a	k_b	k_c	K_i (CoCoSo score)
South	0.340965	1.555747	0.15578	3.171893	0.509248	1.910299
North	0.463071	1.581765	0.167946	3.918919	0.549018	2.257558
East	0.167734	1.365738	0.125947	2	0.411722	1.315719
West	0.596154	2.379867	0.244426	5.296706	0.799032	3.124747
Center	0.868799	2.855733	0.305902	7.270597	1	4.164154

6 | Conclusion

Because of the lack of relief resources in the event of a high-intensity accident, it is very important to prioritize the demand points. In this paper, a relief model was developed considering the priority of the accident regions. The novelty of this paper is to present a hybrid and two-phase approach of decision-making methods. Initially, the accident regions were prioritized with six criteria, then the decision matrix was created with the collected data. Therefore, in order to evaluate the proposed approach, a study was conducted on the city of Amol and the results investigated. Due to the different results of the methods used in the first phase, the second phase was implemented to determine the best region. Finally, the center of Amol city was considered as a place to build a relief center. The most important advantage of the proposed approach is the simultaneous use of the performance of four applied decision-making methods. Also, due to the use of the results of the three methods in the fourth method, the accuracy of the results should be increased. This research provides a valuable insight framework for supply chain managers in critical situations, who face similar problems in other environments. The proposed approach can be used for all service organs of the fire department, crisis management, Red Crescent, and so on. Due to the fact that the proposed method has the following shortcomings, as future research can be done to eliminate them: 1) considering different scenarios of the accident and uncertainty in problem, 2) the occurrence of disruption in the provision of relief teams and relief route, 3) considering the other criteria such as the ability of injured people in the problem and 4) considering the time of the accident and its effect on how to provide relief. One of the practical and management areas that this paper that will be implemented, use the proposed approach in locating a rescue helicopter. Due to the fact that the number of rescue helicopters is very small, it must be located in a suitable place in order to be able to serve all points of demand properly.

Conflict of Interest

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

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Applications of Internet of Things in the Food Supply Chain: a Literature Review

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Abstract

This paper examines the use of the Internet of Things (IoT) in the Food Supply Chain (FSC) and identifies the strengths and weaknesses of this system. Since this paper is a review study, the papers published from 2014 to June 2021 have been studied and 93 articles related to the field of IoT applications in the FSC have been reviewed. By reviewing the literature, six basic applications obtained for this type of network include transportation procurement, food production, resource/waste management, food safety improvement, food quality maintenance, and FSC transparency. Clustering is used to achieve these. Cluster analysis suggests that researchers should pay more attention to IoT applications for product quality and transparency throughout the supply chain, and consider IT-based systems seamlessly at each level of the supply chain.

Keywords: Internet of things, food supply chain, IoT-based supply chain processes, virtualization.

1 | Introduction

Changes in the competitive market environment and the shift of companies to offer products globally have led organizations to optimize their company's supply chain to survive in the market and gain more share of product sales in global markets to be able to quickly respond to the needs of consumers in the shortest time, which have the lowest cost and highest quality [1]. Therefore, all levels of the supply chain from raw material suppliers to product distribution and then to customers must be carefully monitored, planned, and controlled. Supply Chain Management (SCM) can be defined as a process consisting of planning, execution, and control of all operations related to supply, production, warehousing, and distribution of products to customers [2]. In a simpler term, SCM focuses on the integration of activities and flows of financial information and materials between levels of the chain to achieve a sustainable competitive advantage [3]. Today, many supply chains have spread to large parts of the world and are exposed to very high global risks [4].

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So, new customers today want different products or different price levels and different types of customizations. The complexity of products is increasing so rapidly, which has led to rapid changes in technology [5]. Different economic, political, social, environmental, and natural factors affect the demand of customers for different products at different times and places. Therefore, organizations in such a complex competitive environment must have high flexibility and be very agile to be able to estimate a wide range of customer needs and wants in the shortest possible time. To balance the supply chain level, the entire supply chain from the supplier level to the distributor level must be flexible and have the necessary speed to meet customer needs. Information technology is one of the important factors in SCM in complex competitive conditions for the organization and helps each supply chain in the direction of agility and rapid flexibility [6].

Information Technology (IT) has led to customers quickly address their needs and the organization is faster than managing its supply chain levels to meet customer needs. One of the most important and latest developments in the field of IT is the Internet of Things (IoT). The IoT in the supply chain can take supply chain communication to a higher level and improve human-to-human interaction and object coordination [7]. This new technology by collecting and analyzing data can quickly increase supply chain agility and make quick decisions at any level of the supply chain from a supplier to a distributor. Since in the traditional supply chain, collecting and analyzing big data is not an easy task, IoT can perform the ability to collect, analyze, and provide appropriate solutions in the shortest possible time. In this paper, a review study is conducted by studying the existing literature on IoT and its application in the Food Supply Chain (FSC). Therefore, by reviewing articles, books, and documents published from 2010 to 2021, the IoT in the field of the FSC has been studied and its impact on various food supply, production, and distribution companies has been analyzed. In the following, definitions of the FSC, IoT, and its application in different parts of the FSC are presented. Then, the collected information from the study of the literature is examined to show the place of the IoT in the FSC and to determine the research gaps in the future.

The structure of the paper is as follows. In Section 2, definitions of the IoT, FSC, and IoT applications in the FSC are discussed. In Section 3, the method of the classification and analysis of the literature of the studied subject is presented. In Section 4, using different tools and diagrams, different types of IoT applications in the FSC, and finally, the gaps created in the studies are examined. Section 5 concludes and presents future studies for the implementation of the IoT in the FSC.

2 | Literature Review of IoT Applications in the Food Supply Chain

The Food Supply Chain (FSC) is under tremendous pressure to improve not only revenue but also its overall sustainability and supply chain efficiency [8]. Also, if you need to invest to improve performance and sustainability, the goal of the FSC is to keep costs down, which is a difficult task. However, the advent of digitalization and related technologies is helping businesses cope with this difficult task. In particular, FSCs have witnessed a combination of information technology and operations, thanks to developments and synergies between the respective regions that have led to the IoT. The IoT term was coined in 1999 by the MIT Auto-ID Lab with special reference to Kevin Ashton [9]. The IoT-GSI has defined the IoT as a "global infrastructure for the information society that enables advanced services through the connection of physical and virtual objects based on existing and evolving information and communication technologies" [10]. Jagtap et al. [11] described the IoT as a complex physical cyber system, which includes a variety of devices and systems for measuring, identifying, communicating, networking, and informatics, and seamlessly based on people and objects. It connects interests so that anyone can access the information of any object and service more efficiently through devices and media anytime and anywhere.

Therefore, the concept of the IoT can be considered as providing a solution that collects and integrates a huge amount of data generated from supply chains. Applications built on IoT operating systems enable faster, better data collection, analysis, and decision-making to increase operational efficiency. *Fig. 1*

shows a food factory using the IoT. This figure shows how the IoT can empower stakeholders and factory management through the ability to monitor food production flows in real time, which allows them to control and manage connected equipment. It also allows them to identify quality issues and address them promptly. They have more transparency and vision in inventory management and have the necessary flexibility to make forecasts. This figure also shows how managers, R&D professionals, and factory queue employees can reap the benefits of using the IoT [11].

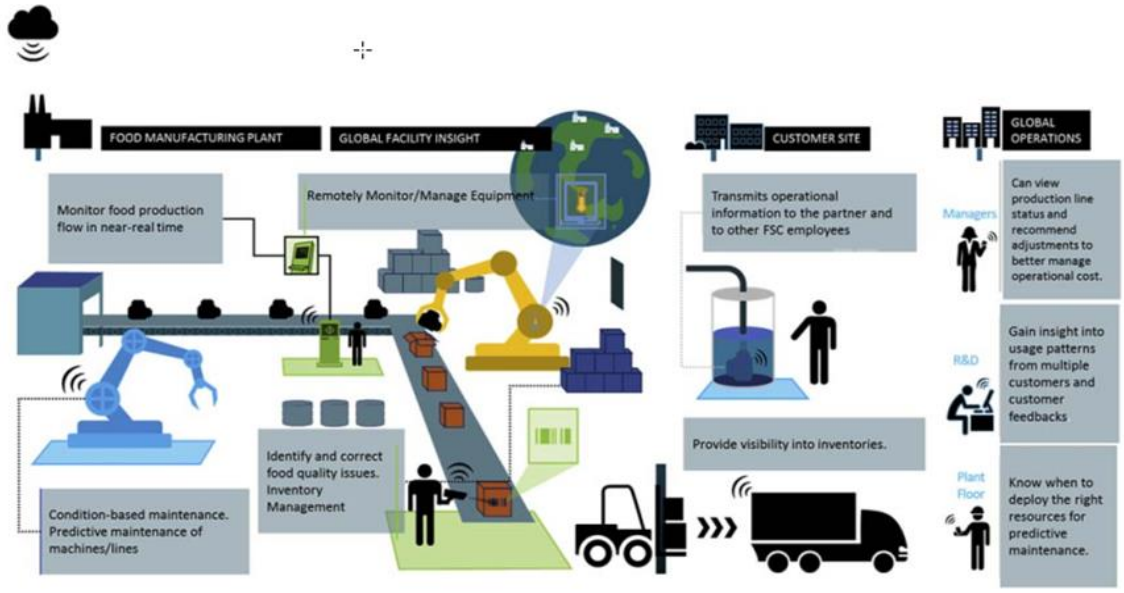

Fig. 1. Application of the IoT in the food supply chain.

2.1 | IoT Architecture in the Food Supply Chain

The IoT in the FSC is designed to easily connect machines, equipment, and other items over the network. Therefore, an IoT architecture is needed to collect data seamlessly and transfer it securely for further analysis [12]. The most basic IoT architecture consists of three network layers and application layers, which are described below [13], [14]:

Observation layer: a physical layer consisting of sensors and actuators to measure and collect data about physical parameters as well as identify other intelligent objects around.

Network layer: responsible for communicating with other intelligent objects, network devices, and servers, as well as its transmission and processing.

Application layer: this layer provides services to specific applications to users and simultaneously defines several applications for installing IoT (e.g., smart health, smart home, and smart city).

However, for FSCs, the most appropriate IoT architecture consists of four layers: measurement, network, service, and application. *Fig. 2* shows the IoT architecture in the FSC [11].

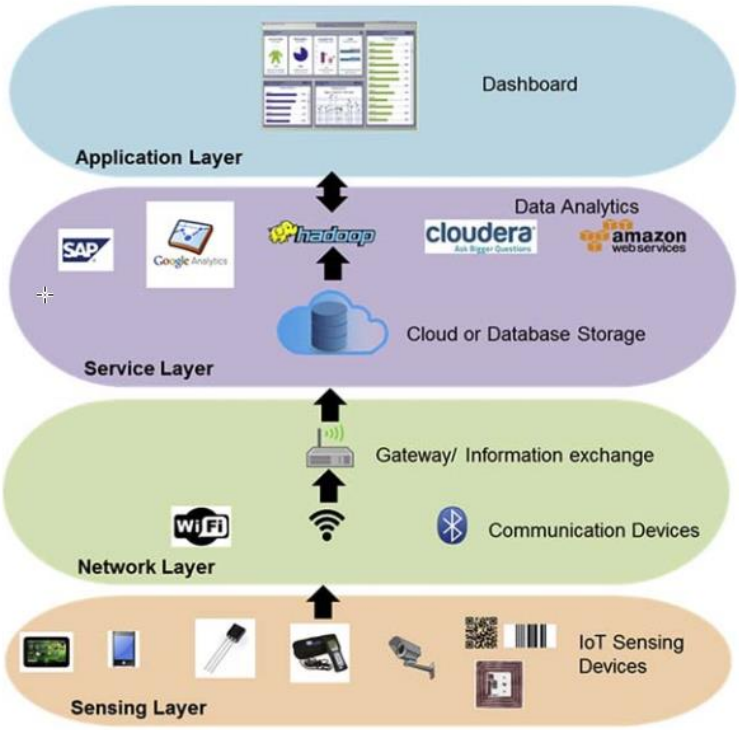

Fig. 2. IoT architecture in the food supply chain.

I. The measurement layer contains data such as time, temperature, location, machine, etc. In general, in the FSC, data are collected using sensors, Radio Frequency Identification (RFID), cameras, and so on. All data collected from the raw material source to the end of the product life is pre-processed in this layer.

II. The network layer transmits the data collected in the sensor layer to the service layer through various network technologies (e.g., Wireless Sensor Network (WSN), Bluetooth, and WiFi router).

III. The service layer includes a wide range of analytics engines and services in which data is analyzed or stored.

IV. The application layer consists of various programs and modules (e.g., tracking, production efficiency, and food quality), which can be done by supply chain actors to view the information in real time and make appropriate decisions.

2.2 | Applications of the IoT in the Food Supply Chain

Currently, many IoT applications depend on the type of industry that they use. They can be classified according to the type of network availability, coverage, scale, heterogeneity, repeatability, user engagement, and impact [15]. Unique FSCs have wide geographical coverage, complex operational processes with a large number of stakeholders throughout the chain, and provide insights into food quality, operational efficiency, and food safety [16], [17]. The availability of nutritious food is more important to everyone than any economic, social, or environmental development. The world's population is projected to reach nine billion by 2050, which will completely change the world and also put a lot of pressure on FSCs. However, the development of IoT technology is likely to provide encouraging solutions [18]. The IoT can play a role in the functioning of every part of the FSC, from farms to food production, processing, storage, distribution, and consumption. The IoT can address tracking, visibility, transparency, and controllability challenges. Safety, efficiency, transparency, and stability are some of the features required in the FSC.

2.3 | Applications of the IoT in Food Transportation Procurement

During the transportation of food, the product that is transported can face various challenges, such as temperature control, hygiene and pest control, traceability, product management (i.e., movement of

goods, damage, rejection, and safety), preventive maintenance of the vehicle/container and staff management (i.e., handling, personal hygiene, safety, policies, and training). Using the IoT, it is possible to track all food-related activities. RFID technology is one of the most effective and inexpensive IoT tools in tracking food products. RFID tags can have specific and important information about the food products shipped and can easily communicate via a wireless network. In the event of a food recall or food safety, alerts are sent immediately throughout the supply chain and the damaged product is quarantined immediately. The low cost of the wireless remote system enables the ability to establish a wireless network in food transport vehicles and to monitor food safety during transport. For example, with the help of IoT systems integrated into risk analysis processes, Hazard Analysis Critical Control Points (HACCP), FSC actors can control temperature and other conditions in real time, effective cold chain management as well as compliance global and monitor and document. Food transport vehicles can use simple and complex wireless systems that allow continuous connection and continuous access to information in real time [19].

2.4 | Application of the IoT in Production and Improvement of Food Safety

Data collected from different plant units (e.g., machinery, staff, vehicles, and materials) can be used in procedures and processes for optimizing food production systems without human intervention. By supporting real-time information, algorithms, and actuators, the designed control software can make the best decision and reduce the stimuli from any deviation from the plot. Current FSCs are long and complex with increasing safety risks and constant pressure from consumers to provide high-quality and safe food products. All actors in FSCs contribute to food safety information, which can lead to unpredictable risks due to incorrect data sharing or delays. IoT development, while providing effective collection and sharing and the opportunity to analyze data, can identify any deficiencies and issue food safety warnings before production. Results in the development of a system that can predict potential food safety hazards and warn if the safety and quality of food produced are violated. Therefore, any player in the FSC can help reduce the deviation in quality and waste of resources and thus prevent any food safety-related incidents. Maintaining and preparing quality food with an advance warning about food safety is the most important aspect of achieving sustainability in the FSC. At present, much attention has been paid to the issue of food safety and much work has been done to address this challenge. One of these is the pre-warning system, which can identify and warn actors about food safety issues before they become a major crisis. The alert system is implemented in conjunction with HACCP-based tracking systems. Current FSCs are composed of several actors that make it difficult to regulate, track, monitor, and control the food trade. Hence, most food safety incidents occur with inadequate monitoring, so the need for a prior warning system to control the food trade in an efficient and fully automated manner is palpable.

2.5 | Use of the IoT in Improving the Quality and Transparency of the Food Supply Chain

Various image processing technologies and sensors can help maintain the quality and specifications of raw materials and final products [20]. Sensors can continuously monitor the quality of the product, and any deviation from the set standards can be immediately detected and corrected. Other benefits of these sensors include product tracking, employee tracking, and real-time production analysis for efficiency. This leads to the optimization of FSC activities. End consumers and buyers need transparency to have a complete view of how their food is prepared and processed. Full tracking and visibility throughout the supply chain help food producers grow their business by gaining customer trust and loyalty. Although current FSCs are often very long and complex, IoT technology can make tracking easy for all FSC actors. Also, transparency can be beneficial for food producers as it leads to better stock management, labor management, cost reduction, and shorter lead times. These benefits can be achieved by addressing supply chain inefficiencies, meeting and exceeding minimum food safety requirements, and providing a full view of customers. In the context of the FSC, transparency can be defined as the information available to all actors involved in a supply chain network. Transparency in the FSC can indicate the ability to trace the product from farm to fork, for example, where the raw material is prepared, how it is processed and delivered to consumers. Blockchain technology can provide greater transparency throughout the FSC [21].

3 | Research method

In this section, the research method is presented to review the literature studied in the field of IoT applications in the FSC. Therefore, first, a summary of descriptive statistics is presented. Then, by using cluster analysis, articles in different clusters are categorized and analyzed. In other words, the main purpose of this article is to provide a roadmap for reviewing the current situation and evaluating the use of the IoT in the FSC, and identifying existing capacities for future research. To do this, first review all published articles on the use of the IoT in the FSC in various databases of some publishers, such as Elsevier (www.sciencedirect.com), Springer (www.springerlink.com), Taylor and Francis (www.tandf.co.uk), Emerald (www.emeraldinsight) and the size of papers published in international conferences from 2014 to June 2021. About this issue, 93 articles that have a direct relationship with the food safety chain and the use of the IoT have carefully been studied and reviewed. To review these articles, the clustering method is used and articles are classified into six categories including transportation procurement, food production, resource/waste management, food safety improvement, food quality maintenance, and transparency in the FSC. The impact of each IoT application on each cluster is also investigated.

4 | Research Findings

In this section, the current status of documents and articles published in the field of IoT applications in the food safety chain and their classification in different sections are discussed. From now on, descriptive statistics (e.g., the numbers of articles published in different years and journals) are presented. Then, by using the *K*-means clustering method, descriptive statistics of each of the clusters are addressed.

4.1 | Descriptive Statistics of Published Papers

According to a search of various publishers' databases from 2014 to June 2021, 93 articles, books, and other documents were found. *Fig. 3* shows the number of publications in different years. Due to this issue, most of the articles (i.e., 21) were published in 2020.

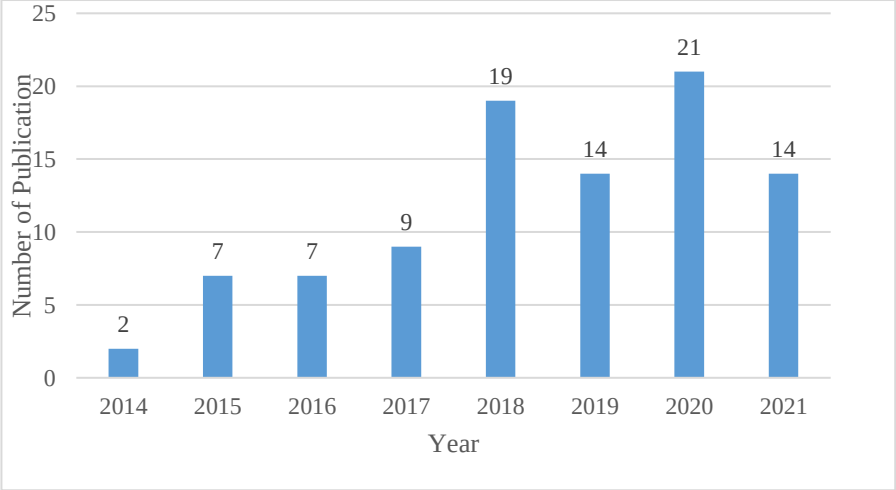

Fig. 3. Number of articles published between 2014 and 2020.

Table 1 shows the number of papers published in the index of different journals. Therefore, the classification in this section is based on the number of articles published in journals with the Journal Citation Report (JCR) index, journals with the Master Journal List index, journals with the Scopus index, and journals with other indices.

Table 2 classifies the literature studied in the field of publication type. According to this table, 74 items of the literature were studied including journal articles, 15 items including articles published in international conferences, and four items in the form of book collections. Also, this table shows the

number of articles and books published by publishers. Based on this and by the research method, the classification of articles was based on the publishers Elsevier, Springer, TanfF, Emerald, IEEExplore, and other publishers. *Fig. 4* shows the number of IoT publications in the FSC by different publishers.

Table 1. Number of papers published in journals with different indices.

#	JCR			Master Journal List	Scopus				Other
Q.	Q1	Q2	Q3		Q1	Q2	Q3	Q4	
No.	30	14	1	45	32	13	2	2	39

Table 2. Number of journal articles, conferences, and books published in journals with different indexes

Type of publications	Number
Journal	74
Conference	15
Book (series/chapter)	4

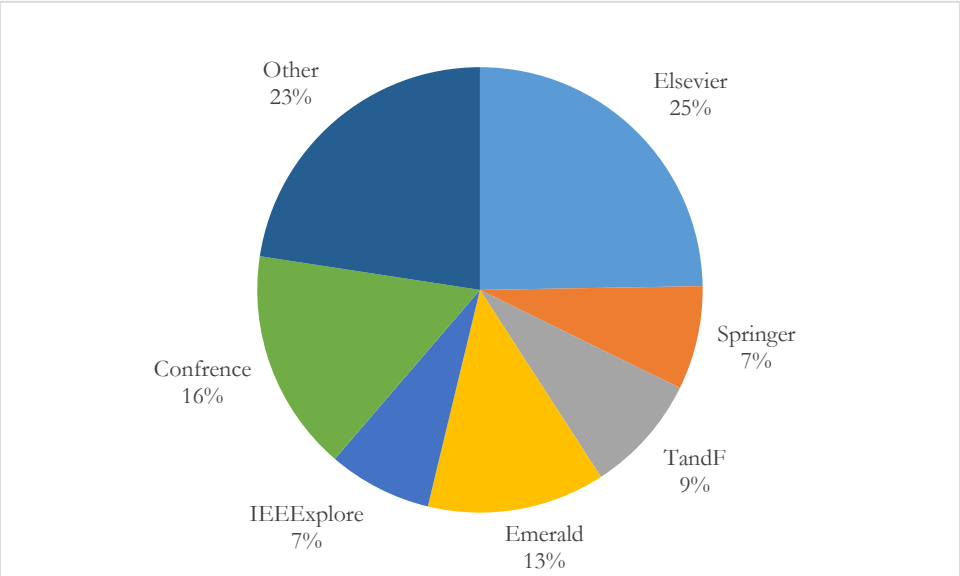

Fig. 4. Number of articles published by different publishers.

According to the summary of the statistics provided, it can be seen that most of the articles published in reputable journals had an impact factor of Q1, with the highest number of citations to 806 articles. Elsevier publishes the most IoT articles in the FSC, with topics such as food control, simulation, blockchain, and food transportation. By studying the articles, it is observed that less than 12% of the articles have been done on mathematical modeling, optimization, and simulation of IoT in the FSC, and in the rest of them, operational strategies and IoT impact have been presented.

4.2 | Literature Review

In this section, clustering and analysis of published articles in various fields of IoT applications in the FSC are discussed. According to *Fig. 5*, six different clusters for IoT applications in the FSC are listed according to the published years. The first cluster includes "Transportation Supplies in the FSC"; the second cluster includes "Food Production"; the third cluster includes "Resource/Waste Management"; the fourth cluster includes "Improving Food Safety"; the fifth cluster includes "Maintaining Food Quality" and the sixth cluster includes "Food Supply Chain Transparency".

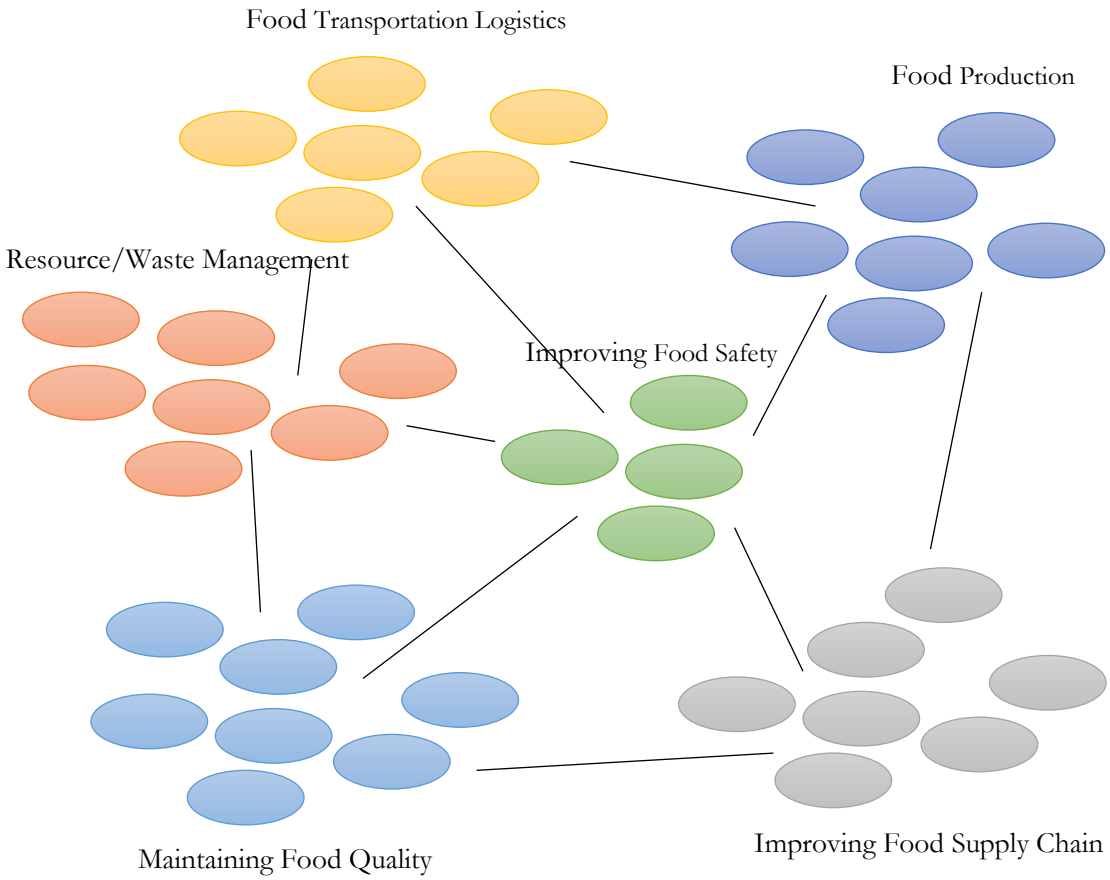

Fig. 5. Clustering of IoT applications in the food supply chain.

According to the clustering, *Table 3* shows the number of publications published in each cluster by year of publication.

Table 3. Number of the journal, conference, and published articles related to IoT applications.

Year	Food Transportation Logistics	Food Production	Resource/Waste Management	Improving Food Safety	Maintaining Food Quality	Improving FSC Transparency
2014	0	1	0	0	1	0
2015	0	1	2	0	2	1
2016	1	1	1	0	2	2
2017	2	0	5	0	2	2
2018	1	3	2	5	4	1
2019	3	2	1	2	2	4
2020	3	5	5	2	5	1
2021	3	4	2	1	1	2

According to the analysis, the focus of articles in recent years has been on food quality, reducing food waste, and food production. Few articles have also discussed food safety and supply chain transparency. By focusing on each of the IoT applications in the FSC, the role of the supply chain in each process can be examined. In the use of the IoT in the field of food transportation procurement, we can name roles (e.g., capacity, planning, optimization, energy management, and error detection). In the use of the IoT in the food production sector, we can mention roles (e.g., raw material supply, material composition, after-sales service, and food storage). Three key roles for resource/waste management in the FSC are identified,

including reducing food waste, reducing energy, and water consumption. In the following, the role of IoT applications processes in the FSC is examined.

4.2.1 | Procurement of food transportation

Ferreira et al. [19] discussed the use of several vehicle measurement applications and network range connections on vehicle nodes. Also, Chen et al. [22] proposed the concept of the IoT to increase transportation safety and network security by extracting effective information from the physical and network data space. The MovingNet e a Vehicle Ad-Hoc network is a sensor consisting of several sensors on a public transportation system to detect the production of counterfeit alcohol [23]. To improve transportation efficiency, Zhang et al. [24] proposed IoT technologies in the food supply chain, including the design of an IoT-based intelligent monitoring system (e.g., RFID, sensors, and wireless communication technology) to monitor the temperature and humidity inside a refrigerated truck, and detect and track loads in real time. Ma et al. [25] examined the integration of the IoT into the Enterprise Resource Planning (ERP) system, a pork supply chain, to establish a rapid alert system to know pork quality, reduce procurement costs, and improve circulation efficiency. Lacey et al. [26] categorized IoT applications in transportation by supply and demand. *Table 4* shows the extensive literature review of the use of the IoT in food transportation procurement in the FSC.

Table 4. Application of the IoT in food transportation procurement in the food supply chain.

Process	Role of the IoT	Impact	References
Food transportation logistics	Capacity sensing	Systems that can detect and communicate open spaces in a warehouse, port, or parking lot	[27]-[29]
	Planning and reporting	Systems that can detect and analyze events, such as traffic accidents within a delivery network, allowing for more accurate delivery dates	[22], [30], [31]
	Route optimization	Tools that can map the shortest or most fuel-efficient route, (e.g., delivery vehicles)	[32], [33]
	Energy management	Tools that monitor and enable decision making about the use of fuel, lighting, and heating/cooling within vehicle fleets and facilities	[34], [35]
	Fault detection and resolution	Systems that can monitor fleets of vehicles, aircraft, or ships for faults and maintenance needs, improving uptime for the fleet	[36], [37]

4.2.2 | Food production

Aung et al. [38] examined the importance of the use of the IoT in providing the raw materials needed to produce quality food through the selection of suppliers. Garcia-Garcia et al. [39] proposed monitoring the efficiency of raw materials in a food factory, IoT technologies in the food supply chain to manage it, and providing a systematic approach to identifying the most sustainable solution for managing it. Ekren et al. [40] provided a net-based system to provide after-sales service for manufactured food products. They sought to improve the food quality of products by gathering macro information from customers. *Table (5)* shows the extensive literature review of the use of the IoT in food production in the FSC.

Table 5. Applications of the IoT in food production in the food supply chain.

Process	Role of the IoT	Impact	References
Food production	Supply of raw materials	Systems that can be used to automate work procedures and processes to optimize food production systems without human interference	[38], [41]-[43]
	After-sales service		[44]-[47]
	Maintenance		[48]-[52]
	Combine product		[53]-[56]

4.2.3 | Resource/waste management

The use of internal and external sensors and simulation systems can provide complete energy monitoring in production systems by ISO 14955 and ISO 50001 [57]. Henningsson et al. [58] demonstrated the value of resource efficiency in the food industry and the importance of reducing electricity and water consumption as well as improving effluent quality, which can lead to significant savings. Therefore, by improving the relationship between all levels (i.e., producer, producer, retailer, and consumer) in the FSC and using technology to reduce labor costs, materials and facilities, can be a production and consumption system achieved more stable. Garcia-Garcia et al. [59] discussed the amount of food waste in the FSCs of developing and developed countries. Sheppard et al. [60] proposed a knowledge-based management system to increase the effectiveness and efficiency of existing tools for the management and added value of food waste. Wang and Yue [61] provided a framework supported by the IoT to warn of food safety hazards and prevent food wastage in the FSC. Hong et al. [62] proposed an IoT-based waste management system for food waste to improve the efficiency and effectiveness of food waste management in Seoul. The proposed system not only wastes 33% of food but also saves 16% of energy. Jagtap et al. [63] showed an IoT-based digital food tracking system that reduces food waste in a ready-to-eat food factory by 60.7%. Jagtap et al. [64] demonstrated the importance of IoT technology, which leads to better energy monitoring and management with significant cost savings. With this technology, energy consumption with tighter controls is greatly reduced. Shrouf and Miragliotta [65] showed how management in a factory can easily approach the implementation of the IoT by collecting and analyzing energy consumption and thus improving the energy-conscious decision-making process. *Table 6* shows the extensive literature review of the use of the IoT in resource/waste management in the FSC.

Table 6. Use of the IoT in resource management/waste in the food supply chain.

Process	Role of the IoT	Impact	References
Resource/waste management	Reducing food waste generation Reducing energy consumption Reducing water consumption	Systems that can reduce waste generation, energy consumption, and water	[37], [66]-[70] [11], [71]-[75] [76]-[81]

4.2.4 | Improving food safety

Robles et al. [82] presented an intelligent model based on linking IoT technologies with operational processes and decision support systems. Melo et al. [83] proposed an automated IoT-based solution to minimize water wastage while improving food safety. Drenoyanis et al. [84] proposed a new IoT system based on a narrow, low-bandwidth network to provide a comprehensive review of food safety monitoring networks. *Table 7* shows the extensive literature review of the use of the IoT in improving food safety in the FSC.

Table 7. Use of IoT in improving food safety in the food supply chain.

Process	Role of the IoT	Impact	References
Improving food safety	Risk High-quality and safe	Systems that can increased safety risk and continuous pressure from consumers to deliver high-quality and safe food products	[85]-[89] [90]-[95]

4.2.5 | Maintaining food quality

Jagtap and Rahimifard [96] stated that various image processing technologies and sensors can help maintain the quality and specifications of raw materials and final products. Barandun et al. [97] designed paper-based electric gas sensors to warn of food quality loss. This system can detect perishable gases emitted from meat. *Table 8* shows the extensive literature review of the use of the IoT in maintaining food quality in the FSC.

Table 8. Use of the IoT in maintaining food quality in the food supply chain.

Process	Role of the IoT	Impact	References
Maintaining food quality	Monitoring Product quality	Systems that can continuously monitor the product quality and any deviation from the set standards can be immediately notified and rectified	[98]-[103] [104]-[114]

4.2.6| Transparency of the food supply chain

Skilton and Robinson [115] acknowledged that transparency and traceability are interrelated. They also defined traceability as the process of identifying and validating components and timelines across events in the supply chain. Abad et al. [116] used the smart RFID tag for real-time tracking and cold chain monitoring along a fresh fish logistics chain. Mattoli et al. [117] designed, developed, and tested an IoT-based system to improve logistics during transportation, storage, and sale of wine bottles, as well as their safety assessment. *Table 9* shows the extensive literature on the use of the IoT in the FSC transparency in the FSC.

Table 9. Application of the IoT in the food supply chain transparency in the food supply chain.

Process	Role of the IoT	Impact	References
Improving FSC transparency	Whole supply chain	Systems that can be caused to better stock management, labor management, reduced costs, and shorter lead times	[118]-[132]

In general, IoT technology has been around for several years and has reached maturity. Studies show that the benefits of the IoT in the FSC outweigh its disadvantages. As the costs associated with supply chain digitization have been significantly reduced with the advancement of IoT technologies, more food manufacturers are willing to use such technologies. Adoption of this technology leads to long-term benefits and gaining significant market share. The use of IoT technologies in every aspect of the food supply chain helps to optimize and increase the stability of the entire supply chain. Benefits (e.g., better transparency, monitoring, and control of various food operations) enable the IoT to increase production, alert and prevent problems, and perform multiple functions in the FSC automatically.

5 | Concluding and Future Suggestions

Internet technology allows the FSC to use dynamic permutation in operations management processes. This support improves food companies in the face of perishable products, unpredictable changes in supply and food safety, and the sustainability required. Virtualization enables supply chain agents to plan and optimize business processes remotely via the internet as virtual objects rather than in a supervised location. In the IoT, FSCs can become a self-adapting system, in which smart objects can be deployed, make decisions, and learn things automatically. In this article, the use of the IoT in the FSC is discussed and several articles from different publishers are scrutinized. Current IoT applications in the FSC are demonstrated and the advantages and disadvantages of the IoT are described. Studies show that IoT has more advantages than disadvantages, so it is recommended that most supply chain actors use IoT technologies. A review of the literature showed that supply chain activities face many problems due to a lack of awareness or availability of accurate real-time data. Monitoring and analyzing the activities of each actor is an essential step towards achieving efficiency and transparency. The availability of credible information is essential to change the various activities in the FSC. By collecting real-time data and analyzing this data, economic and environmental issues can be decided simultaneously, leading to an improved and improved FSC. The cluster analysis in the study of journals shows that researchers should pay more attention to IoT users in terms of product quality and transparency throughout the supply chain, and integrate IT-based systems at each level of the supply chain seamlessly.

Conflicts of Interest

No potential conflict of interest was reported by the authors.

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Designing a Resilient Location-Allocation Model for Cell Site Networks with Regional Coverage Enhancement Approach Using Robust Programming–Lagrangian Relaxation

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Abstract

The development of cell sites as part of the infrastructure of telecommunication technology is playing a unique role in emerging businesses at present. Natural disasters and crises can disrupt communication equipment and create severe challenges in service provisions, especially health and security, by damaging sites. This might lead to traffic congestion in certain network sections, causing chaos and social crises and increasing the commissioning and equipping costs of backup sites for operators. This study developed an integrated location–coverage–allocation model to improve sustainability through maximum coverage, enhanced flexibility, and minimized overhead expense by determining the position of backup sites and mitigating environmental pollution resulting from the establishment of sites. The stochastic robust optimization model was employed to control the effect of nonparametric uncertainty, while acceptable solutions were generated using the Lagrangian relaxation to address complicated model constraints.

Keywords: Location, Coverage, Robust, Lagrangian relaxation, Resilient.

1 | Introduction

Telecommunication systems, especially mobile phones and the Internet, have spread worldwide in recent years. Recent smartphone functionalities and improved wireless network performance have boosted the demand for mobile multimedia content, leading to the emergence of cellular systems [1]. A cellular system refers to a group of mobile phone subscribers at any location, such as a street, a moving vehicle, a road, or a mountain. A mobile phone network is a cellular network consisting of cells. Generally, a cellular network is connected to a telephone center, which is connected to the public phone network [2]. A telecommunication channel is an environment exploited to transfer information between a transmitter and a receiver. Basic Station Controllers (BSCs) are also embedded to cover users through a central control structure. An area covered by a BSC is called a cell. The

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arrangement of BSCs aims at achieving good telecommunication coverage depending on the surrounding environment (*Fig. 1*).

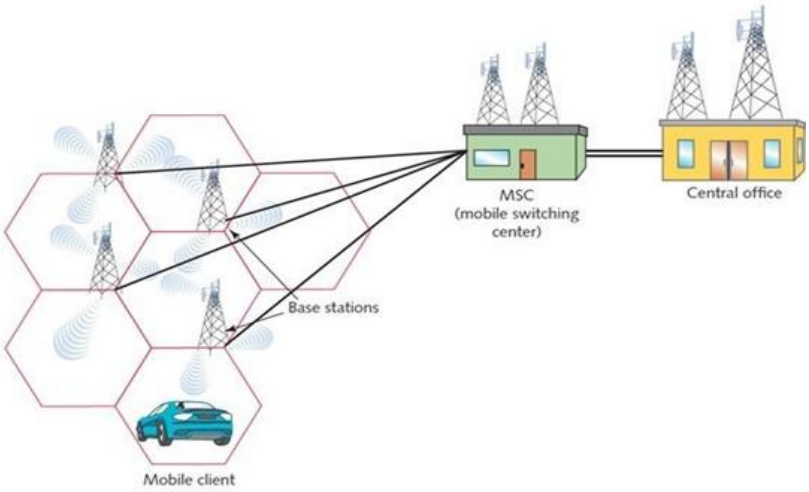

Fig. 1. Design and arrangement of the coverage radii of telecommunication cells.

Nevertheless, crises are inevitable; a crisis refers to a condition, natural or manufactured, that disrupts the routine life patterns and imposes damages and unwanted changes to the human society or the environment. The disruption of life routines, damage to communication systems and emergency services, an outbreak of diseases, destruction of infrastructure, and fatality are devastating outcomes of crises, which require extraordinary emergency management, planning, and measures [3]. During a crisis, many facilities would be unable to provide services due to failure, leading to loss of customer demands and many other unpleasant outcomes. Moreover, inattention to systems reliability can cause tremendous damage in any country. This indicates the necessity of proposing mathematical models that take into consideration the failure of facilities during crises and resulting consequences such as the loss of clients [4]. Based on a study conducted by Ahmadi at el. [5], a method has been proposed that by analyzing GIS information, the optimal areas for the deployment of relief forces in times of crisis have been identified, which can be used to locate telecommunication sites with minimal damage in natural disasters [5]. Telecommunication systems usually communicate via base stations or antennas. These stations should be positioned so that to provide complete services. Evidently, the quantity and position of these facilities (base stations) can significantly affect the quality of their services. In such cases, it isn't easy to increase the capacities of facilities for various reasons, such as fixed capital. Moreover, facilities are always prone to different kinds of natural hazards (earthquakes, hurricanes, and floods), intentional hazards (terrorist attacks, sabotage operations, and labor strikes), and accidental hazards (industrial accidents, fires, and failure of system components); however, effective and resilient systems can be developed to withstand natural disasters by optimal location and improvement of antennas [6].

Communication networks play a crucial role during crises, including providing information, connecting with the victims and relief centers, and the like [7]. The following obstacles may disrupt the services provided by a communication network during crises:

I. Sudden congestion and heavy traffic in one zone of the network.
II. Probable damage to the infrastructure on which communication networks rely to provide services.
III. Physical damage and failure of communication network components.

The positions of base and main stations affect the performance of mobile communication networks; thus, having backup stations to be used at times of failure and natural disasters is of utmost importance [8]. The establishment of backup stations for main sites is a sustainable approach that would provide clients with telecommunication coverage in case of disruptions. The coverage problem is involved determining the position and quantity of facilities at the minimum cost of providing services in demand points [9]. First, the maximum coverage problem was introduced as the objective function maximization, where the number of covered demand points was maximized against a fixed number of facilities [10]. Due to the importance

of providing services for demand points in some cases, researchers have considered the multi-coverage problem, where one demand point might be covered by more than one piece of equipment to enhance service accessibility [11].

With the ever-increasing developments in mobile phone technology, the information and telecommunication transmission industry has gained growing importance. The number of subscribers to this type of communication is increasing daily. The positions of base stations (towers) play a significant role in the performance of a telecommunication network. Therefore, determining their optimal positions is necessary for maximum coverage [12]. At the same time, deciding the places of telecommunication masts and towers is among the long-term strategic decisions, which are less flexible due to heavy financial consequences [11]. These decisions are made to prevent the failure of telecommunication coverage when a crisis emerges [13]. With the widespread establishment of wireless 5G networks, there has been a growth in different Internet-based systems and services [14]. Furthermore, network services based on the geographical positions of individuals and objects are now expanding [15]. It is essential to guarantee access to the data traffic required by various broadband devices such as computers, smartphones, security systems, and healthcare systems. The COUNTERACT technology, for example, is used in cellular network applications to detect Covid 19 contaminated areas by acquiring location information from a mobile device connected with an infected individual [16], [17]. This calls for the development of a resilient model for locating cell sites to increase the maximum profit while ensuring complete coverage so that no demand is lost during crises and disruptions. *Fig. 2* illustrates network recovery and flexibility approaches in three phases, namely before, during, and after a crisis. These approaches are divided into two main sections: network resilience design and network recovery design (ITU-T, 2010–2014).

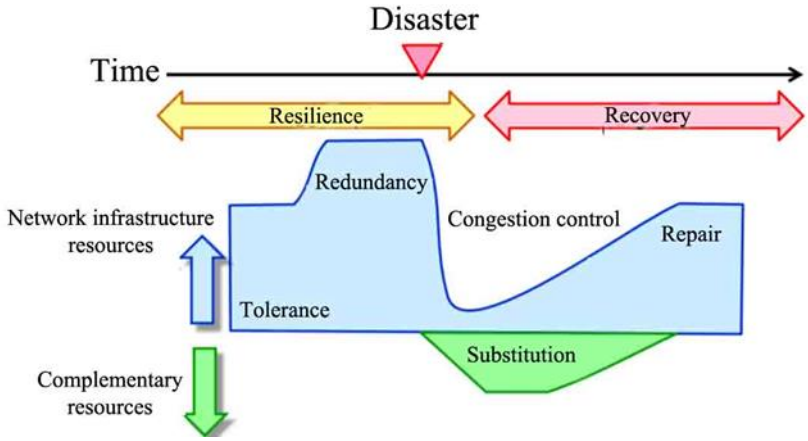

Fig. 2. Network recovery and flexibility approaches.

The costly and challenging task of finding the best positions for mobile phone operators in order to cover all subscribers shall be considered. However, the essential problem is to find appropriate strategies for estimating the positions of subscribers, an area which has interested many researchers due to the necessity of compliance with the Bylaw of the US Federal Committee Organization (ITU-T, 2013) that requires mobile operators to determine the positions of subscribers with an accuracy of 50–100 m in 67% of cases and an accuracy of 150–300 m in 95% of cases. Operators are also to provide the whole city with mobile network coverage, including the interior spaces of buildings, parks, and conventional markets, as part of the condition of their licenses. Therefore, appropriate positioning and maximum coverage are considered essential tasks. The statistics reported by the Communications Regulatory Authority (CRA) of the IR of Iran in the statistical quarterly of the third quarter of 1399 (2020–2021) indicated a penetration rate of 151.8% for mobile phones with more than 127 million SIM cards sold and more than one thousand active sites. Therefore, it is essential to optimize the costs of mobile site designing and upgrading and stabilize communication with the lowest rate of failure. Although the resilient supply chain network might not be the least expensive one, it can compensate for uncertainties and disruptions in the business environment [18].

This paper proposes a mathematical mixed-integer model to maximize coverage in case of failure and locate primary and secondary facilities and towers to maximize coverage, profit, and network resilience by considering design redundancy and backup and substitute sites. The realistic robust optimization approach was employed to solve the model, whereas Lagrangian relaxation was utilized to deal with complex and complicated constraints and reduce the model solution time.

This paper consists mainly of the following sections: the research literature review and the novelty and innovations of the research are presented in Section 2. Section 3 introduces the mathematical model of the problem, which consists of the mathematical model, robust optimization, and Lagrangian relaxation for the rigid constraints of the problem. The solution procedure, numerical results, and sensitivity analysis are presented in Section 4. Finally, Section 5 provides the conclusion and recommendations for future research.

2 | Literature Review

A brief literature review revealed some of the most critical studies on facility location and telecommunication site coverage. Andrew [19] proposed maximizing communication and overlap to improve telecommunications. Balakrishnan et al. [20] examined the development of telecommunication networks, assuming that there would be no planning. The problem would focus on installing centralized antennas and expanding communication ranges at the lowest costs in response to the project demand. Therefore, they developed a decomposition method based on the Lagrangian coefficient and dynamic programming. Kremling [21] addressed network development and optimization by giving a challenging insight into the mobile phone industry. He discussed the very complicated non-optimal expansion of network topology that could cause serious problems. Arguing that the future mobile phone networks would need higher levels of reliability. Kremling stated that costs should be controlled at the same time. Using mathematical models, also proposed linear programing for network topology optimization. Buys et al. [22] proposed a novel location layout for mobile phone towers and their coverage in terms of population. Vinu et al. [23] discussed the maximum use of ICT tools (mobile phones and the Internet).

Wilson [24] proposed a location model using telecommunication tools (mobile phones) and considering the maximum communication between origin and destination points. Dorn and Reuven [25] analyzed the minimum distance between origin and destination points (transmitter and receiver) for the coverage of mobile phone towers. They determined the locations of service centers, assuming that demand points can receive indefinite services. Lemamou et al. [26] proposed a model for mobile programming networks to minimize installation costs by considering network maintenance operations while maximizing its durability. They also mentioned a few constraints on the received signal's allocation, capacity, and quality.

It is crucial to determine the locations of designated stations to provide appropriate services for all mobile phone subscribers in terms of coverage. Subscriber demand is uncertain given the different coverage radii and geographical conditions of every region. Khalafi and Tavakoli Moghaddam [27] employed a novel approach to the location of mobile phone telecommunication stations with two-level services and stochastic demand as well as the set coverage model in which the coverage strategy was adopted for all demanded regions.

Peppanen et al. [28] proposed a technique with novel dimensions for the wireless WiMAX technology, providing a new level and more accurate outcomes compared to conventional methods. They also introduced the optimization framework for programming the WiMAX network in three steps: 1) network dimension definition, 2) initial segmentation, and 3) final network configuration. The proposed framework is employed to simultaneously solve two major problems, i.e., cellular programming and frequency programming, using a simulation algorithm.

Lee et al. [29] analyzed a two-level location-allocation problem in a tree topology for the design of access networks in order to find the optimal location of a switch and allocate demand to minimize the total cost of switches and fiber cables by meeting the constraints on switch ports, switch capacity, and to route with no division. This problem was formulated as a mixed-integer programming model in which the substitute formulas developed a MIP-based method by using the re-linearization technique and the tree structure based on tree partitioning to find high-quality solutions to large-scale problems.

Furthermore, Lee [30] addressed the location problem in a 3D space and introduced a 3D coverage location model for Wi-Fi Access Points (APs) in an interior environment. For this purpose, a public radio transmission was first installed in the environment by assuming the ordinary obstacles of a building in the standard coverage model through the 3D Euclidean distance. The proposed model was then introduced for an efficient AP installation program in a multistory building. A practical modeling framework was proposed to integrate the positioning model with the wireless network design in a 3D environment.

Tohidinasab et al. [31] proposed a coverage-positioning model for antennas and towers using the robust optimization approach. They modeled the telecommunication networks on certain cells, each of which would cover a specific region. Different coverage radii of stations, their locations, and geographical conditions made the location of stations an NP-hard optimization problem.

Asghar et al. [32] proposed a 5G coverage model by offering a solution for presenting and preparing the new generation of the Internet. Akpakwu et al. [33] conducted a comprehensive review of newly emerged robust technologies by focusing on the 5G mobile networks predicted to support the exponential traffic growth upon IoT activation. They also proposed the open-ended research challenges and paths regarding the establishment of extensive and vital IoT applications as well as an efficient mechanism for network traffic congestion control.

Akhtar [34] analyzed and compared 2G to 5G mobile phone networks. In addition to exploring different services that can be or are provided on every network, he suggested the exciting and unbelievable growth of users' interest in using online videos to be among the main reasons for the need for developing next generations. Santhi et al. [35] analyzed the performance of 4G networks and their improvement in comparison with the third generation and the fundamental concepts of networks, spectra, technologies, standards, terminals, and services. They concluded that 4G networks would be unable to provide the necessary bandwidth in the future. Goodarzian et al. [36] proposed an incomplete model which considered just coverage maximizing under crises and natural disasters with three target functions. In the mentioned paper, a novel Mixed-Integer Non-Linear Programming (MINLP) model is proposed to best cover and assign base mobile communications rigs in various locations under critical situations.

In a study entitled A Model for Improving and Enhancing the Cell Phone Tower Coverage for Service during Natural Disasters, Akbarpour et al. [12] proposed a model to maximize mobile phone coverage in different areas, minimize the damage caused by the average failure of towers, and maximize coverage in the worst-case scenario of failure in mobile phone towers at the time of natural disasters. Their computational results indicated the importance and efficiency of the proposed model in real decision-making because the construction and enhancement of main stations and antennas improved the radio transmission coverage, especially in low-signal areas and high-traffic stations. The proposed model aimed at supporting the system in the worst- and moderate-case scenarios of loss to maximize the number of clients that the network would cover after the failure of facilities.

In addition to analyzing the principles and concepts, Janevski et al. [37] regarded 5G networks as user-oriented rather than operator-oriented. They believed that the need for operator response was the main reason for developing new technologies in previous networks. In contrast, in 5G networks, this is motivated by the demands of the users.

Pokorny et al. [1] optimized the costs of establishing and maintaining services in wireless networks, aiming to optimize the number of service centers to cover locations selected by customers based on requirements. This need for optimization is observed primarily in 5G networks and cellular systems characterized by many interconnected devices, which are usually difficult to control by wireless systems. Currently, the network infrastructure planning tools used in the industry include the Atoll Radio Planning Tool and Radio Planner, which do not provide the automatic selection of establishment position for specific nodes of gNodeB in a particular region with the predefined requirements. They intended to develop novel mathematics and propose models with the emerging scenarios adaptable to wireless network installation and maintenance.

Soleimani et al. [38] considered backup hubs with diverse objective functions to respond to interruption and uncertainties. In their research, backup hubs are chosen for each major hub to deal with interruptions and natural calamities and avoid delays. Then, to cope with uncertainty, a resilient possibilistic strategy is provided. Two metaheuristic algorithms are used to solve the problem: a non-dominated sorting genetic algorithm (NSGA-II) and Multi-Objective Particle Swarm Optimization (MOPSO).

Khalili Damghani et al. [39] suggested a bi-level two-echelon mathematical model reduce pre-disaster expenditures while increasing post-disaster aid coverage. The model uses a geographic information system (GIS) to categorize the disaster region and estimate the ideal number and location of distribution centers while reducing the inventory costs of relief goods. The objective of this research is multifold: 1) to recognize vulnerable urban infrastructures in sequential disaster events, 2) to prioritize urban areas using a GIS due to the severity of cascade disasters, and 3) to develop a bi-objective multi-echelon multi-supplies mathematical model for the location, allocation, and distribution of humanitarian supplies under uncertainty.

In a recent study entitled Location-Allocation Model in Telecommunication Technology and Presentation of a Novel Solution, Dinu and Ciucur [40] proposed a location-allocation model in a telecommunication network called the "Capacitated Concentrator Location-Aligning Problem" (CCLA). It is based on a general network location-allocation model focused on analyzing clients, demand, and facilities. Like in a location-allocation model, every client node has demand traffic that should be serviced, while facilities can respond to the requests within their capacity ranges. The CCLA problem was proposed as a single-source location-allocation model in this study. The optimization goal was to determine the minimum network costs, including the fixed costs of developing centralized places, execution costs, and the costs of allocating terminals. This problem is known as a hybrid NP-hard optimization problem requiring robust solutions. The research approach proposes a fuzzy genetic algorithm with a local search method for calculating the optimal values of location and allocation variables.

Table 1 compares a few of the recent studies regarding the coverage problem in the telecommunication industry and their proposed models. They considered four main categories:

- *Demand coverage strategy.*
- *Objective function.*
- *Mathematical model type.*
- *Network structure.*

2.1 | Novelty and Innovation

Studies on the resilience of communication networks are scarce, despite the use of 5G generation being necessary for places or at least in the proximity of places where the previous generations of networks were established, given disruptions during the network traffic transmission and occurrence of natural disasters, which leads to loss of active subscribers. The literature review revealed a substantial research gap regarding the comprehensive decision-making models that take into account the robustness and sustainability of

communication networks at all times through broad criteria for reducing costs and environmental pollutants, increasing profit, and maximizing coverage.

Table 1. Review of the literature on coverage problems, comparison of models, and the research gap.

References	Year of Publication	Demand Coverage Strategy					Objective Function		Model Type		Network Structure		Problem Approach		
		Complete	Maximal	Full Coverage	Incomplete Coverage	Average Coverage	Cost/Profit	Environmental	Deterministic	Stochastic	Resilient	Non- Resilient	Location	Allocation	Coverage
[19]	2004	*		*		*	*		*			*	*		
[20]	2006	*			*		*			*		*			
[10]	2006	*			*		*			*		*			
[21]	2007	*		*			*		*			*			
[22]	2009	*					*		*			*	*		*
[34]	2009	*			*	*	*			*		*	*		*
[37]	2009	*				*	*			*		*	*		*
[23]	2011	*			*		*		*			*			*
[24]	2012	*		*			*			*		*	*		
[25]	2013	*				*	*			*	*	*			
[28]	2015	*		*	*		*			*		*	*		
[58]	2015	*											*		
[32]	2017	*		*		*	*		*			*			*
[55]	2017	*			*		*		*			*			
[57]	2018		*										*		
[56]	2020												*		
[40]	2021	*		*	*	*	*			*		*			
[36]	2021		*						*				*	*	*
This study	2021	*	*	*	*	*	*	*		*	*		*	*	*

2.1.1 | Research limitations

I. How the geographical distribution of facilities in a system plays a vital role in the vulnerability of this system to disruptions, while in the establishment of telecommunication sites, we have to have a different geographical distribution.

II. Although choosing a place to install equipment faces various challenges of ownership and beautification of urban space, planning can provide the most suitable place to build and strengthen the coverage of sites and increase the number of subscribers covered by sites. Costs should also be reduced.

III. Considering environmental and health considerations of citizens in designing and locating telecommunication sites to optimize energy consumption in sites requires spending more money to purchase up-to-date equipment, which of course, this comprehensive mathematical model pays attention to both aspects.

IV. Deploying facilities at remote distances reduces the likelihood of identifying and destroying facilities. Although the BTS coverage radius in rural areas is usually larger than in urban areas, this model is considered a fixed coverage radius for the entire study area.

V. In an unstable economy with repeated exchange rate changes, design and deployment costs are different and inconsistent but do not affect the proposed model.

2.1.2 | Innovations

The innovations of this study and its significant distinction from other studies are as follows:

I. Proposing a multi-objective location-allocation model for the maximum coverage of mobile phone sites before and after the emergence of a crisis.
II. Offering a green model for the system.
III. Providing multiple support facilities in critical conditions.
IV. Considering general disturbances and possible scenarios for uncertainty parameters.
V. Presenting a model through the robust approach to solve the uncertainty problem.
VI. Proposing a Lagrangian relaxation solution to eliminate hard and complicated constraints.

3 | Mathematical Model

3.1 | The Mathematical Model

The mathematical model presented in this section seeks to locate the sites in the first place. The best optimal locations must be selected from various options, taking into account the probability of failures and problems in providing services. The radiation pollution of towers must be minimized and kept within a safe range set by the national standard of non-ionizing rays-radiation limits. These radio and telephone radiations are among the non-ionizing low-energy rays. This energy is measured in terms of density, i.e., the amount of energy radiated per square centimeter of human skin, irrespective of the distance from the telecommunication tower. The safe energy reception limit of non-ionizing rays is 0.45 mW/cm. The safe electric field intensity is also considered up to 28 V [41]. Based on these location requirements, the second step in the proposed model is to allocate a site to a group of clients to maximize the regional coverage.

Assumptions

I. All facilities (sites) have limited capacities.
II. The demand is an uncertain scenario.
III. The costs of establishing sites are limited.
IV. The capacities and costs of all sites are considered separately and differently.
V. Every site has a backup set for support and substitution in case of failure.
VI. The probability of failure is different for various sites.
VII. The costs of different generations of mobile phone technology are additional.
VIII. The capacities of different generations of mobile phone technology are various.
IX. Maximum coverage is considered.
X. The failure of facilities is probable.

Sets

i	demand points set; $i = 1, 2, \ldots, m$.
j	potential locations for the installation of sites (towers); $j = 1, 2, \ldots . n$.
k	different generations of networks; k= 1, 2, …, en.
S	set of scenarios for demand; S= 1, 2, …, se.

$$a_{ij} \begin{cases} 1, & \textit{Site (tower) } j \textit{ covers client } i, \\ 0, & \textit{Otherwise}. \end{cases}$$

Parameters

Wis	the demand of client i under scenario S.
e_{jk}	cost of setting up the jth tower for the kth generation of Internet.
q_j	pollution level of setting up tower j and support.
price	maximum budget considered for setting up a tower.
cap	maximum capacity of a tower for coverage.
d_{ij}	distance between client i and tower j.

P_{ik}	probability of tower failure in location *i* for the Internet generation k.
RT_j	the maximum radius of tower j.
BigM	a big number.
R_j	A percentage of coverage radius of tower j in which all signals are received.

Decision variables

x_{ij}	$\begin{cases} 1, & \text{if client } i \text{ is covered by tower } j, \\ 0, & \text{Otherwise.} \end{cases}$
Y_j	$\begin{cases} 1, & \text{potential site (tower)} j \text{ is activated,} \\ 0, & \text{Otherwise.} \end{cases}$
z_{ij}	$\begin{cases} 1, & \text{if client } i \text{ is covered by backup tower } j, \\ 0, & \text{Otherwise.} \end{cases}$
Y'_j	$\begin{cases} 1, & \text{if client } i \text{ is covered by backup tower } j, \\ 0, & \text{Otherwise.} \end{cases}$
k_{ij}	$\begin{cases} 1, & \text{if distance between client } i \text{ and tower } j \text{ is shorter than the coverage radius,} \\ 0, & \text{Otherwise.} \end{cases}$
v_i	≥ 0 *the lost (unallocated) sites if the facility fails at location l.*
O	the number of active sites (towers) and accessible backups.
r_j	the variable radius of site j.

Modeling

$$\text{MAX } Z1 = \sum_i^m \sum_j^n \sum_S^{se} x_{ij} w_{iS} + \sum_i^m \sum_j^n \sum_s^{se} w_{iS} z_{ij}. \quad (1)$$

$$\text{MAX } Z2 = \sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \max\{v_i\}. \quad (2)$$

$$\text{MAX } Z3 = \sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n z_{ij} w_{is} - \sum_i^m \sum_k^{en} v_i p_{ik}. \quad (3)$$

$$\text{MAXZ4} = \sum_j^n e_{jk} \sum_k^{en} Y_j + \sum_j^n \sum_k^{en} e_{jk} Y_j'. \quad (4)$$

$$\text{MIN } Z5 = \sum_j^n q_j Y_j + \sum_j^n q_j Y_j'. \quad (5)$$

$$\sum_j^n Y_j + \sum_j^n Y_j' = O. \quad (6)$$

$$x_{ij} \leq (1 - Z_{ij}). \quad (7)$$

$$\forall\, i\, j \qquad x_{ij} \leq Y_j. \quad (8)$$

$$\sum_j^n x_{ij} \leq 1 \qquad \forall\, i. \quad (9)$$

$$a_{ij} Y_j \geq x_{ij} \qquad \forall\, i\, j. \quad (10)$$

$$\sum_j^n \sum_k^{en} e_{jk} Y_j + \sum_j^n \sum_k^{en} e_{jk} Y_j' \leq \text{price}. \quad (11)$$

$$\sum_i^m \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} \leq \text{cap}\left(Y_j + Y_j'\right) \quad \forall\, j. \quad (12)$$

$$x_{ij} \leq Y_j \quad \forall\, i\, j. \quad (13)$$

$$z_{ij} \leq Y_j \quad \forall\, i\, j. \quad (14)$$

Objective functions

$$V \geq v_i \qquad \forall I. \tag{15}$$

$$d_{ij} \leq R_j RT + \left(1 - K_{ij}\right) \text{Big M}. \tag{16}$$

$$r_j \leq RT_J. \tag{17}$$

$$r_j \geq 0. \tag{18}$$

$$x_{ij}, y_j, z_{ij}, y_j', k_{ij} \ \epsilon\{0,1\}. \tag{19}$$

The first objective function, *Eq. (1)*, is for coverage maximization of the design of the primary and backup sites. *Eq. (2)* addresses the coverage maximization of towers in the worst-case coverage scenarios of sites for clients at the time of failure. The difference between the total allocated towers and the maximum number is the set of unallocated towers. To linearize the objective function, $v = max\{v_i\}$ Considered. In this case, *Constraint (20)* is added:

$$V \geq v_i \quad \forall I. \tag{20}$$

Eq. (3) considers the average coverage of sites. In other words, a backup tower is destructed randomly. If the failure probability of the backup site at location l is $\frac{1}{O}P_i$, then the anticipated failure is obtained from $v_i = \frac{1}{O}\sum_i^m v_i \sum_i^m p_i$. This objective function expresses the coverage maximization of sites in the average failure at the time of natural disasters. It also maximizes the difference between the allocated sites and the sites covered even once. The fourth objective function tries to minimize the costs of setting up the main and backup sites. For this purpose, a constant cost is considered for both sites, which the objective function tries to minimize. *Eq. (5)* aims to reduce a constant pollution value for primary and backup sites, whereas *Eq. (6)* indicates a limited number for setting up the centers. According to *Eq. (7)*, if the main tower fails to respond to the client's need, the backup tower should do the task. *Eq. (8)* expresses allocation; a site should first be set up to be allocated to a client. This constraint is considered only for the main tower. *Eq. (9)* indicates that every client receives services from at least one of the activated sites. *Eq. (10)* denotes the necessity of providing client demand coverage by sites within the coverage radius. It also guarantees that every client's request to activate potential centers and sites should be allocated. *Eq. (11)* indicates the maximum budget for setting up sites, whereas *Eq. (12)* denotes the coverage capacity. According to *Eq. (13)*, only if a site is set up its allocation to one of the clients is justifiable. *Eq. (14)* indicates allocation for the backup site, whereas *Eq. (15)* results from the linearization of the objective function that adds a constraint to the problem. *Eq. (16)* indicates that client l receives all signals. According to *Eq. (17)*, the variable radius should be shorter than the maximum radius, whereas *Eq. (18)* indicates that the variable radius should be more significant than zero. According to *Eq. (19)*, the analyzable values can only be zero and one.

3.2| Robustification

Generally, optimization models consist of two separate sections: the structural section that is constant and lacks any input data volatility and the control section that is a function changed by unreliable and volatile data. The LP optimization model is defined as below

$$\text{Min } z = c^T x + d^T y. \tag{21}$$

$$\text{Subject to } Ax = b. \tag{22}$$

$$Bx + Cy = e. \tag{23}$$

$$x, y \geq 0. \tag{24}$$

X is the decision variable of certain parameters, and Y indicates the control variables. The LP model includes structural constraints, whose coefficients are constant (i.e., reliable coefficients), and control constraints, whose coefficients include unreliable cases. Moreover, a finite set of scenarios $\varphi = \{1, 2, \dots \dots, S\}$ is assumed for uncertain parameters. Based on each scenario $s\epsilon\varphi$, $\{d_s, B_s, C_s, e_s\}$ is defined as the realization of its performance. In addition, P_s refers to the occurrence probability of each scenario, and $\sum P_s = 1$.

According to the multiple scenarios, the objective function $C' = c^T x + d^T$ is a random variable that takes $C'_s = c^T x + d_s^T y_s$ with the probability of P_s. The multiple-criteria decision-making (MCDM) concept performs the exchange between solution and model robustness. The above robust optimization model can measure this exchange. Furthermore, σ_0 is considered a nonlinear expression. The model is based on a stochastic nonlinear programming model [42], [43]. The expression $\sigma(x, y_1, \dots ., y_s)$ includes the average value σ_0 and the constant value λ multiplied by its variance

$$\sigma(x, y_1, \dots, y_s) = \sum_{s\epsilon S} P_s C'_s + \lambda \sum_{s\epsilon S} p_s \{C'_s - \sum_{s\epsilon S} P_s C'_s\}^2. \quad (25)$$

Since the above equation has an expression by the power of 2, making it a quadratic equation, it was formulated as below by [42]:

$$\sigma(x, y_1, \dots, y_s) = \sum_{s\epsilon S} P_s C'_s + \lambda \sum_{s\epsilon S} p_s \ |C'_s - \sum_{s\epsilon S} P_s C'_s|. \quad (26)$$

While this objective function is still nonlinear, it can be transformed into a linear function through Yu and Li's approach [44] by adding nonnegative deviation variables. The two deviation variables are minimized concerning constraints instead of reducing the reference of absolute deviations from the mean of the above two functions:

$$\text{Min } z = \sum_{s\epsilon S} P_s C'_s + \lambda \sum_{s\epsilon S} P_s [(C'_s - \sum_{s\epsilon S} P_s C'_s) + 2\theta_s]. \quad (27)$$

$$C'_s - \sum_{s\epsilon S} P_s C'_s + \theta_s \geq 0. \quad (28)$$

$$\theta_s \geq 0. \quad (29)$$

The robust optimization approach is employed to deal with the uncertainty of parameters through a set of possible scenarios by transforming the particular model into a robust model.

3.2.1 | General form of robust optimization model

The research problem is modeled using the method proposed by Mulvey et al. [42] as the following:

$$\begin{aligned} &\text{Max } z_1 = \sum_s P_s \left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij}\right) + \\ &\lambda \sum_s P_s \left[\left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij}\right) - \sum_{s'} P_{S'} \left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \right.\right. \\ &\left.\left. \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij}\right) + 2\theta_s \right] + \omega \sum_i \sum_j \sum_s P_S \delta_{ijs}. \end{aligned} \quad (30)$$

$$\begin{aligned} &\text{Max } z_2 = \sum_s P_s \left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \max\{v_i\}\right) + \\ &\lambda \sum_s P_s \left[\left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \max\{v_i\}\right) - \right. \\ &\left. \sum_{s'} P_{S'} \left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \max\{v_i\}\right) + 2\theta_s \right] + \\ &\omega \sum_i \sum_j \sum_s P_S \delta_{ijs}. \end{aligned} \quad (31)$$

$$\begin{aligned} &\text{Max } z_3 = \sum_s P_s \left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \sum_i^m \sum_k^{en} v_i p_{ik}\right) + \\ &\lambda \sum_s P_s \left[\left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \sum_i^m \sum_k^{en} v_i p_{ik}\right) - \right. \\ &\left. \sum_{s'} P_{S'} \left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \sum_i^m \sum_k^{en} v_i p_{ik}\right) + 2\theta_s \right] + \\ &\omega \sum_i \sum_j \sum_s P_S \delta_{ijs}. \end{aligned} \quad (32)$$

$$\begin{aligned} &\left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij}\right) - \sum_s p_s \left(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \right. \\ &\left. \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij}\right) + \theta_s \geq 0 \ \ \forall \ s \ . \end{aligned} \quad (33)$$

$$\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \max\{v_i\}) - \sum_s p_s\Big(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \max\{v_i\}\Big) + \theta_s \geq 0 \qquad \forall\, s. \tag{34}$$

$$\Big(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \sum_i^m \sum_k^{en} v_i p_{ik}\Big) - \sum_s P_s\Big(\sum_i^m \sum_j^n \sum_s^{se} w_{is} x_{ij} + \sum_i^m \sum_j^n \sum_s^{se} w_{is} z_{ij} - \sum_i^m \sum_k^{en} v_i p_{ik}\Big) + \theta_s \geq 0 \qquad \forall s. \tag{35}$$

$$\theta_s \geq 0. \tag{36}$$

3.2.2 | Solving the problem using lagrangian relaxation

The main idea of Lagrangian relaxation is to relax complicated constraints by multiplying them by Lagrangian coefficients and adding them to the objective function of a problem. This method is employed to simplify the complicated constraints to make the problem easier to solve. For every constant Lagrangian coefficient, the optimal solution to the relaxed minimization problem is a lower bound of the main problem. In other words, each solution to the relaxed problem is bound to the solution to the main problem. Due to the elimination of some constraints and the expansion of the feasible area, the relaxed problem is solved more easily than the main one [45], [46].

Many of the large-scale linear programming models have successfully been solved through Lagrangian relaxation. Examples include studies conducted by Hamdan and Diabat [47], Heidari-Fathian and Pasandideh [48], Diabat and Richard [49], and Pakravan and Behnamian [50]. Some researchers have also adopted the Lagrangian relaxation method to relax complicated constraints and achieve an acceptable approximate solution to the robust problem [51]-[53].

Furthermore, the solution to the relaxed problem is an upper bound if feasible in the main problem. For this purpose, a heuristic algorithm is usually proposed to create a feasible solution (an upper bound) out of the solution of the lower bound. Therefore, a better lower bound is achieved by maximizing the minimum obtained from the relaxed problem, and the resultant solution can be approximated to the solution of the main problem in iterations. For this purpose, the gradient method is employed to solve the Lagrangian duality problem. The Lagrange function optimization problem with the duality variable (Lagrangian coefficients) is called the Lagrangian duality problem [54]. Consider the following optimization problem

$$\begin{aligned} &\text{Max } c^T x + \lambda^T (b_2 - A_2 x), \\ &A2X \leq b2, \\ &A1X \leq b1, \\ &X \epsilon R^n, A \epsilon R^{m,n}, \end{aligned} \tag{37}$$

where $\lambda = (\lambda_1, \ldots \ldots \ldots \lambda_{m2})$ represents nonnegative weights. If *Constraint (2)* is violated, there will be a fine, and if it is satisfied, there will be a reward. A practical feature of this solution is that the result of Lagrangian optimization will not be smaller than the optimal result of the main problem for every constant set of λ. The problem constraints can be analyzed and rewritten as below:

$$\begin{aligned} &c^T X \leq \overbrace{c^T x + \lambda^T}, \\ &b_2 - A_2 \hat{x} \leq c^T x + c^T \ddot{x} + \widehat{\lambda^T} \, b_2 - A_2 \hat{x}. \end{aligned} \tag{38}$$

Evidently, both inequalities are correct because $\hat{x}$ is accepted in the main problem and $\ddot{x}$ is the optimal solution to the Lagrangian relaxation. In fact, if the maximum value obtained from the relaxation problem is minimized, a more robust constraint will be obtained in the objective value of the main problem. Hence, we can analyze the main problem instead of analyzing a partial duality problem. As a result, a Lagrangian simplification algorithm searches for a range of λ values in order to minimize the result generated by the internal problem P. Every value returned by P is a candidate for the upper bound of the problem, the smallest value of which is considered the best. In addition, if a heuristic function is employed, the problem can be repeated to find the best upper bound, and the cost of the best acceptable solution is close to the

main solution as much as desired. The enhanced Lagrangian method is entirely similar to the Lagrangian simplification method in terms of structure; however, the former adds one expression to the latter to update the dual parameters of λ in a more standard way.

In the integer variable planning problem, the constraints with binary variables, which make the problem difficult to solve, are generally called complicated constraints. The most complicated constraints should be transferred to the objective function to solve a relaxed problem. According to the model evaluation, *Eq. (39)* is among the complicated, hard constraints. The Lagrangian relaxation problem is created by multiplying this constraint by the Lagrangian coefficient $\lambda_{ij} \geq 0$ and adding it to the objective function.

$$d_{ij} \leq R_j RT + \left(1 - K_{ij}\right) \text{Big M}. \tag{39}$$

$$\sum_i^m \sum_j^n \lambda_{ij}\left(d_{ij} - R_j RT - \left(1 - K_{ij}\right) \text{Big M}\right). \tag{40}$$

Eq. (39) is deleted from the constraints, and *Eq. (40)* is added to the objective function.

4 | Numerical Calculations and Sensitivity Analysis

Since the proposed model is a multi-objective one, it was solved using LP metric method. The objective functions were first solved separately for every proposed constraint and then weighted to create a single objective function, which can be solved as a single-objective problem. The computations were performed in GAMS v24.8.2 in a small-scale local model in Tehran.

4.1 | Definitions of Data and Scenarios

The problem is first modeled by applying scenarios to create a single-objective model. Values obtained before and after the robust solution were then compared, and the results were analyzed. In case of disruptions at telecommunication towers, various scenarios can occur. In this study, demand is considered uncertain. Three scenarios can happen that are presented in *Table 2*.

Table 2. Demand for every scenario and values of parameters.

Occurrence Probability	Descriptions	Scenario
0.20	$w_{is=1}$=(1-0.25)w_{is} Demand is 25% lower than the average prediction value.	1
0.50	$w_{is=1}$=50 The average prediction value for demand	2
0.30	$w_{is=1}$=(1+0.25)w_{is} Demand is 25% higher than the average prediction value.	3

BigM	R_j	RT_j	p_{ik}	d_{ij}	Capacity	Price	q_j	e_{jk}	w_{is}	Parameter
10^{10}	0-10	0-30	0-1	Uniform (0-20)	100	10000	0-0.5	2000-5000	0-100	Value

Table 2 reports the demand values. Moreover, as discussed earlier, the values of parameters were obtained from the analysis of an urban district in Tehran and extracted from the relevant papers.

4.2 | Model Analysis

The model was solved, and the values of five objective functions were determined by solving all constraints under the scenario (*Table 3*).

Table 3. The values of objective functions with LP metrics.

W	0.01	0.13	0.21	0.33	0.41	0.53	0.61	0.73	0.81	0.93	1
Z1	1710	3254	4522	3390	4910	6101	6501	7410	7560	7836	7963
Z2	540	850	1950	3250	4501	4360	4510	4952	5320	5620	5852
Z3	650	1100	1501	1650	1952	2410	2785	3265	3654	3950	4020
Z4	22450	20650	17840	16980	15450	13020	10523	9100	8410	8023	4750
Z5	1002	650	325	569	320	215	198	102	98	91	81

The value of W in every objective function increases from 0.01 to 1. The maximum coverage decreases as W increases from Z1 to Z3, whereas the setup cost and pollution decrease by increasing the LP-metric weight. The robust model was employed to acquire a near-optimal solution to every feasible scenario. Moreover, the proposed solutions were expressed for analysis by considering $\omega = 1$ *and* $\lambda = 1$. *Table 4* reports the values of variables obtained from the solution per scenario for the single-objective and the robust model.

Table 4. The values of objective functions for different rj, O, vi, yj, and y'j.

Values	r_j					o	v_i	y_j					y'_j				
	j_1	j_2	j_3	j_4	j_5	o	v_i	j_1	j_2	j_3	j_4	j_5	j_1	j_2	j_3	j_4	j_5
Metric	115	139	129	126	115	13	7	1	1	1	1	1	1	1	1	1	1
Obj5	115	150	123.12	140	150	10	5	1	1	1	1	1	0	1	1	0	1
Obj4	1500.52	1200	1390	1400	1290	31	2	0	0	0	1	0	0	1	0	1	1
Obj3	150	139	129	121.7	170	12	7	1	0	1	0	1	0	0	0	0	1
Obj2	137.5	122	115	129	139	50	3	1	0	1	1	1	0	0	0	1	1
Obj1	139	151	139	139	170	25	5	1	1	0	0	1	1	1	1	1	0

4.3| Sensitivity Analysis

In this section, we investigated the amount of change in the objective function with the changes in the value of parameters to determine the sensitivity of these parameters to the objective function. The most important parameter of the sensitivity analysis with the greatest effect is "demand." Therefore, the demand values were changed through a loop in GAMS, and the observations were analyzed. *Table 5* presents the values of the objective function for 0–100 demands (the demand was changed from 100 to 200).

Table 5. The values of the objective function with demand change.

w(i,s)-2	100	150	170	100	130	170	158	190	187	120	165	105	150	140	140
Z1-2	1800	2500	4650	4850	3650	5050	5120	6590	6980	6970	6970	7980	7850	7900	8150
w(i,s)-1	90	100	25	30	12	95	23	10	15	6	87	16	95	30	15
Z1-1	1710	2340	4401	4522	3250	4910	5610	5970	6101	6301	6501	7410	7403	7836	7955

Fig. 3 compares values of the objective function recorded after the demand was changed from 0 to 100 and then from 100 to 200. In fact, by increasing the demand by 100 units, the first objective function increased in some points and decreased in fewer ones. The objective function rises after a specific moment when the demand increases by a higher ratio because this would definitely increase the need for maximum coverage. As a result, the coverage increases when the demand increases.

As is shown in *Fig. 3*, increasing the demand increases the values of Objective Function 1 and 2 with a mild slope. The second and third objective functions indicate coverage in different cases. The results revealed an increase in both following the increase in the demand. Analysis of λ for each function suggested that increasing this coefficient when the probability is constant leads the model to adapt strategies characterized by A) maximum coverage, B) minimum cost and C) minimum pollution as managerial implications of the findings (*Fig. 4*). In other words, the more significant these coefficients, the more risk-evasive the decision-maker, which finally affects the expected coverage costs

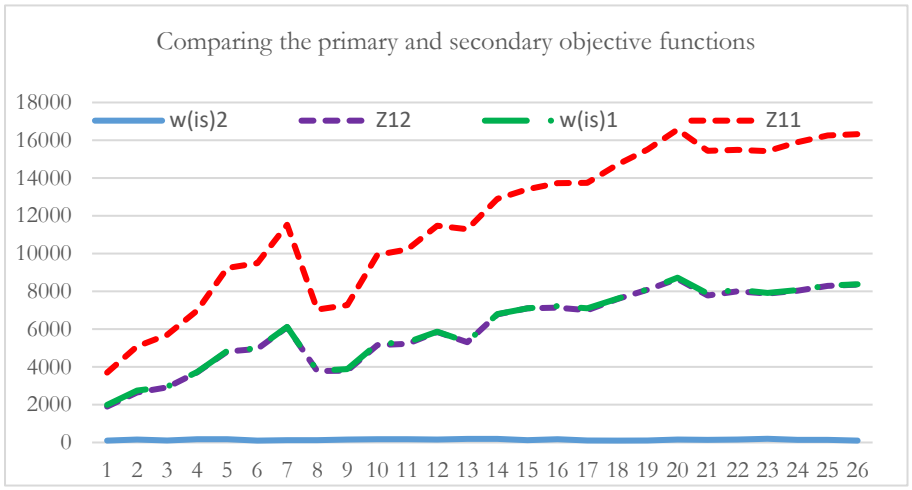

Fig. 3. Comparing the primary and secondary objective functions in terms of changes in the demand.

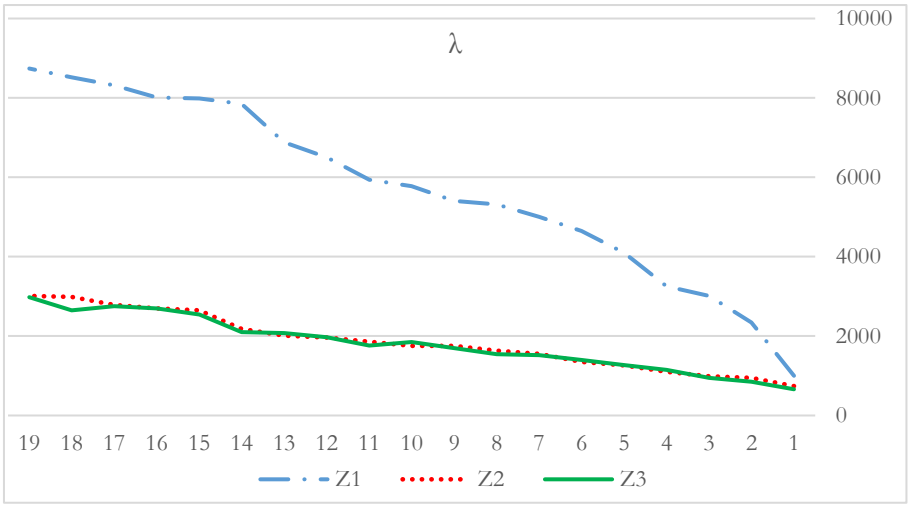

Fig. 4. Changes in the objective function by changes in λ.

Fig. 4 demonstrates three objective functions per the robustification coefficient. As λ increases, the values of all three parts increase. However, Z1, which denotes the maximum complete coverage, grows with a steeper slope than the second and third objective functions, indicating incomplete coverage scenarios. Therefore, the first objective function stands above the other two.

Fig. 5 shows that the first, second, and third objective functions improved in the robust scenario instead of the non-robust one. In other words, they yielded larger values. Furthermore, the third objective function, i.e., the average coverage of sites, is more optimal in the robust scenario than the first and second objective functions, i.e., the maximum coverage and coverage during crises. In addition, according to the sensitivity analyses of the fourth and fifth functions (*Fig. 5*), changes in demand were relatively ineffective on the primary and secondary functions. In general, they proved to descend

Constraint 16 of the primary model is complicated and complex; therefore, the Lagrangian relaxation method eliminated its complexity. While d_{ij} was determined as the lower bound, an upper bound was obtained in every iteration of the Lagrangian method. The algorithm ended when the upper bound was equal to the lower bound, which meant that the optimal solution was obtained (*Fig. 6*).

The distance (d_{ij}) between Uniform (0-20) and Uniform (20-40) was prolonged, and the objective function behavior was analyzed.

Fig. 7 shows that the substitute objective function resulting from Lagrangian relaxation had an undefined behavior (sometimes ascending and sometimes descending) after the distance was increased, while it proved ultimately climbing after a certain point compared to the primary function

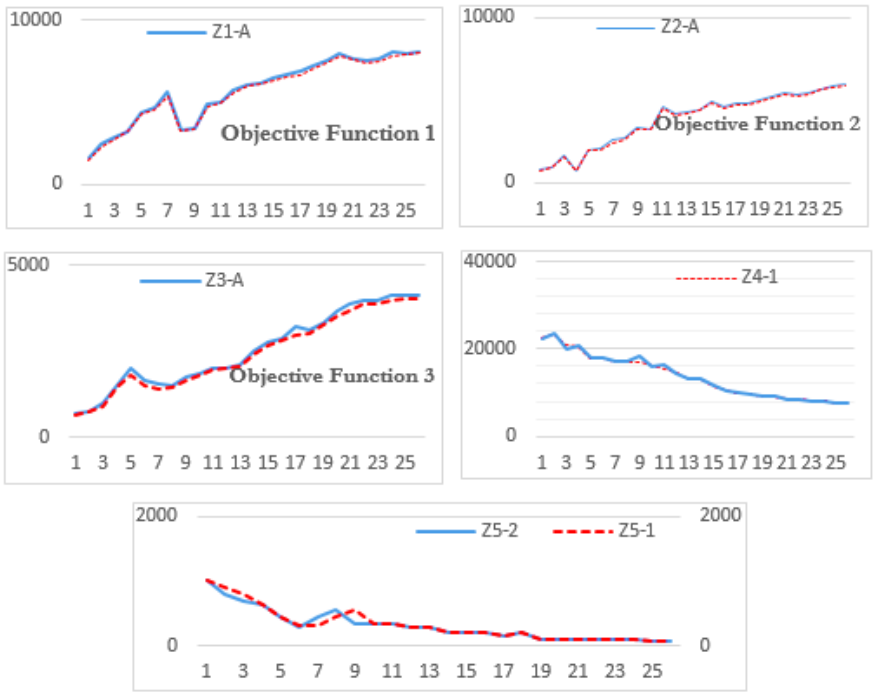

Fig. 5. Comparing the objective functions before and after robustification (UN: before – A: after).

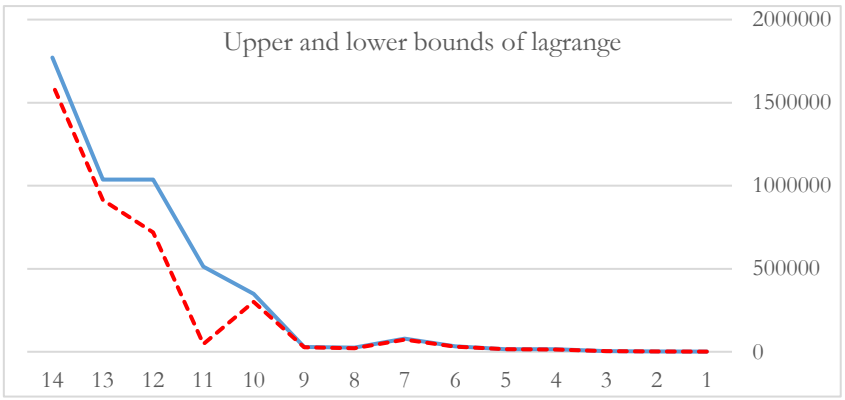

Fig. 6. Convergence of upper and lower bounds of the Lagrange algorithm after relaxing a hard constraint.

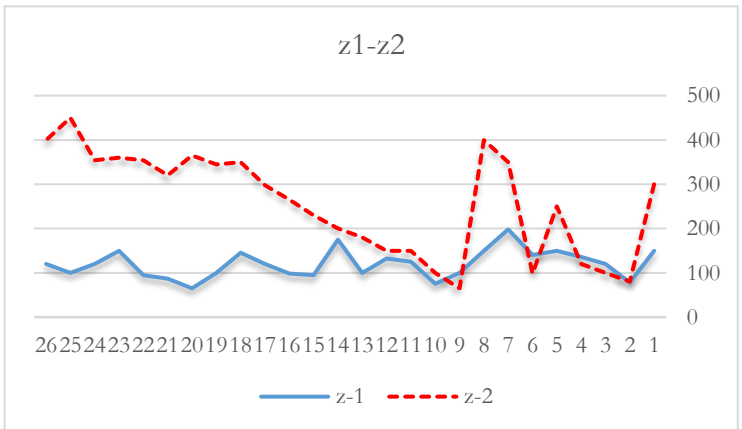

Fig. 7. Comparing the objective function before and after the distance is prolonged (lagrangian relaxation).

5 | Conclusion and Recommendations

As shown in the tables, as the value of λ increases when the scenario probability is constant, the model adopts strategies that are characterized by maximum coverage, minimum cost, and minimum pollution. In other words, the larger this coefficient, the more elusive the decision-maker, which eventually affects the expected costs of the coverage.

Mobile phones and the Internet play crucial roles in the modern world. Men perform most of their activities via the Internet at present. For instance, they use their mobile phones and the Internet to chat, use social media, send and receive documents, and do many other things. Even most of the material used for writing this manuscript was extracted from the Internet. Hence, the Internet and smartphones are indispensable components of human life in the 21st century. The perfectionist human being always seeks optimal and advanced use of tools. The Internet has been developed from Generation 0 to Generation 5 so far. In Iran, mobile phone operators have always been trying to provide the best services and attract more subscribers. This would be more challenging during accidents and disasters when disruptions happen. Hence, this paper aims to propose an optimal location-allocation model for the maximum coverage of client demand and the provision of better services.

In today's world, our daily lives depend significantly on communication networks in a tangible way. Any performance disruption in critical situations can have irreversible consequences in many sectors affected by communication, especially providing relief and security services for the health of citizens. Moreover, businesses that are based on mobile phone networks can be disrupted during crises. Therefore, it is necessary to address the design of mobile phone networks and the Internet in terms of resilience and resistance in such situations. This is considered an indispensable area of knowledge in operations research studies. Literature review showed that few models were proposed that comprehensively analyzed coverage maximization as well as minimization of environmental pollutants by considering backup sites for the network resilience. Due to particular political and geographical situations, Iran has always been prone to natural and artificial disasters. In recent years, a great deal of damage has been sustained by telecommunication networks in the floods of Golestan, Khuzestan, and Ilam Provinces and the earthquake in East Azerbaijan Province. Therefore, investigation of this problem was proven crucial in Iran. From an environmental point of view, the installation conditions of BTS antennas in Iran are practically based on information approved by the international scientific community. If these conditions are applied correctly during design and deployment, people can benefit from this technology without disrupting communication. This study has several suggestions for the development of communication technology for future research, as follows:

I. Using a mobile phone with existing guidelines requires a set of low-risk, green solutions. Therefore, creating environmental and health standards should be a priority.
II. For future research, the location of restricted areas can be considered in possible shapes in rectangular or circular shapes, and the use of several limited regions instead of one local area can bring the model closer to reality.
III. The parameters of the proposed model in this study can follow other distributions, such as the binomial pattern and fuzzy conditions that can be used to improve the relevant problems.
IV. Due to the changeable nature of urban elements, it is necessary to expand the model for use in developing networks over networks under construction. Therefore, it is helpful to pay close attention to the number of rigs when installing new rigs in an area and increase, decrease, or maintain the capacity of the rigs after reinforcement.

5.1 | Recommendations

I. Considering ideal planning in the model.
II. Considering a more significant number of uncertain parameters (using the fuzzy approach).
III. Considering the hierarchical coverage instead of partial coverage.
IV. Using metaheuristic methods for location-allocation.
V. Proposing novel and operational strategies for dealing with the demand points lost in critical conditions.

5.1.2| Future research areas in robust optimization

I. Robust optimization based on the average case.
II. Nonlinear and discrete robust optimization.
III. Proposing a solution to complicated robust optimization problems, especially when the uncertainty set has a general form.

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A Novel Numerical Approach for Distributed Order Time Fractional COVID-19 Virus Model

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Abstract

In this paper, we proposed a numerical approach to solve a distributed order time fractional COVID 19 virus model. The fractional derivatives are shown in the Caputo-Prabhakar contains generalized Mittag-Leffler Kernel. The coronavirus 19 disease model has 8 Inger diets leading to system of 8 nonlinear ordinary differential equations in this sense, we used the midpoint quadrature method and finite different scheme for solving this problem, our approximation method reduce the distributed order time fractional COVID 19 virus equations to a system of algebraic equations. Finally, to confirm the efficiency and accuracy of this method, we presented some numerical experiments for several values of distributed order. Also, all parameters introduced in the given model are positive parameters.

Keywords: COVID-19 virus, Distributed-order, Finite difference method, Caputo-prabhakar derivative.

1 | Introduction

Newly, Fractional Differential Equations (FDEs) have been widely applied to describe abundant seemingly diverse and different fields because of their vast potential to explain many phenomena in economics [1], biology [2], physics [3], engineering [4] and science [5], etc. Among types of FDEs, the distributed-order ones, for the first time in 2002 studied by Chechkin et al. [6], have been accurately applied to explain the relaxation and anomalous diffusion phenomena where the diffusion exponent can shift in the course of time. Extending numerical and analytical methods for the solutions of FDEs is very significant duty. In fact, it is not feasible to find the exact analytic solutions of FDEs. Thus, several numerical methods have been showed to solve the FDEs. Sousa and Li [7] applied the weighted finite difference method to obtain the fractional diffusion equation; Babolian et al. [8] found the numerical solution of nonlinear FDEs by using Adomian decomposition method; Yang et al. [9] used variational iteration method for the solution of multi-order FDEs; Hosseinnia et al. [10] obtain the numerical solution of FDEs by using Homotopy perturbation method; Bhrawy et al. [11] used Chebyshev and Legendre polynomials method to solve the multi-term FDEs; Rahimkhani et al. [12] used fractional-order Bernoulli functions method for solving the fractional

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Fredholm-Volterra integro-differential equations; Rahimkhani et al. [13] used wavelet method for obtaining solution of the fractional pantograph differential equations; Rahimkhani et al. [14] applied fractional-order wavelet method; Mahboob et al. [15] found a numerical solution of the Benjamin-Bona-Mahony-Burgers equation based on finite difference method of sixth order.

FDEs include distributed-order fractional derivatives can serve as a normal extension of the multi-term fractional different equation and single order fractional different equation. To find solution of the distributed-order time FDEs, Mashayekhi and Razzaghi [16] applide a numerical method based on the Bernoulli polynomials and block-pulse functions; Chen et al. [17] studied a numerical method based on the finite difference/spectral to solve the time-fractional reaction-diffusion equation of distributed-order; Aminikhah et al. [18] found a combined Laplace transform and new homotopy perturbation method for solving a special class of the distributed order fractional Riccati equation; Aminikhah et al. [19] proposed two numerical methods for solving distributed-order fractional Bagley-Torvik equation; Mashoof et al. [20] used a numerical method based on operational matrix of fractional order integration from fixed point for distributed order FDEs; Mashoof et al. [21] found the stability of two classes of distributed-order Hilfer-Prabhakar differential equations; Mashoof et al. [22] applied the stability of distributed order form of Hilfer-Prabhakar differential equations; Li and Wu [23] showed the numerical method for finding solutions of the time-fractional diffusion equation of distributed-order with variable coefficients; Liu et al. [24] studied a numerical method based on the finite volume method to obtain such equation; Fan and Liu [25] used a numerical method based on the finite element method for solving a two-dimensional fractional diffusion equation of distributed-order on an irregular convex domain; Jia and Wang [26] extended a fast finite difference method for the fractional partial differential equation of distributed-order on convex domains; Morgado et al. [27] used a numerical method based on the Chebyshev collocation method for solving distributed order FDEs; Zaky [28] studied a Legendre collocation method for solution of fractional optimal control equations distributed-order; Hu et al. [29] used an implicit numerical method; Ye et al. [30] showed an implicit difference method for solving the distributed-order time fractional equation; Ford et al. [31] investigated an implicit difference method for solving the distributed-order time fractional equation; Gao and Sun [32] showed some alternating direction implicit difference methods for solving the distributed-order time fractional equation; Jin et al. [33] studied a rigorous numerical analysis for the distributed-order time fractional diffusion equation.

The COVID-19 are a large collection of viruses which have a specified corona or 'crown' of sugary-proteins and because of their form, they were called COVID-19 in 1960. Due to the World Health Organization (WHO), COVID-19 is spreaded via people who have been infected with the corona virus. The virus may quickly transmit via small drops from the mouth compilation or nose of anybody infected via this virus to cough or sneeze. The small drops then land on surfaces or objects which are touched and the healthy person regulates their nose, mouth or eyes. For the first time in the Wuhan city the COVID-19 was appeared that this virus has not been previously known in humans. Bats or snakes have been skepticed as a potential source for the prevalence, though other experts currently consider this unlikely. Cough, fever, breathing difficulties and shortness of breath are the initial signs of this infection. In the next stages, the infection may reason pneumonia, kidney failure, even death and severe acute respiratory syndrome.

In this paper, we introduce a class of distributed order time fractional Coronavirus-19 disease involving one Caputo-Prabhakar derative in time t. For solving this modol, we use the midpoint quadrature method and finite difference method for discretizing the distributed order time fractional derivative and Caputo-Prabhakar derative.

The remainder of the paper is organized as follows. Section 2 we give some notations, basic definitions and lemma of fractional calculus. In Section 3, we show the finite difference method for solving the distributed order time fractional Coronavirus-19 disease. In Section 4, we illustrate some numerical examples using the presented method.

2 | Preliminaries and Some Notations

In this section, we introduce the basic definitions of Prabhakar fractional integral and derivative, Caputo-Prabhakar derative and some basic lemmas which are applied for later.

Definition 1 ([39]). Let $m-1<\Re(\mu)\leq m$ and $u\in L^1[0,b]$, $0<t<b\leq\infty$. Then the left-sided and the right-sided Prabhakar fractional integrals are given as

$$\begin{aligned}(\mathbf{E}^{\gamma}_{\rho,\mu,\omega,0^+}u)(t)&=\int_0^t(t-\tau)^{\mu-1}E^{\gamma}_{\rho,\mu}(\omega(t-\tau)^{\rho})u(\tau)d\tau,\\(\mathbf{E}^{\gamma}_{\rho,\mu,\omega,b^-}u)(t)&=\int_t^b(\tau-t)^{\mu-1}E^{\gamma}_{\rho,\mu}(\omega(\tau-t)^{\rho})u(\tau)d\tau.\end{aligned}\tag{1}$$

Definition 2 ([39]). Let $u\in L^1[0,b]$, then for $m-1<\Re(\mu)\leq m$, the left-sided and the right-sided Prabhakar fractional derivatives are given by

$$\begin{aligned}(D^{\gamma}_{\rho,\mu,\omega,0^+}u)(t)&=\frac{d^m}{dt^m}\mathbf{E}^{-\gamma}_{\rho,m-\mu,\omega,a^+}u(t),\\(D^{\gamma}_{\rho,\mu,\omega,b^-}u)(t)&=(-1)^m\frac{d^m}{dt^m}\mathbf{E}^{-\gamma}_{\rho,m-\mu,\omega,b^-}u(t).\end{aligned}\tag{2}$$

Also, for the given absolutely continuous function u, the Caputo-Prabhakar fractional derivatives is given by

$${}^{CP}D^{\mu}_t u(t)=\mathbf{E}^{-\gamma}_{\rho,m-\mu,\omega,0^+}\frac{d^m}{dt^m}u(t),\tag{3}$$

Where for $m=1$, *Eq. (8)* is obtained.

Lemma 1 ([3]). Suppose that $\rho,\gamma,\mu,\omega\in\mathbb{C}$ that $\Re(\rho),\Re(\mu)>0$. Then the following relation is resulted.

$$\int_0^t\tau^{\mu-1}E^{\gamma}_{\rho,\mu}(\omega\tau^{\rho})d\tau=t^{\mu}E^{\gamma}_{\rho,\mu+1}(\omega t^{\rho}).\tag{4}$$

2.1 | Description of the Distributed Order Time Fractional Coronavirus-19 Disease Model

Here, we study the distributed order time fractional Coronavirus-19 disease (COVID-19) model as

$$\begin{aligned}{}^{CP}\mathbb{D}^{\zeta(\mu)}_t S(t)&=-S(t)\big(\alpha_1 I(t)+\alpha_2 D(t)+\alpha_3 A(t)+\alpha_4 R(t)\big),\\{}^{CP}\mathbb{D}^{\zeta(\mu)}_t I(t)&=S(t)(\alpha_1 I(t)+\alpha_2 D(t)+\alpha_3 A(t)+\alpha_4 R(t))-(\epsilon_1+\zeta_1+\lambda_1)I(t),\\{}^{CP}\mathbb{D}^{\zeta(\mu)}_t D(t)&=\epsilon_1 I(t)-(\eta_1+\rho_1)D(t),\\{}^{CP}\mathbb{D}^{\zeta(\mu)}_t A(t)&=\zeta_1 I(t)-(\theta_1+\mu_1+\kappa_1)A(t),\\{}^{CP}\mathbb{D}^{\zeta(\mu)}_t R(t)&=\eta_1 D(t)+\theta_1 A(t)-(\nu_1+\xi_1)R(t),\\{}^{CP}\mathbb{D}^{\zeta(\mu)}_t T(t)&=\mu_1 A(t)+\nu_1 R(t)-(\sigma_1+\tau_1)T(t),\\{}^{CP}\mathbb{D}^{\zeta(\mu)}_t H(t)&=\lambda_1 I(t)+\rho_1 D(t)+\kappa_1 A(t)+\xi_1 R(t)+\sigma_1 T(t),\\{}^{CP}\mathbb{D}^{\zeta(\mu)}_t E(t)&=\tau_1 T(t).\end{aligned}\tag{5}$$

With the initial conditions

$$S(0) = S_0, I(0) = I_0, D(0) = D_0, A(0) = A_0, R(0) = R_0, T(0) = T_0, H(0) = H_0, E(0) = E_0. \quad (6)$$

Also, all parameters introduced in the given model are positive parameters and their physical interpretation and meaning can be given in [34]. In *Eq. (5)*, $S(t)$ is the class of susceptible, $I(t)$ is the class of infected asymptomatic infected undetected, $D(t)$ is the class of asymptomatic infected, detected, $A(t)$ is ailing symptomatic infected, undetected, $R(t)$ is recognized symptomatic infected, detected, $T(t)$ is the class of acutely symptomatic infected detected, $H(t)$ is the healed class, $E(t)$ is the death class and ${}^{CP}\mathbb{D}_t^{\zeta(\mu)}$ displays the distributed order fractional derivative of given functions in time t, defined by:

$${}^{CP}\mathbb{D}_t^{\zeta(\mu)} = \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu} d\mu, \mu \in (0,1], \quad (7)$$

where $\zeta(\mu) > 0$ is the weight function and;

$$\int_0^1 \zeta(\mu)d\mu = C, C > 0. \quad (8)$$

Further, the symbol ${}^{CP}D_t^{\mu}$ is the Caputo-Prabhakar derivative of μ order in time t and it is given by [39]

$$\int_0^1 \zeta(\mu)d\mu = C, C > 0. \quad (9)$$

Here $E_{\rho,\mu}^{\gamma}(\omega t^{\rho})$ is a generalization of one-parameter Mittag-Leffler and two-parameter Mittag-Leffler functions and it is defined by [39]:

$$\int_0^1 \zeta(\mu)d\mu = C, C > 0. \quad (10)$$

Due of the plenty application and use of the generalized Mittag-Leffler function in fractional calculus a reason was to select this type of the Caputo-Prabhakar fractional derivative of order μ. Applications of the three-parameter Mittag-Leffler function may be used in mathematical fields as physics and stochastic processes, electromagnetic, various materials, viscosity and several media [35]-[38].

3 | The Numerical Method for Solving Distributed Order Time Fractional Coronavirus-19

In this section, we apply a finite difference method to approximate the solution of *Eq. (5)*. For this aim, first, we apply a quadrature method to approximate the distributed order fractional derivative term on the left-hand side of *Eq. (5)*. We consider a segmentation of $[0,1]$, the interval $[0,1]$ where the order of the derivative in time t lies, into N sub-intervals $[\omega_{j-1}, \omega_j]$ that $j = 1,2, \dots, N$ with $h = \frac{1}{N}$. Showing the midpoints of any one of sub-intervals $[\omega_{j-1}, \omega_j]$ as

$$\mu_j = \frac{\omega_{j-1} + \omega_j}{2}, \quad (11)$$

where $j = 1,2, \dots, N$. Therefore, we apply the midpoint method for the approximation of the distributed order fractional derivative term in *Eq. (5)*, then we have

$$
\begin{aligned}
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}S(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}S(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}S(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}S(t))'',\\
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}I(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}I(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}I(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}I(t))'',\\
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}D(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}D(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}D(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}D(t))'',\\
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}D(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}D(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}A(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}A(t))'',\\
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}R(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}R(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}R(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}R(t))'',\\
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}T(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}T(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}T(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}T(t))'',\\
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}H(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}H(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}H(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}H(t))'',\\
{}^{CP}\mathbb{D}_t^{\zeta(\mu)}E(t) &= \int_0^1 \zeta(\mu)\,{}^{CP}D_t^{\mu}E(t)d\mu = h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}E(t) - \frac{h^2}{24}(\zeta(\mu)\,{}^{CP}D_t^{\mu}E(t))''.
\end{aligned}
\tag{12}
$$

Putting *Eq. (12)* into *Eq. (5)* by neglecting $O(h^2)$, we obtain

$$
\begin{aligned}
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}S(t) &= -S(t)(\alpha_1 I(t) + \alpha_2 D(t) + \alpha_3 A(t) + \alpha_4 R(t)),\\
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}I(t) &= S(t)(\alpha_1 I(t) + \alpha_2 D(t) + \alpha_3 A(t) + \alpha_4 R(t)) - (\epsilon_1 + \zeta_1 + \lambda_1)I(t),\\
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}D(t) &= \epsilon_1 I(t) - (\eta_1 + \rho_1)D(t),\\
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}A(t) &= \zeta_1 I(t) - (\theta_1 + \mu_1 + \kappa_1)A(t),\\
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}R(t) &= \eta_1 D(t) + \theta_1 A(t) - (\nu_1 + \xi_1)R(t),\\
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}T(t) &= \mu_1 A(t) + \nu_1 R(t) - (\sigma_1 + \tau_1)T(t),\\
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}H(t) &= \lambda_1 I(t) + \rho_1 D(t) + \kappa_1 A(t) + \xi_1 R(t) + \sigma_1 T(t),\\
h\sum_{j=1}^{N}\zeta(\mu_j)\,{}^{CP}D_t^{\mu_j}E(t) &= \tau_1 T(t).
\end{aligned}
\tag{13}
$$

Next we discretize the time derivatives. For simplicity, $S(t_j)$, $I(t_j)$, $D(t_j)$, $A(t_j)$, $R(t_j)$, $T(t_j)$, $H(t_j)$, $A(t_j)$ and $E(t_j)$ are define as S_j, I_j, D_j, A_j, R_j, T_j, H_j and E_j, respectively. Then the value of Caputo-Prabhakar derivative ${}^{CP}D_t^{\mu_j}$ for given functions as $S(t)$ at the nodes $t_l = l\Delta t, l = 0,1,\dots,N, \Delta t = \frac{1}{N}$ can be calculated as

$$\begin{aligned} {}^{CP}D_t^{\mu_j} S(t)|_{t=t_l} &= \int_0^{t_l} (t-\tau)^{-\mu_j} E^{-\gamma}_{\rho,1-\mu_j}(\omega(t-\tau)^\rho) S'(\tau)d\tau, \\ {}^{CP}D_t^{\mu_j} S(t)|_{t=t_l} &\simeq \sum_{m=0}^{l} \frac{S_{m+1}-S_m}{\Delta t} \int_{t_l}^{t_{l+1}} (t-\tau)^{-\mu_j} E^{-\gamma}_{\rho,1-\mu_j}(\omega(t-\tau)^\rho)d\tau. \end{aligned} \tag{14}$$

Applying *Eq. (4)*, we obtain

$${}^{CP}D_t^{\mu_j} S(t)|_{t=t_l} \cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} S_m, \tag{15}$$

where the coefficients $a_{m,l}^{(\mu_j)}$ are obtained by

$$a_{m,l}^{(\mu_j)} = (\Delta t)^{-\mu_j} \begin{cases} 0 & \text{for } l = 0, \\ (l-1)^{1-\mu_j} E^{-\gamma}_{\rho,2-\mu_j}(\omega(l-1)^\rho(\Delta t)^\rho), & \\ -l^{1-\mu_j} E^{-\gamma}_{\rho,2-\mu_j}(\omega l^\rho(\Delta t)^\rho) & \text{for } l>0 \ \wedge m=0, \\ (l-m+1)^{1-\mu_j} E^{-\gamma}_{\rho,2-\mu_j}(\omega(l-m+1)^\rho(\Delta t)^\rho), & \\ -2(l-m)^{1-\mu_j} E^{-\gamma}_{\rho,2-\mu_j}(\omega(l-m)^\rho(\Delta t)^\rho), & \\ +(l-m-1)^{1-\mu_j} E^{-\gamma}_{\rho,2-\mu_j}(\omega(l-m-1)^\rho(\Delta t)^\rho) & \text{for } l>0 \ \wedge m=1,2,\cdots,l-1, \\ E^{-\gamma}_{\rho,2-\mu_j}(\omega(\Delta t)^\rho), & l>0 \ \wedge m=l. \end{cases} \tag{16}$$

Similarly, for functions I, D, A, R, T, H and E, we have

$$\begin{aligned} {}^{CP}D_t^{\mu_j} I(t)|_{t=t_l} &\cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} I_m, \\ {}^{CP}D_t^{\mu_j} D(t)|_{t=t_l} &\cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} D_m, \\ {}^{CP}D_t^{\mu_j} A(t)|_{t=t_l} &\cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} A_m, \\ {}^{CP}D_t^{\mu_j} R(t)|_{t=t_l} &\cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} R_m, \\ {}^{CP}D_t^{\mu_j} T(t)|_{t=t_l} &\cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} T_m, \\ {}^{CP}D_t^{\mu_j} H(t)|_{t=t_l} &\cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} H_m, \\ {}^{CP}D_t^{\mu_j} E(t)|_{t=t_l} &\cong \sum_{m=0}^{l} a_{m,l}^{(\mu_j)} E_m. \end{aligned} \tag{17}$$

Substituting *Eqs. (15)* and *(17)* into *Eq. (13)*, we get the following finite difference method to approximate of the solution of *Eq. (5)* as

$$
\begin{aligned}
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}S_m(t_l) = -S(t_l)\big(\alpha_1 I(t_l)+\alpha_2 D(t_l)+\alpha_3 A(t_l)+\alpha_4 R(t_l)\big),\\
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}I_m(t_l)\\
&\qquad = S(t_l)(\alpha_1 I(t_l)+\alpha_2 D(t_l)+\alpha_3 A(t_l)+\alpha_4 R(t_l)) - (\epsilon_1+\zeta_1+\lambda_1)I(t_l),\\
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}D_m(t_l) = \epsilon_1 I(t_l) - (\eta_1+\rho_1)D(t_l),\\
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}A_m(t_l) = \zeta_1 I(t_l) - (\theta_1+\mu_1+\kappa_1)A(t_l),\\
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}R_m(t_l) = \eta_1 D(t_l)+\theta_1 A(t_l) - (\nu_1+\xi_1)R(t_l),\\
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}T_m(t_l) = \mu_1 A(t_l)+\nu_1 R(t_l) - (\sigma_1+\tau_1)T(t_l),\\
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}H_m(t_l) = \lambda_1 I(t_l)+\rho_1 D(t_l)+\kappa_1 A(t_l)+\xi_1 R(t_l)+\sigma_1 T(t_l),\\
&h\sum_{j=1}^{N}\zeta(\mu_j)\sum_{m=0}^{l}a_{m,l}^{(\mu_j)}E_m(t_l) = \tau_1 T(t_l).
\end{aligned}
\tag{18}
$$

Then, the finite difference numerical method for solving *Eq. (5)* provided by *Eq. (18)*.

4 | Numerical Experiments

In this section, we present numerical experiments to study the performance and efficiency of the finite difference method which is introduced in Section 3 for the distributed order time fractional Coronavirus-19 disease (5). We use here all the computations done in Matlab (R2020b) software for the problems implemented in numerical experiments. For this end, we let that the general population is $N = 100$. Here, we show numerical experiments for various values of distributed order μ. The numerical experiments are reported in *Figs. (1)-(8)*. We observed that with this given method all types are increasing exponentially. The numerical results obtained in *Figs. (1)-(8)* illustrates the comparison between the numerical experiments demonstrated for the distributed order time fractional COVID-19 virus model with Caputo-Prabhakar derivative for different values of μ and the distributed order time fractional COVID-19 virus model with Caputo-Prabhakar derivative for for one value of $\mu = 1$, arbitrarily selected. The graphical numerical simulations present that the model depends especially to the fractional order μ and the chosen system parameters. The new described model with generalized Mittag Leffler function kernel authorizations give anomalous spread like that infection biological systems. This new given model authorizations a better explanation of the history of the biological process.

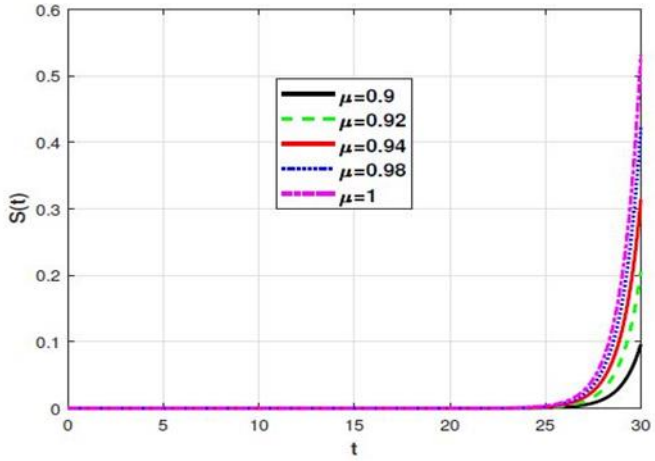

Fig. 1. Numerical experiments of susceptible class for various value of fractional order μ.

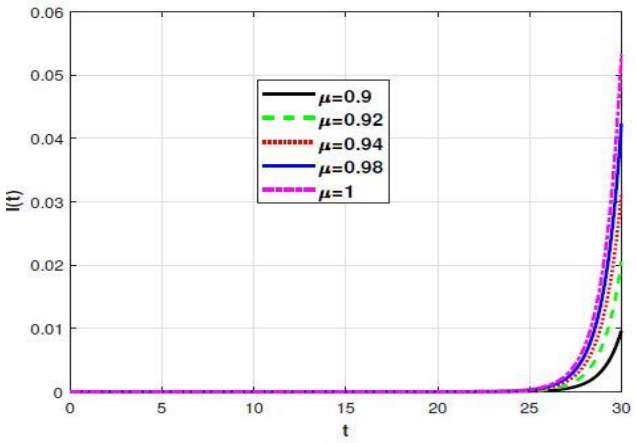

Fig. 2. Numerical experiments of infected asymptomatic infected undetected class for various value of fractional order μ.

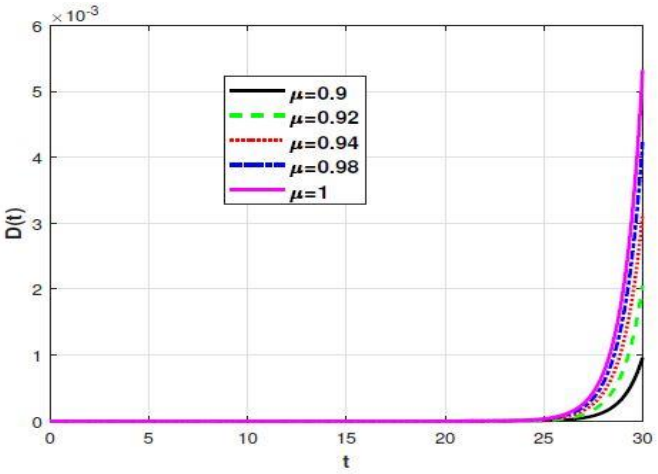

Fig. 3. Numerical experiments of asymptomatic infected class for various value of fractional order μ.

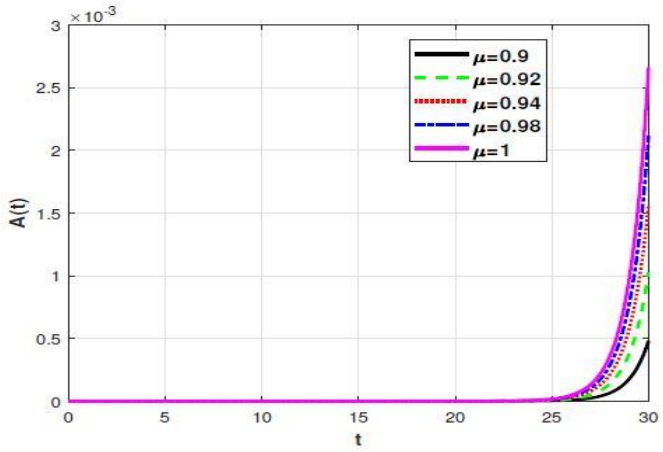

Fig. 4. Numerical experiments of healed class for various value of fractional order μ.

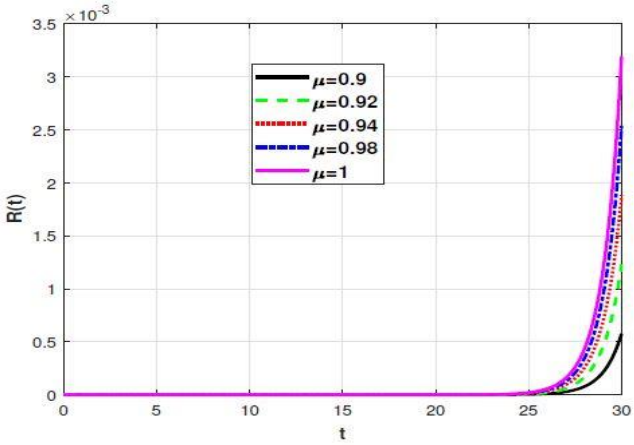

Fig. 5. Numerical experiments of ailing symptomatic infected class for various value of fractional order μ.

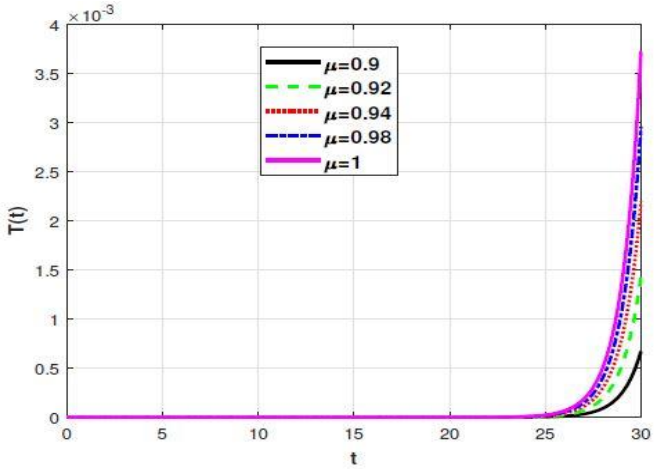

Fig. 6. Numerical experiments of recognized symptomatic infected class for various value of fractional order μ.

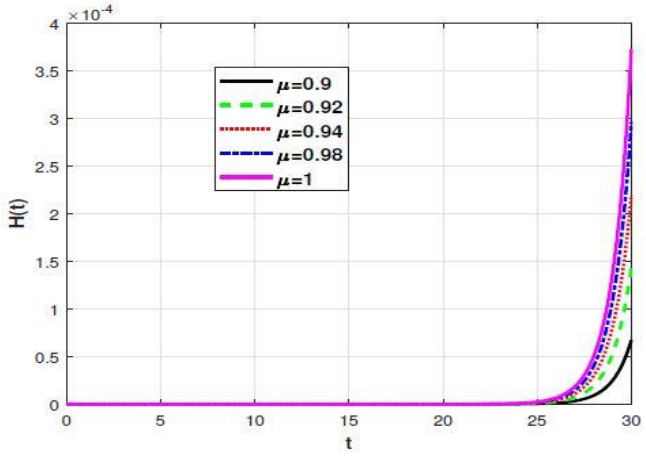

Fig. 7. Numerical experiments of acutely symptomatic infected detected class for various value of fractional order μ.

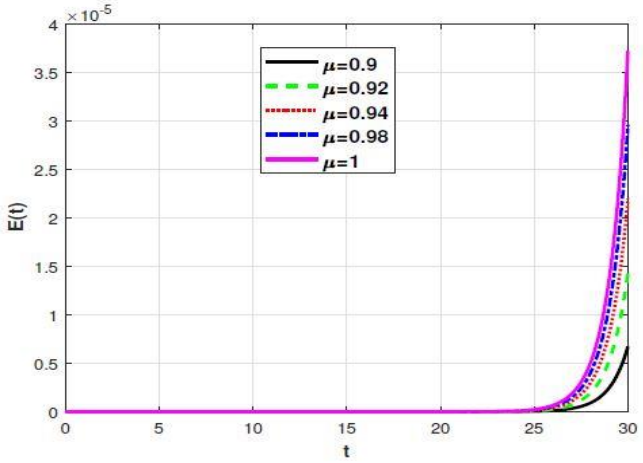

Fig. 8. Numerical experiments of death class for various value of fractional order μ.

5 | Conclusion

Because of recent expansion in the fractional calculus, scientists and authors are many interested in the comparative study of the integer order models with the fractional order models. In this paper, we shown a numerical approach based on the midpoint quadrature method and finite difference method to obtain the solution of distributed order time fractional Coronavirus-19 disease. The fractional order derivative is used in the Caputo-Prabhakar sense. We get numerical solutions in convergent series. The midpoint quadrature and finite difference techniques reduces the introduced systems to a equation of non-linear algebraic equations. The obtained equation is then solved by Newton-Raphson method. In all of the items, we obtained a remarkably well agreement. Finally, the dynamic behavior of the distributed order time fractional COVID-19 virus model was showed by allocating various values to the order of the fractional derivative as well as for various values of the other parameters involved. With the numerical experiments, we show a picture for COVID-19, which presents the rapid transmission of the virus to various sets of people. The high applicability of the discussed results in Section 4 demonstrate the high accuracy and practical applicability of the considered method.

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Conflicts of Interest

There is no conflict of interest in connection with this paper.

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Eco-Tourism Residences in Iran: a Multiple Case Study Research with a Creative Tourism Approach

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Abstract

This paper aims to introduce a business model for eco-tourism residences based on Osterwalder's canvas business model with a creative tourism approach. Despite of the significance of creative tourism and business model of eco-tourism residences, there is still a lack of sufficient attention to this issues in the literature. Moreover, regarding the growing tourism industry in Iran and the importance of creative tourism in cultural and adventure tourism, it is necessary to seek new ideas to improve service quality and the business owners' knowledge of their industry. In this regard, this multiple case study research is conducted by semi-structured interviews with seven eco-tourism residence owners in Iran. Open and axial coding methods were adopted for data analysis. This research identifies the main components of nine blocks of the Osterwalder's canvas business model for eco-tourism residences, including, value proposition, customer segments, customer relationships, channels, key resources, key activities, key partners, revenue streams and cost structure. The results of this study show that the supply factors of creative tourism framework including diversity of world cultures, the provision of unique culture, infrastructure, local crafts, hospitality, creative industries, cultural tourism resources, and more types of tourism are connected to the value propositions in the presented business model.

Keywords: Business model, Value proposition, Eco-tourism residence, Creative tourism, Multiple case study.

1 | Introduction

One of the most significant facilities and infrastructure in tourism industry is accommodation services. Hotels, guest houses, and eco-tourism residences play a pivotal role in providing hospitality services to tourists. Therefore, accommodation service providers should provide their services to satisfy tourists' expectations [1]. Moreover, according to Ferreira and Sousa [2], tourists tend to be involved in creative experiences and activities during their trips. Early tourism and hospitality was considering as creating value for guests and travelers with products and services as well as the joy and money earned were relatively simple in the last centuries: a shelter for the night, food and drink and enjoyment, visiting around and helping them find their way, or sharing local tales for entertainment, all in exchange for cash or barter goods. This simplistic view of tourism and hospitality might still hold some truth in isolated pockets of today's market, but this is not the reality of tourism businesses

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nowadays [3]. The combination of actors, activities, and transactions involved in creating value for people who travel and capture value from those activities has become much more complex [3]. This combination can be defined as a business model in tourism industry, which could be based on potentials of a place and customers' needs.

Iran is a country that is rich in cultural and historic diversity, representing a recorded human history that stretches back some 10,000 years [4]. Moreover, the people who inhabit this country have a long history of involvement in tourism with considerable evidence for hostels that dates back to at least 2000 BC [5]. Old houses in historical cities, with their unique indigenous architecture and monuments attracting a great number of tourists [6]. Old houses, mansions, palaces, caravanserais, baths, and cisterns are some of the well-known manifestations of traditional Iranian architecture, because of that the country of Iran makes up the geographic boundary of this study.

Eco-tourism residences as a major part of tourism industry, have an important role in terms of job creation and revenue [7] for locals and are one of the key attractions in destinations. The services that are provided by these residences, such as the cleanliness [8], staff, management, nearness to the tourists, play an important role in extending the tourists' stay in the destination [9]. This is stated that providing hospitality services for visitors cannot exist without some crucial elements in their basic structure. Some of these elements are including pampering the guests, calling guests by their first names to create an intimate atmosphere, expecting the guests' needs [10], working attentively to ensure the guests are comfortable, patience and tolerance in the case of potential differences with guests, encouraging the guests to participate in different activities and adventures [7], treating the guests as politely as they greeted them at the beginning [11]. Customer satisfaction cannot be measured unless the factors affecting it are determined [12].

Moreover, creative tourism is one of the most important indications of heritage hybridization in urban contexts [13]. Creative tourism is an approach that has been adopted and going through various stages of development in diverse locations around the world, the United State and Canada in North America, New Zealand in Oceania, Taiwan in Eastern Asia, and Spain and Austria in Europe being examples of countries which have successfully adopted the approach. It must be noted that not all the mentioned countries see creative tourism in the same way. However, there are a number of key hallmarks, such as development of creativity, and creative authentic experiences which are almost invariably found in the localized versions of creative tourism everywhere [14]. With the study of the civilizations, cultural heritage, customs and traditions, and indigenous businesses that found in Iran, business actors may identify some ways to engage tourists in to the unique experiences that can be provide by the various businesses that are available in the tourism destinations. These experiences are mainly "creativity-based" and related to everyday life, with traditional visual arts, local dishes, perfumes, painting, and folk dance [15].

The lack of an academic pathway to establish eco-tourism residence in Iran causes some issues for the tourism industry. Firstly, the number of eco-tourism residences which have become established in an inappropriate way is increasing rapidly. Secondly, historical houses which are changed to eco-tourism residences are endangered by unsuitable renovating. In this regard, in order to providing a solution to these problems this study contributing to represent a new business model for eco-tourism residences in Iran, which is connected to a creative tourism business model. Based on the purpose of this research, there are two main questions as follows:

I. What are the factors of nine dimensions of business model for eco-tourism residences in Iran?
II. How can value propositions of an eco-tourism residence be connected to creative tourism business model?

2 | Literature Review

The systematic literature review method has been largely adopted in the tourism and hospitality researches [16]. Thus, a literature review is done to assess the theoretical definitions of the key concepts, and to choose the most appropriate business model. The literature review in this paper includes some indicated theoretical definitions as follows.

2.1 | Business Model

Scholars agree that generally, a business model can be described as a logic based on creating and presenting value to customers to earn money. Thanks to the business model, businesses are able to employ new ideas, create new value, and meet customer needs better [17]. Moreover, the competitiveness of a business in the market is settled not by its products or services, but by a successful business model [11]. Several definitions exist for the concept of business model in the literature, some of the most comprehensive of which will be presented here.

A business model is a conceptual instrument for understanding how a company does its business. With this view, it is possible to use a business model for analyzing, comparing, evaluating, managing effectively, transferring, and informing about a business to others [18], [19]. A business model may be defined as the value that an organization creates and then offers to its various customer clusters, in addition to the hierarchical structure the organization develops along with its partners to create, promote, and make the value widely available in order to creating, or increasing, its revenue streams and succeeding in maintaining them consistently [20].

In an organization, the business model is a microcosm of the activities being carried out as part of the organization's main operation. The model is expected to explain how the organization creates the value (e.g., products, services, or even information) that it does through the various means it has at its disposal. Furthermore, the model should describe how the organization uses its customers and market share to achieve and maintain a competitive advantage over its rivals. Moreover, the business model can be extremely flexible and adaptable, as it needs to take into consideration, and effectively cope with the changes that organization goes through both internally and externally [21].

Several researchers recognize the factors which influence the success of the business model in the hospitality industry [11], [22], [23]. The research by Bowen [23] emphasized a market-driven approach to the business development and service improvement in the hospitality industry. According to this approach, getting feedback and information from customers and involving customers in the hospitality business development will lead the hospitality organizations to choose the right segments and create more value propositions for them. Kandampully [22] identified the essential factors for the hospitality business model to operate effectively: technology, external orientation, value, products, efficiency, relationship, empowered employees, uniqueness, networks, services and internal coordination. According to the Langvinienė & Daunoravičiūtė [11], there are six factors which influence the success in hospitality business models most: innovation, empowered employees, customer relationship management, technology, value propositions, and internal marketing.

2.2 | Creative Tourism

Creative tourism goes beyond the general tourist gaze [2], [24]. Although creative tourism is generally perceived as a form of cultural tourism, it is essentially different from the mainstream cultural tourism as will be elaborated further in the paper. While traditional cultural tourism is based on "viewing," "seeing," and "contemplating" (e.g., visiting museums, art galleries, concerts, ballet performances), creative tourism is based on "experiencing" [2], [25], "participating," and "learning" (e.g., not only observing icons or icon painting but taking courses in icon painting in the destination). This puts creative tourism as the next generation of cultural tourism that satisfies the higher level need of self-actualization with a primary focus

of active skill development. Furthermore, creative tourism is not so place-bound as cultural tourism in general is, because creative tourism utilizes tourist resources that are processes, such as dancing, singing, doing crafts, painting, participating in festivals [26]. It "offers visitors the opportunity to develop their creative potential through active participation in courses and learning experiences which are characteristic of the holiday destination where they are undertaken" [27].

The growing competition that exists between businesses in the tourism industry forces the suppliers to add more experimental elements to unify their products and services. However, those who win in the competition are those who are able to invest in what the tourists expect, because these are the unique experiences that are considered to be the value of a business. However, the development of more creative tourism experiences is often a part of the supplier's approach [28]. The two factors of supply and demand directly affect the business model in creative tourism. The demand side factors include cultural interaction, deep link with culture, cultural heritage conservation, creativity, interaction, cultural travel and innovation, and credibility. However, supply factors include everything that is available in a tourist destination, such as the diversity of world cultures, the provision of unique culture, infrastructure, local crafts, hospitality, creative industries, cultural tourism resources, and more types of tourism [29].

Regarding the demand and supply factors, a product or service that is produced in creative tourism can be divided into tangible and intangible categories. Tangible factors include capitalization, market development, innovation, protection of the heritage, stability, job creation, brand creation, and export. On the other hand, the intangible benefits include the creation of regional identity, social capital, the protection of cultural values, the preservation of cultural heritage, the cultural exchange, the cultural diversity of the region, the spiritual values, the national pride and the sense of touching it, which ultimately results in a creative tourism boom, the success of businesses, as well as the increase of social welfare in the destination of tourism [29].

2.3 | Different Approaches to Business Model

A business model generally addresses the company's core structures which include the value structure (how value is created), resource structure, and transaction structure. To explicate these components, researchers have adopted a variety of approaches. Design approaches are factor-based [30], resource-based approaches focus on the structure of the company and its key activities [31], [32], the storytelling approach focuses on describing key organizational outputs [33], the innovation approach puts the emphasis on open innovation with the purpose of transforming functions [34], the organizational turnover approach emphasizes intra-organization flow and transactions [35], [36], and the opportunity-based approach focuses on activities conducive to creating and exploiting opportunities in the organization [37]-[40]. In each of these approaches, in accordance with the researcher's field of choice, a certain definition of business model is presented whose components and the way these components combine to form a whole (i.e., business model) are different. Osterwalder focuses on factors internal to the enterprise [41].

Regarding the main purpose of the research that is to introduce a business model for eco-tourism residences to improve their service quality, the Osterwalder business model canvas was selected as the most suitable one. Osterwalder's business model is comprehensive, usable by businesses in diverse industries [42], and features adequate indexes to measure each of the model's dimensions.

2.4 | Towards the Conceptual Model

A desirable conceptual model is a model that includes the various dimensions of the subject under investigation and illustrates the relationships of the components to pave the way for the analyst [43]. If a company's executives intend to get past these obstacles and try a fresh type of business model, how should they start their endeavor? An excellent approach is to develop a flowchart of business models, identify the elements and activities that shape them, and then tweak these underlying elements and

activities and observe the differences they cause by doing this. A prime example of such an approach has been proposed by Alex Osterwalder, a recognized authority on the subject of business models [34]. Osterwalder business model canvas, consists of four general pillars and nine building blocks as listed below:

Customer segments are people or companies on which an organization set its sights to do business with them. Value propositions refer to a group of products and/or services which a company creates to meet the demand of its customer base. Channels are the means of communication a company establishes with its customer base and through which it introduces and markets its value propositions. Customer Relationships refer to the type of bond a company means to form with its customer base. Revenue Streams are simply the money a company makes through interaction with its customer base (clearly, to determine the net earnings we must deduct the costs of gross revenues). Key resources are the crucial resources a company needs to make its business model function. Key activities are the crucial tasks and projects a company carries out to make its business model function. Key partnerships consist of suppliers, retailers, and delivery services with whom the company forms partnerships to make its business model function. Finally, cost structure describes the total costs a company needs to cover to make its business model function. In this study, Osterwalder's business model is proposed as the model of choice to conduct the study. According to the literature, there is no study that makes a connection between a business model and creative tourism, therefore, this study contributes to connect the value proposition dimension in business model with the supply factors of creative tourism to improve service quality in eco-tourism residences.

3 | Methodology

In view of the main objective of this study, which is to introduce nine dimensions of an eco-tourism business model that can improve the service quality of eco-tourism residences with considering the creative tourism, the research methodology is qualitative with an applied approach. Applied research is a systematic research method which, at its most basic level, emphasizes the practical use of science. Applied research makes use of theories, sciences, methods and techniques introduced by research institutes to achieve practical purposes such as business success. Moreover, it deals with solving practical problems using mostly empirical methods [44].

3.1 | Multiple Case Study

To achieve the main purpose of the study, the authors needed to analyze more than one case study to identify different aspects of an eco-tourism residences. Therefore, the method of multiple case study was used. According to the Gray [45] surveys focusing on collecting data on a limited range of topics. On the other hand, case studies can explore many themes and subjects, but from a much more focused range of people, organizations, or contexts. Case studies can prove invaluable in adding to understanding, extending experience, and increasing conviction about a subject [46]. For multiple case study research, the cases need to be similar in some aspect or share some common characteristic or condition but each case gets organized and analyzed around the specific research question it is expected to answer. In a multiple case study, the researcher examines different activities in cases. Besides, multiple cases have significant advantages compare with single case study research, they offer the prospect of producing results that are less likely to be deemed individualistic or unscientific. The evidence from multiple cases is often considered more convincing, and the results tend to be more robust [47].

3.2 | Participants

The statistical population of this research is the eco-tourism residences in Iran that already established their business and are well-experienced in the tourism industry. According to Strauss and Corbin [48], "Sampling should be open to those persons, places, situations that will provide the greatest opportunity to gather most relevant data about the phenomenon under investigation." Therefore, to select the most appropriate case studies, some critical conditions would be considered: 1) the eco-tourism should be in Iran, 2) the location of the cases is preferred to be in historical cities that attract more tourists and 3) the interviewee

should have a great knowledge of the procedures of the business and customer experiences, therefore we chose the business-owners to interview. The purpose of the interviews was explained to the interviewees and the right to use and publish the information of their businesses is allowed.

According to these conditions, the participants of this research is composed of the owners of eco-tourism residences in seven different cities in Iran; Isfahan, Yazd, Kashan, Iva, Khor and Biabanak, Shiraz, and Choupanan, each interviewee had a code number I1, I2 to I7. We use the snowball method to recruit business owners [49]. Sampling was completed when the theoretical saturation was reached, that is, when the most recent piece of information obtained is the same as the one already obtained from the previous interviews. In this case, the researcher continues the interview process until theoretical saturation is achieved in such a way that, the closer he gets to the final interviews, the less new data are generated regarding the research subject [43].

3.3 | Data Collection

Initially, the information needed for this study was gathered through library research and surveying the applied literature in the field [50]. Further information was obtained by conducting specialized and semi-structured interviews with field experts in tourism and hospitality fields [51]. In this study, the interview questions were first extracted from Osterwalder's Value Proposition Design Book [52]. The interview questions are divided into 9 categories according to 9 dimensions of the business model. Each category contains special questions about the related dimension of the business model. For instance, the questions of the first category are related to the first dimension of the business model.

3.4 | Validity and Reliability

In an attempt to evaluate their validity, were submitted to field experts so that the latter should make the modifications they deem necessary to make sure the questions comply with the research subject [52]. Additionally, the interviewees were asked beforehand to express their opinion on each question they are asked during the interview and also ask questions themselves if they need further clarification as to the questions in order for the answer to be precise and consistent with the research objectives. Data research was also performed in a systematic manner, while the rationale and theoretical foundation behind the identified categories and the process in which they were extracted have all been recorded. The final pattern, therefore, was obtained solely from the collected data. A significant point as to the validity of the model proposed in this study is the multiple revisions and analyses performed on the data.

It was ensured that a suitable data collection method i.e. deep semi-structured interviews as well as a sufficient statistical sample would be used to reach the point of theoretical saturation. Furthermore, to ensure the reliability of the data, following each of the answers given by the interviewees and again at the end of each interview, the interviewer stated her understanding of the answers so that the interviewees would have the chance to clarify potential confusions or misunderstandings to make certain that their answers were all recorded and interpreted correctly [52]. Finally, according to the interview questions every question was asked to identified the structure of a specific block in the business model and, Theoretical coding was continued up to achieving the final model, to identify each dimension of the business model.

4 | Findings and Discussion

The owner-managers of seven businesses i.e., traditional residences were interviewed to collect the corresponding data of each business regarding the aforementioned nine building blocks of the business model. The businesses were located in different historical cities of Iran; the interviewees were labeled with (I1:I7) to further analysis.

4.1 | Data Analysis

The open and axial coding techniques were used to conduct data analysis [53]. This stage in the qualitative analysis of the research data is carried out immediately after the first interview. In other words, following each interview, the researcher attempts to find concepts and then determines appropriate labels for them and, finally, combines the concepts associated with each interview. Open coding is a part of the qualitative analysis where the data and phenomena are individually named and categorized after meticulous examination and then compared to find the possible similarities and differences between them [54]. Finally, relevant questions are asked about the categories of data. The first step in open coding labeling (naming) the phenomena; in this process, each paragraph is split into certain parts and each event or idea is given a name. It is very easy for researchers to merely repeat the main points and sentences, yet what happens here is not brainstorming, but summarization. The next step in open coding is the discovery of categories. When particular phenomena are identified in the data, the concepts are grouped based on the phenomena. This reduces the number of units that need to be worked with it.

The process of classifying the concepts is such that similar phenomena are placed in the same category. The category that contains relevant codes (labels) is given a conceptual name. It is important that this name be more abstract than the names given to the concepts (codes) the sum of which constitutes the categories. The categories have conceptual power because they are able to collect other concepts around themselves. The technical features of the tool are summarized by two qualities: validity and reliability. A sample of data coding is given in the *Table 4*.

Table 4. Data code sampling.

Dimension	Axial-Code	Open-Code	Verbal Proposition	Case
Revenue Stream	Sale of lodging services	Residential services sales	Providing welfare services is the first way to earn from a residence	11 12 13 14 15 16 17
	Providingadvertising spaces	Providing space for various events	With providing space for advertising	11
	Hosting events café and restaurant	Providing restaurant and cfe services	Providing a hoe-based café and restaurant is another wa of earning money in low seasons	11 12 13 14 15 16

4.1.1 | Final conceptual model

Value proposition

After reviewing the value proposition questions in the interviews, open coding was conducted on the verbal statements [54]. According to the interviewees, travelers expect to see the following in the eco-tourism residences: First of all, cordial and hospitable staff "a residence becomes special with its good treatment of guests, not its state-of-the-art facilities." Moreover, the interviewees addressed that calm environment, guaranteed security, interaction with local people and experiencing their way of life are important factors in the eco-tourism residences. Besides they mentioned that hygiene and discipline play a pivotal role in a residence "the residence should be clean and tidy both on the inside and outside." Another important point is participating in or observing local events "the most attractive type of entertainment a residence can provide for its guests is either hosting region-specific events inside the establishment or taking the guests where such events are held". Finally, possibility to buy local arts and handicrafts and to try local cuisine

were important for the interviewees "this helps create job opportunities for the locals and introduces the guests to the region's culture in the best possible way."

Any free-of-charge services, no matter how trivial, from a free drink to free Wi-Fi, is often quite pleasing and exciting to the guests. The high quality of services is subject to continuous training of the staff so that customers are kept completely satisfied from the moment of arrival until check-out. Residences hosting foreign guests could have customized arrangements according to the guests' nationalities and cultures, an example of which being the placement of the flags of the travelers' countries of origin in the courtyard. Eventually, the following twenty-four open codes were extracted from the interviews: peripheral recreational activities, use of earthenware, seasonal dishes, free tea, free Wi-Fi, bedroom cleanliness, outdoor space cleanliness, high service quality, recreational facilities, cooling and heating systems, interaction with the locals, food quality, valuing different nationalities, creating a sense of security in guests, relaxed atmosphere in the establishment, experiencing local way of life, staff cordiality to guests, employment of locals, simplicity and authenticity, watching the night sky, feeling of traveling through history, Korsi[1], lodging, and daily nature trips. Next, the resulting open codes were divided into the following eight axial codes: local events, supplying handicraft, supplying local cuisine that can also refer to where the food is produced and varies if the raw materials can be produced in the area or are growing naturally in the region compared to plants or animals not naturally found in the area, but are instead imported into the region. Free-of-charge services, compliance with sanitation standards, service quality, honoring the guests' cultures and nationalities, and creating unique experiences.

Customers

From the point of view of business owners, "nature adventurers are the regular customers of eco-tourism residences" and "most of the peak season guests are foreign tourists;" while Iranian travelers, non-staying visitors, foreign travel agency managers, researchers and historians, tour operators looking for new destinations, and music bands are some of the other recognizable customers of eco-tourism residences who were identified and extracted as open codes from the interviews. Finally, foreign guests, domestic guests – including staying travelers, non-staying visitors, and adventurers – foreign travel agency managers seeking to find potential clients or to sign contracts, researchers and historians traveling to historic villages, tour operators and music bands are considered as axial codes.

Customer relationships

To establish a close rapport with the visiting tourists, business owners apply the following eleven solutions: "letting the guests participate in simple chores like setting the table and preparing food," text messages, needs assessment (corresponding with upcoming visitors to find out what they need), starting campaigns and photography competitions on Instagram using relevant hashtags, promoting the business by taking part in exhibitions and on Twitter, TripAdvisor, Telegram channels, websites, promotional emails, and electronic catalogs and brochures, which are included in the customer relations section of the study's open codes. After thoroughly examining the open codes, the following seven axial-codes were obtained: visitor participation in events, text messages, telephone calls, social networking events, surveys, "contacting customers to conduct needs assessment is a crucial element in establishing an effective rapport with them," exhibitions, catalogs ("publishing electronic catalogs and brochures helps us keep communication with our customers on a monthly basis").

Channels

Communication, distribution, and sales channels comprise a company's interface with customers. Channels are customer touch points that play an important role in the customer experience. In the

[1] A type of low-table with a brazier or electrical heater underneath and blankets on top

business model of eco-tourism residences, sales are handled directly or through partners. The organizations' exclusive channels may be directly handled, such as the domestic sales manager or the website manager. In general, if the services are sold in person, online or by phone, they are considered direct sales. On the other hand, the sales handled by retail stores owned or managed by the organization are considered indirect. Other ways of sales are through travel agencies, sales websites or tour operators; "travelers can book their residence and pay for it through TripAdvisor. They can also use the website to learn more about their destination." This distribution channel is considered as sale through partners.

Key resources

According to the interviewees' responses to questions on key resources, over 70% of the interviewed owner-managers self-financed the initial capital required to start their traditional residence business, most of them purchased the property outright and believe that, if possible, renting must be avoided at all costs. Some of the interviewees stated that they had bought their historical house with the help of facilities provided by banks and the cultural heritage, handicrafts and tourism organization of Iran and then set up their business. Specialized staff in the reception, housekeeping and purchasing departments and the kitchen are some of the important human resources of a traditional residence. The reputation of a residence is also part of the spiritual capital of the business "over time, customer satisfaction has risen to the value propositions of our resident at the national level and gradually increased internationally", while restoration and maintenance experts could be considered valuable corporate resources. The open codes of this section include: specialized staff in the reception, housekeeping, purchasing, and kitchen, reputation of the residence, and restoration experts. Axial codes include: physical resources, financial resources, human resources, brand (Ibid) and corporate resources.

Key activities

All the activities a firm carries out to create customer value is in this building block of the business model. The key activities business owners engage in at the start and during actual operation include: registration of the historical house as a national heritage, acquiring permission to alter the land usage of the historical house, acquiring work permission from the municipality, refurbishment and restoration of the structure, continuous training of the staff, "pre-employment and post-employment training programs for the staff to instruct them on how to best interact with the guests so as to achieve the targeted value proposition," and regularly updating the website.

The above activities were grouped into the following six axial codes: national registration (strategic), altering land usage, acquiring permissions (strategic), restoration, training, and updates.

Key partnerships

A partnership is a voluntary cooperative agreement between two or more companies to initiate joint ventures based on previously negotiated terms and conditions. The key partnerships building block of the business model, which also compose the axial codes obtained by analysis on the data, include private partners, business partners, raw material suppliers, and service providers. Over 85% of the interviewees had started their businesses without a private partner. Their business partners included travel agencies, TripAdvisor ("when a customer books their trip through TripAdvisor, the website automatically deducts a percentage as commission fee"), tour operators ("freelance tour operators who have a contract with us and bring their tourist groups to our residence") music bands, raw material suppliers, in addition to restoration and maintenance companies.

Revenue streams

The income model measures the company's ability to convert value proposition presented to customers into money and income streams. The company's income model can consist of different revenue streams,

each of which having a different pricing mechanism. The income of traditional residences is generated through selling lodging services ("providing welfare services is the primary way of a traditional residence to make money"), renting advertising spaces, "the café and restaurant of the residence help us stay afloat in low seasons," while some residences generate additional income by hosting various events.

Cost structure

In the proposed business model, the costs are divided into two categories: administrative, marketing and sales costs, and value proposition costs. Administrative, marketing, and sales costs in this model include those associated with the human resources ("the most expensive cost is the cost of human resource. Education and salaries and wages include Human resource costs."), advertising and marketing, the annual TripAdvisor subscription fee, as well as utilities and maintenance. The second category, value proposition costs, includes the purchase of raw materials, consumer goods, and services.

The purpose of this study was to design a business model for Iranian Eco-Tourism residences to improve the quality of services with a creative tourism approach. The first step in this research, was to select an appropriate research model using a qualitative method following an extensive survey of the literature on the subject. In this process, the research method of choice consisted of deep semi-structured interviews along with field research. The case studies for the field research were successful traditional and eco-tourism residences in the provinces of Yazd, Isfahan, and Fars. The number of interviewees was initially unclear and the situation remained unchanged until theoretical saturation was reached. Despite reaching theoretical saturation with the sixth interview, it was decided to conduct one further interview and end up with a sample of seven businesses. Finally, after analyzing the data and concepts extracted from the interviews, the desired business model components were identified.

4.2 | Discussion

Considering the main purpose of this study which is to provide a business model for eco-tourism residences, that is connected to creative tourism, nine blocks of Osterwalder's canvas business model are identified. As the first block of Osterwalder's canvas the customer segment includes foreign customers such as international tourists, domestic customers such as national visitors [55], music bands, researchers and historians, tour operators [56], and foreign travel agency managers. The second block, customer relationships are formed and maintained through catalogs [60], text messages, telephone calls, social networking events, surveys, exhibitions and engaging the tourists in the organized events. The third block channels contains hospitality services that are sold directly by the owner-manager of the residence and indirectly through hotel booking websites [56] or by partners. To create the value propositions block, eight values were found: organizing traditional events, supplying local handicrafts [29], and cuisine [57], providing free-of-charge services, compliance with sanitation standards, high service quality [11], also, Ali et al. [58] stated that the customer satisfaction is directly related to the service quality in hotels. The last identified value proposition is honoring the guests' nationalities and cultures that Lam et al. [59] notes that considering cultural diversities of the guests is one of the vital issues for customer satisfaction in the hospitality industry. Key activities include national registration as a first step for stablishing the eco-tourism residence, altering land usage as administrative works for registration of the business, acquiring permissions, restoration [60], and regular training of the staff [61], and updates.[3], [62]. Key resources of the business model include the historical house, human resources [3], financial resources, corporate resources, and brand, as Ardakani et al. [63] state the brand of the hotels as a corporate resource which is directly connected to the human resource of the hotels. The key partners of the business model can be categorized in three groups: business partners to expand the business, private partners in the starting stage of the business, and suppliers to supply the needed materials. The revenue streams of eco-tourism residences are generated by selling lodging services [29], advertising areas, and providing food and beverages in restaurant and coffee shops of the eco-tourism residence. Two separate cost structures were identified, including administrative, marketing and sales costs, and value proposition costs [60]. *Fig. 4* demonstrates the business model for a traditional eco-

tourism residence. Since this study employs a creative tourism approach, the supply factors are compared with the value propositions. Regarding "cultural events" "local cuisine" and "creating unique experiences" as value propositions can be connected to the diversity of world cultures, cultural tourism resources and unique local culture in supply factors of creative tourism [64]. Moreover, "supplying handicrafts" is directly related to the creative industries, local arts, local tourism [18], [64], [65]. As "honoring the guests' nationalities and cultures" refers to different cultures and nationality of tourists, this value proposition can be connected to global culture. One of the important supply factors of creative tourism is hospitality that can be connected in to "Free services" "high service quality" and "Sanitation standards" as the value propositions of an eco-tourism residences.

Key Partners	*Key Activities*	*Value Proposition*	*Customer Relationships*	*Customer Segments*
• Business partners (travel agencies, TripAdvisor, refurbishment and restoration companies) • Private partners (investors) • Tour operators • Raw material suppliers • Service suppliers	• National registration (strategic) • Altering land use (Strategic) • Acquiring permissions (strategic) • Restoration • Training • Updates	• Events • Supplying Handicrafts • Honoring the guests' nationalities and cultures • Free services • Sanitation standards • High service quality • Local cuisine • Creating unique experiences	• Catalogs • Text messaging • Telephone calls • Social Networks • Surveys • Exhibitions • Guest participation	• Foreign travelers • Domestic travelers • Researchers and historians • Music Bands • Tour Operators • Foreign travel Agency managers
	Key Resources • Physical resources • Financial resources • Human resources • corporate resources • Brand		*Channels* • Direct sales • Indirect sales • Sales through partners	
Cost Structure • Administrative, marketing and sales costs • Value proposition costs			*Revenue Streams* • Sale of lodging services • Providing advertising spaces • Hosting events • Café and restaurant	

Fig. 4. Business model for Eco-tourism residences.

5 | Conclusion

According to the written literature there is a lack of attention to the business model for eco-tourism residence and creative tourism. Additionally, a business model for eco-tourism as a road map for business owners may help them to improve their service quality. Considering these issues this paper firstly tried to provide a business model for eco-tourism residences (e.g., *Fig. 4*). Secondly to consider creative tourism approach, the supply factors of creative tourism business model were connected to the value propositions of the eco-tourism business model. The present paper introduced a business model for Eco-Tourism residences based on Osterwalder canvas business model with a creative tourism approach. A qualitative approach with a multiple case study design was adopted to answer the research questions of this study. Seven semi-structured interviews with eco-tourism business owners of different historical cities in Iran were conducted. After adopting open and axial coding, the data analysis indicates the main components of nine blocks of the Osterwalder's canvas business model. These main components are value proposition, customers, customer relationships, channels, key resources, key activities, key partners, revenue streams and cost structure. Finally, the results show that each item of introduced value propositions of this business model can be related to supply factors of creative tourism framework. The supply factors of the creative tourism framework include diversity of world cultures, the provision of unique culture, infrastructure, local crafts, hospitality, creative industries, cultural tourism resources, and more types of tourism are connected to the value propositions in the presented business model.

6 | Implication and Future Research

Through the answers to the research questions, this article contributes to the literature of business model, eco-tourism residences, hospitality and creative tourism. This paper, tried to fill the existed gap of the connection between business model studies, eco-tourism residences and creative tourism. Moreover, the authors believe that the introduced business model for eco-tourism residences in Iran would maintain these historical houses, increase job creation in small towns, and it can be considered as a road map for the actors in the hospitality industry. It can also be implemented to existing eco-tourism residences in order to adopting creative tourism and increasing guests' satisfaction. Ultimately, this new business model would suggest value propositions which could be effective in improving the service quality of eco-tourism residences. In addition, what makes this study novel is that it is conducted on Iranian eco-tourisms context with a creative tourism approach as there is no similar study so far.

The literature on tourism business models still has the potential to expand and grow. Researchers are expected to anticipate the components of tourism business models and pioneer the implementation of academic solutions [66]. Considering the importance of incoming tourism in Iran, conducting comprehensive research works to evaluate the application of creative tourism approach in attracting foreign tourists seems essential. Since every region across Iran possesses its own unique culture, architecture, art, etc. owing diverse climatic and demographic characteristics, it is suggested that business owners pay sufficient attention to these features and take them into consideration when designing a business model for their eco-tourism residences. Since there is a great potential to launch various businesses in historical houses, it is suggested that different business models can be designed and implemented in future research works. To this end, cooperation of researchers in art, architecture, and entrepreneurship fields together could be an optimal start to help use the many valuable historical houses in Iran in the best possible way.

6.1 | Limitations

Limitations of this study include the lack of cooperation of some business owners, their lack of familiarity with the business model, the rarity of internal research related to the subject, and the lack of evaluation of the profitability of the designed business model.

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Automated Sleep Stage Detection Based on Recurrence Quantification Analysis Using Machine Learning

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Abstract

In recent years, the use of intelligent methods for automatic detection of sleep stages in medical applications to increase diagnostic accuracy and reduce the workload of physicians in analyzing sleep data by visual inspection is one of the important issues. The most important step for the automatic classification of sleep stages is the extraction of useful features. In this paper, an EEG-based algorithm for automatic detection of sleep stages is presented using features extracted from the recurrence plot and artificial neural network. Due to the non-stationary of the EEG signal, the recurrence plot was used in this paper for nonlinear analysis and extraction of signal features. Various extracted features have different numerical ranges. Normalization was performed to prevent the undesirable effects of large values of data. As all normalized features could not correctly classify different stages of sleep, effective features were selected. The results of this paper show the selected features and the Multi-Layer Perceptron (MLP) neural network able to achieve the values of 98.54 ± 1.88%, 99.03 ± 1.43%, and 98.32 ± 2.11%, respectively, for specificity, sensitivity, and accuracy between the two types of sleep, i.e., Non-Rapid Eye Movement (Non-REM) and Rapid Eye Movement (REM). Also, the results show that the selection of Pz-Oz channel compared to Fpz-Cz channel leads us to a higher percentage for the separation of stages I-IV, awake, while the separation of REM stage using Fpz-Cz channel is better. The results show that the proposed method has a higher success rate in classifying sleep stages than previous studies. The proposed method could well identify and distinguish all stages of sleep at an acceptable level. In addition to saving time, automatic analysis of sleep stages can help better and more accurate diagnosis and reduce physicians' workload in analyzing sleep data through visual inspection.

Keywords: Sleep stages, EEG signal, Recurrence plot, Nonlinear features, Artificial neural networks.

1 | Introduction

Sleep is the brain's primary function and plays a fundamental role in individual performance, learning ability, and physical movement [1], [2]. One of the essential physiological processes of humans is sleep vital for physical and cognitive well-being and resurgence [3]. Sleep is a reversible state in which the eyes are closed, and several nerve centers are disabled [4]. Sleep creates partial or unique or full anesthesia for the individual, in which case the brain becomes a less complicated network [5], [6]. Today, PSG is done to identify various disorders based on the analysis of sleep stages, the main component of which is the measurement of brain activity with EEG signals [7]. *Fig. 1* shows the sleep cycle, which is divided into two parts of Rapid Eye Movement (REM) and NREM.

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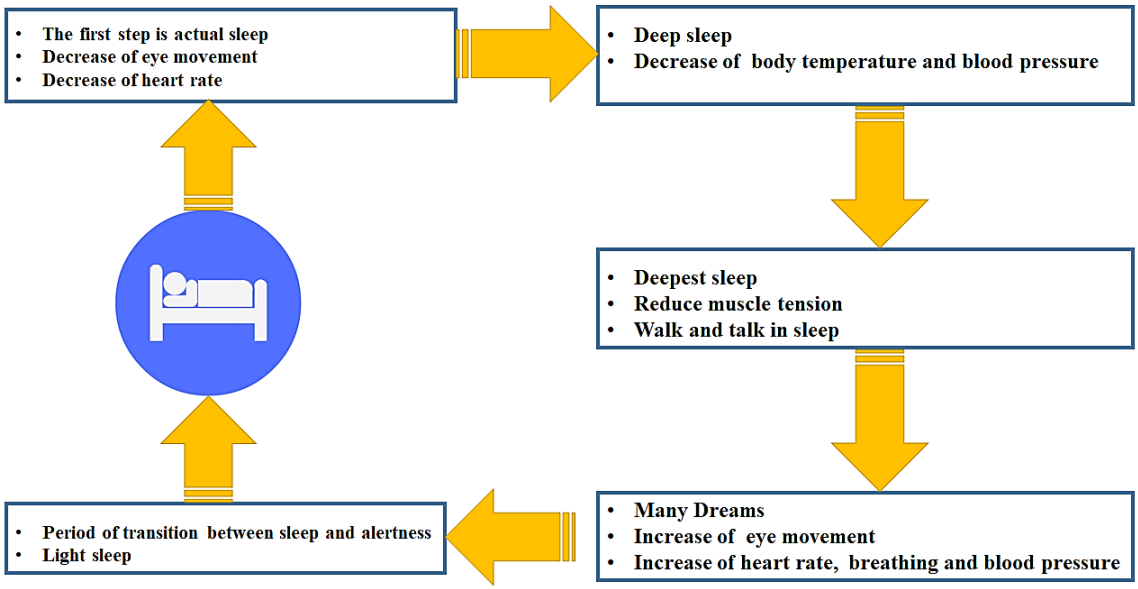

Fig. 1. Different stages of the sleep cycle.

Sleep disorders include several disorders associated with various symptoms such as insomnia, respiratory disorders, behavioral and motor-related sleep disorders that significantly affect EEG signals [8]. By classifying the different stages of sleep, the correct diagnosis of sleep-related disorders can be achieved. After recording the EEG signal, feature extraction, and analysis of the signal recorded in a specified range, a classification algorithm to identify the sleep stage is used [9], [10]. However, improving the classification accuracy and reducing complexity are two main challenges in the classification of sleep stages [11]. In the following, some of these methods are described.

Rechtschaffan & kales suggested a visual sleep scoring method for classifying sleep stages used for about 40 years [12]. According to the rules provided by R & K, human sleep consists of the WAKE, REM, and the four stages of the NREM (stages 1 to 4, which contain a light sleep to deep sleep). In a study carried out by Doroshenkov et al. [13], temporal features and Hidden Markov Model (HMM) were used in such a way that they measured signals with two channels of the EEG signal (Fpz-Cz and Pz-Oz). In 2012, Koley and Dey [14] used 39 features to differentiate sleep stages, including time-domain, frequency-domain, and nonlinear parametric analyses. A certain combination of the subset of optimal features from the single-channel EEG signal was selected to help the binary Support Vector Machine (SVM) classifier. A study on different models of classifying sleep stages was conducted by Şen et al. [15] in 2014. The data used in this method was recorded by a dataset provided by the Vincent University Hospital and the Dublin University College. Many extraction features were addressed, the selected features of which included time-domain, frequency-domain, time-frequency-domain. These features were applied as inputs to five classification algorithms, called a Random Forest (RF), a feed-forward neural network, an SVM, a radial basis function neural network, and a decision tree. According to other study, the two-stage classification was developed by Phan et al. [16] in 2013 with a single-channel EEG signal (Fpz-Cz). This method is called the KNN (k-nearest neighbors), which classifies the sleep stages to wake, Stage 1 + REM, Stage 2, and Slow Wave Sleep (SWS).

Deep Belief Network (DBN) is an algorithm that was welcomed in machine calculations because of its high accuracy. DBN works unsupervised where there is no calculation of output adjustment targets and is suitable for learning nonlinear features. Bi-LSTM is a combination of Long Short-Term Memory (LSTM) and Bi-Directional Recurrent Networks (Bi- RNN) [17].

In 2017, the proposed project of Tunable-Q factor Wavelet Transformed (TQWT) was raised by Hassan and Subasi [18] for the automatic classification of sleep stages. In this work, eight individuals of both genders, men and women with an age range between 21 and 35, were studied. The EEG signal with

Fpz-Cz and Pz-Oz channels has been used in this research to differentiate sleep stages. The method used in this work is different from EMD and Fourier transform [18]. TQWT is an advanced signal decomposition technique. It is ideal and flexible for processing oscillatory signals. The Q factor for the processing of signals with high oscillation should be low and, on the other hand, should be high for the processing of signals with low oscillation. TQWT eliminates this problem by setting the parameter Q for the analysis of signals and classification of EEG.

In recent years, research has been conducted to identify the stages of sleep with the help of brain and heart signals, some of the most important of which are listed below. Nico Surantha et al. [19] presented an accurate model for classifying sleep stages based on Heart Rate Variability (HRV) features extracted from an Electrocardiogram (ECG). The maximum classification accuracy obtained by the SVM method was 82.1%. Rahimi et al. [20] presented a sleep stage classification using HRV, and ECG-Derived Respiration (EDR) features with the SVM classification. The obtained results showed that this method's accuracy was 81.76% for two sleep stages and 76% for three sleep stages. In another paper, an automatic sleep stage classification was introduced based on a Polysomnographic (PSG) recording. The EEG, ECG, EMG (electromyographic), and respiratory signals were used as input. To sleep stage detection, the RF classifier was proposed. The maximum classification performance using RF classifier based on the combination of the EEG and respiratory signals achieved an accuracy of 93% [21]. Sharma et al. [22] proposed an automated sleep stage classification based on the unipolar (C4-A1) and bipolar (F4-C4) EEG. In this study, 1-D Wavelet Decomposition (WD) was used for feature extraction from each 30s epoch of EEG signal. The maximum accuracy obtained of this method was 85.1% with Cohen's Kappa coefficient of 0.8214 for balanced data based on the Ensemble of Bagged Tree (EBT) classifier with a 10-fold cross-validation strategy.

According to recent studies, most of the methods presented in the papers have not yet identified the types of sleep stages. In addition, most of the methods have the complexity of calculations, low execution speed, relatively acceptable results. But the method proposed in this article and the fast and automatic diagnosis of different stages of sleep can produce better results in terms of accuracy, sensitivity, and specificity in diagnosing sleep stages compared to similar studies.

The organization of this paper is as follows: Section 2 presented the data that we have used and the method proposed in this paper. Section 3 illustrated the neural network structure proposed in this paper. Section 4 has shown the results using the presented method, and Section 5 compares the results of studies conducted in this field so far. Finally, limitations and suggestions have been expressed in the conclusion part, presented in Section 6.

2 | Materials and Methods

A new method of nonlinear processing is based on a Recurrence Plot (RP). An important advantage of this approach is that it can also be used for non-stationary signals. Given the past efforts on the use of this method to diagnose brain-related diseases, it can be suggested that RPs and Recurrence Quantification Analysis (RQA), as a nonlinear method for analyzing the EEG signal of individuals in different sleep modes, can also be applied. In addition to the visualization of the transition situations in the signal due to the placement of people in different sleep positions, RQA sizes can also be used to quantify changes in the structure of brain dynamics. So, we introduce the nonlinear parameters obtained using a RP in this section. We will be looking for features that can effectively detect and differentiate the different stages of sleep.

Nonlinear methods in processing vital signals have been considered due to the nonlinear nature of the biological systems that produce these signals. Among these methods is the RP that provides a graphical and qualitative representation of the dynamics in the signal. After extracting the feature, because the features are of different types and have different sizes, the normalization method is used. Then the features were applied to the classifier, and by changing the classification structure and applying other training methods, the classifier's performance was evaluated. It should be noted that in each performance, the data for training and testing were selected by the cross-validation technique. *Fig.* 2 shows the different steps of the algorithm proposed in this paper to detect sleep stages automatically.

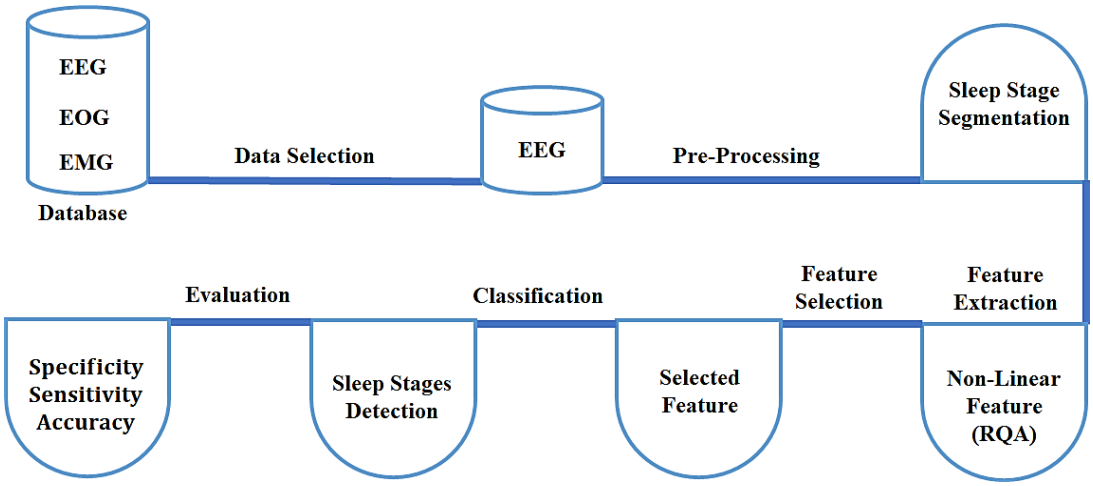

Fig. 2. Sleep stage classification system block diagram.

2.1 | Recurrence Quantification Analysis (RQA)

Two major small-scale structures can be seen in the RPs. The first is the structure of diagonal line with length L indicating that the two trajectory units have been in the neighborhood ε of each other for L the period, and the second is the structure of vertical line with length v indicating that the trajectory has not changed much for the v period.

2.2 | Complexity Sizes

To go beyond the visual expression resulting from the RPs, several sizes have been proposed for the complexity that quantifies the low-scale structures in RP and are known as RQA. These sizes are based on the density of recurrence points and the diagonal and vertical line structures in the RP.

2.3 | Recurrence Plot

Recurrence is an essential feature for many complex dynamic systems [23], and the human heart and brain are known as a dynamic systems with high complexity. Henry Poincaré first introduced the main concept of recurrences in 1890 [24], [25]; nevertheless, the issues raised by Poincaré has long remained dormant due to the lack of appropriate processing tools. Eventually, Eckmann et al. [26] in 1987 presented the RP method to visualize the recurrence of dynamic systems visually.

If we assume that the trajectory $\{\vec{x}_i\} \quad i = 1. \ldots . N$ exists for a system in phase space; the corresponding RP of this trajectory can be drawn using the recurrence matrix *R* with *Eq. (1)* in this case.

$$R_{i,j} = \Theta(\varepsilon - \| \varepsilon_i - x_j \|), i, j = 1,2,...N. \quad (1)$$

In the above relation, ε neighborhood radius, Θ Heaviside function, and N is the number of points measured $\vec{x}_i$. In the above relation, if the vectors of phase space *i* and *j* are close enough to each other,

then the value of $R_{i,j}$ is one and otherwise it will be zero. Because systems typically do not return exactly to the state they were previously in, considering this neighborhood is, therefore, essential [24], [25], [27]. In the defined matrix, if the system status at times *i* and *j* is similar (neighbors), the corresponding array of these two in the matrix is equal to one. Otherwise, the array is considered equal to zero. If only time series $x(i)$ is available, then the Taken's time delay theory can be used to reconstruct the phase space [28]. Accordingly, the trajectory$\vec{x}_i$ is reconstructed from the time series $x(i)$ and by *Eq. (2)*:

$$\vec{x}_i = [x(i), x(i+\tau), \ldots x(i+(m-1)\tau)]. \quad (2)$$

In which m is the reconstruction dimension of τ time delay. A common method for determining the reconstruction dimension is the False Nearest Neighbor (FNN) method and for the delay is the Mutual Information (MI) method [28] that these two approaches were used in this paper.

2.4 | Mutual Information Method

Swinney and Fraser presented the MI method as a tool for determining the delay time. Before applying this method, the autocorrelation function method was used to determine the delay time, but the problem with the autocorrelation function method was that the method only considered linear correlations [29]. Unlike the autocorrelation function, the MI method also considers the nonlinear correlations in the time series. MI for different values is calculated from *Eq. (3)*.

$$M(\tau) = -\sum_{i,j} p_{i,j}(\tau) \ln \frac{p_{i,j}(\tau)}{p_i p_j}. \quad (3)$$

In the above relation, p_i is the probability of finding a value of time series in i space and $p_{ij}(\tau)$ is the joint probability that observation happens at i-th space and the next observation happens with delay τ at j-th space. Finally, the first minimum of the function M regarding τ is considered as the optimal delay value.

2.5 | False Nearest Neighbor

To determine the minimum proper embedding dimension m, a method called the FNN was proposed by the kennel. Suppose that the minimum embedding dimension for time series {xi} is equal to m0. This means that the reconstructed absorption platform of a one-to-one image in an m0 dimensional delayed space is from the real absorption platform in the main phase space, especially since the topological properties are preserved in this dimension; so the neighbor of a point in the main space will be mapped to a neighbor in the delayed phase space. Due to supposing that the dynamics are smooth, the neighbors of points are also mapped to neighbors that shape and diameter of the neighborhood change based on Lyapunov exponents. But now suppose that absorption platform is imbedded in the dimension smaller than the real dimension (m < m0), the topological structure is not well maintained as a result of this imaging. Points are mapped to neighbors from other locations that were not neighbors in the higher dimension. These points are called false neighbors. Theoretically, it can be said that the nearest neighbor xi in the m-dimensional space can be found for every point xj in the time series. Then the distance between these two points in this space is calculated, and E(i) is calculated using *Eq. (4)* for all values i.

$$E(i) = \frac{\| x_{i+1} - x_{j+1} \|}{\| x_i - x_j \|}. \quad (4)$$

If E(i) exceeds a certain threshold, this point is labeled as the false neighbor. The criterion for determining the proper embedding dimension is that the fraction of the points in which > E(j) E(i) is zero or very small, or in other words, the $\frac{E(j)}{E(i)}$ the plot almost reaches saturation. *Fig. 3* shows the EEG signal and the RP generated with the above descriptions. Marwan toolbox has been used to plot the RP [30].

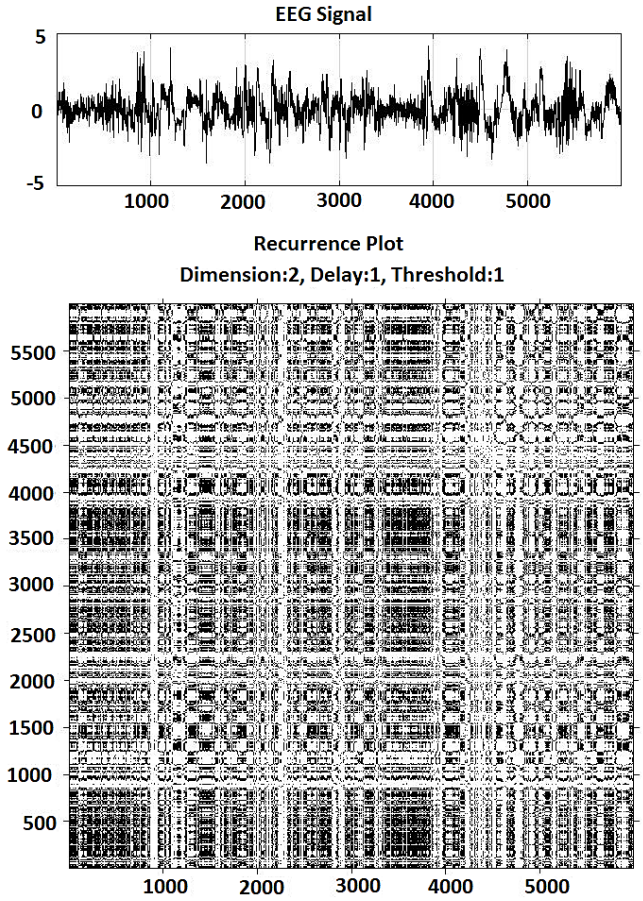

Fig. 3. Recurrence plot of EEG signals during sleep stages.

2.6 | Quantification of the Recurrence Plot

Three small-scale structures, including vertical lines, diagonal lines, and single points, are visible in the RPs.

Single points: it can occur when a rare condition happens; if this state only stands for a short time or strongly fluctuates.

Diagonal lines: a diagonal line of length L occurs when a part of the trajectory is traversed approximately parallel to the other part of the trajectory.

Vertical lines: a vertical line of length V represents the emergence of a stable state for V unit of time. In other words, the system is trapped for a few moments. To evaluate the structures quantitatively in the RPs, several features have been presented so far, which are further examined [24], [25].

Deterministic: the ratio of the recurrence points that follow the structure of the diagonal lines (with a minimum length l_{min}) to total recurrence points is defined as the deterministic feature, which is calculated from *Eq. (5)*.

$$DET = \frac{\sum_{l=l_{min}}^{N} lp(l)}{\sum_{l=1}^{N} pl(l)}. \quad (5)$$

In relation $P(l)$, the histogram of the diagonal lines is to the length of l. The emergence of diagonal lines in RPs is due to the parallel movement of two trajectory pieces. The duration of this movement is directly associated with the length of the diagonal lines. Deterministic is considered as the magnitude of predictability and determination in a system [31].

Recurrence Rate (REC): this index is a measure of the density of the recurrence points in the RP.

$$\mathrm{REC}(\varepsilon) = \frac{1}{N^2}\sum_{i,j=1}^{N} R_{i,j=1} R_{i,j}(\varepsilon). \tag{6}$$

The average length of diagonal lines: this feature is considered the average prediction time in a system.

$$L_{mean} = \frac{\sum_{l=l_{min}}^{N} lp(l)}{\sum_{l=l_{mim}}^{N} p(l)}. \tag{7}$$

Eq. (7) shows how to calculate the diagonal lines.

If a system is stochastic, then the average prediction time is expected to be very small; in other words, the nature of a stochastic system makes it impossible to predict its behavior in the future.

The maximum length of diagonal lines: this feature is equal to the longest diagonal line available in the RP; contrary to this feature is considered as a divergence. *Eq. (8)* is the definition of this feature. N is the total number of diagonal lines.

$$L_{max} = \max(\{l_i; i = 1,2,\ldots,N_i\}). \tag{8}$$

The entropy of diagonal lines: this feature states the complexity of the RP compared to the diagonal lines [25]. The entropy related to the diagonal lines is obtained from *Eq. (9)*.

$$\mathrm{ENTR} = -\sum_{l=l_{min}}^{N} p(l)\ln p(l). \tag{9}$$

Laminarity: this feature is defined as the ratio between the recurrence points constituting the vertical structures to the total recurrence points and is achieved from *Eq. (10)*.

$$\mathrm{LAM} = \frac{\sum_{v=v_{min}}^{N} vp(v)}{\sum_{v=1}^{N} vp(l)}, p(v) = \sum_{i,j=1}^{N}(1-R_{i,j})(1-R_{i,j+v})\Pi_{k=0}^{v-1} R_{R_{i,j+k}}. \tag{10}$$

Calculation of *LAM* is realized for all v that is more than vmin so that the effect of tangential motion is reduced. *LAM* Shows the occurrence of laminar situations in the system, without describing the length of these laminar phases.

Trapping time: the average time a system stays in a certain situation or how much it will get stuck in the trap. In other words, this feature indicates the average length of the vertical lines. This feature can be calculated from *Eq. (11)*.

$$TT = \frac{\sum_{v=v_{min}}^{N} vp(v)}{\sum_{v=v_{mim}}^{N} p(v)}. \tag{11}$$

The maximum length of vertical lines: this feature can be considered somewhat in comparison with the standard size l_{max}. All of these features can be calculated over the whole RP or in windows that move along the main diagonal of the RP [32].

A detailed study of dynamic systems has shown that chaos is widely used in natural and engineering systems. Chaotic behavior was known as abnormal and unpredictable behavior and often attributed it to the random effects of the environment; while such systems are not stochastic and are deterministic systems, but their accurate prediction is very difficult. Thus, methods based on chaos theory and nonlinear theories have been considered in recent years to extract the EEG signal features.

3 | Neural Network Structure

One of the most important technologies in data mining is classification. Many of the different problems in the real world, whether commercial, industrial, or medical, can be solved by the classification method. As the correct diagnosis of individuals' condition is of great importance, it is necessary to use the methods for this diagnosis that have minimum error and maximum accuracy. Thus, an artificial neural network is used in this paper to classify different sleep stages on EEG signal data for enhancing the efficiency of the detailed classification process in the training and testing stages. This paper's intended neural network has a Multi-Layer Perceptron (MLP) structure that works better than other methods [33]. The structure of an MLP is a standard combination of inputs, linear and nonlinear neural units, and outputs. *Fig. 4* shows an MLP neural network structure with two layers (with a hidden layer). In this Figure, the network has three inputs, four neurons in the hidden layer, and two outputs.

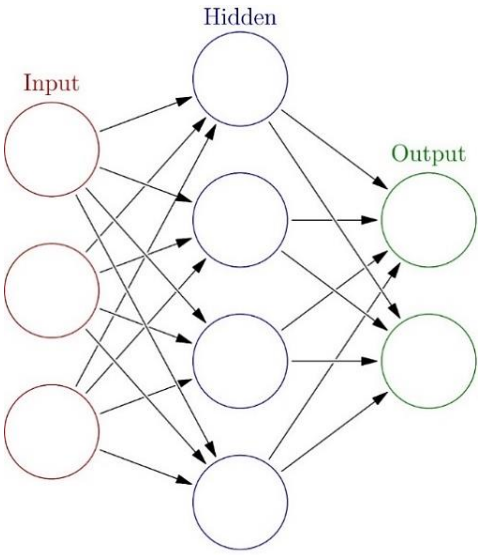

Fig. 4. Structure of the two-layer MLP neural network with a hidden layer.

3.1 | Evaluation of the Proposed Method

To evaluate the proposed method's performance in identifying the sleep stages, the specificity, sensitivity, and accuracy indexes were used by *Eqs. (12)-(14)*.

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}}. \tag{12}$$

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}}. \tag{13}$$

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FN} + \text{TN} + \text{FP}}. \tag{14}$$

4 | Simulation Results

The data used in this paper is extracted from a resource called Sleep-EDF in the Physionet database by Bob Kemp at the MCH-Westeinde Hospital located in the Netherlands [34]. This dataset was registered in 1989 and is still today available as a valid reference for researchers' studies. The samples were named based on steps 1, 2, 3, 4, REM and WAKE, and the polysomnography recorded from individuals within 48 hours includes EEG signals (Fpz-Cz and Pz-Oz channels), (horizontal) EOG and chin EMG. The EEG signals recorded from individuals and the private channel Fpz-Cz were used in this study to analyze various features and the classification of various sleep stages. The sampling frequency to record the EEG signal is considered to be 100 Hz. Ten samples to the separation of 5 men and five women were examined with different sleep stages and mean age of 39.7 ± 13.11; all subjects were healthy and did not use any medications. As shown in *Fig. 5*, a sample of an EEG signal is depicted for each part of the sleep stage, and *Table 1* also shows the number of each of the sleep stages in the studied samples.

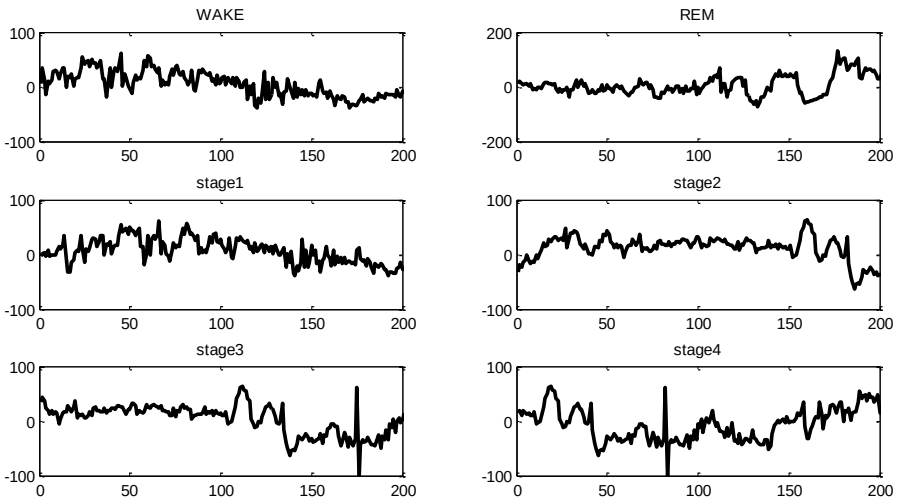

Fig. 5. Representing EEG signals at different stages of sleep.

Table 1. The number of sleep stages that occurred for the studied samples.

Number	Stage1	Stage2	Stage3	Stage4	REM	WAKE
sc4002	32	37	30	16	12	23
sc4012	42	55	29	9	18	17
sc4032	20	33	28	16	12	13
sc4062	25	26	17	9	6	14
sc4072	40	43	37	18	31	9
sc4082	23	55	46	11	8	12
sc4092	30	37	13	4	12	7
sc4102	41	50	10	0	3	12
sc4162	15	47	42	14	6	8
sc4171	15	53	64	17	10	22
Sum	283	436	316	114	118	137
Duration (min)	1-15	20	30-40		5-30	90

After identifying the target data, we dealt with the separation of various parts of the sleep stages in this paper using the existing labels of the EEG signals in the database. Then, to better identify these steps, we used seven nonlinear features that the calculation of them has been described in detail in the methods section. After that, the results of these features at different stages of sleep will be investigated and analyzed.

4.1 | Results of Nonlinear Features Extracted from Different Stages of Sleep

Because nonlinear features can reveal the dynamics of the EEG signal well, a comparison of the results obtained from the nonlinear features of the individual's EEG signal in the various sleep stages has been made in this section. *Table 2* indicates the mean and standard deviation of the nonlinear features extracted from each 10 seconds section of the EEG signal obtained for individuals at different sleep stages. In total, 100 sections of 30 seconds were selected from the database, and 300 sections of 10 seconds were obtained for feature extraction and classification of all available data. *Table 3* also shows the mean and standard deviation values of the first four stages, known as the Non-Rapid Eye Movement (Non-REM) stage. Considering that there were three different modes for the classification of sleep stages, 1125 feature vectors were obtained.

Table 2. The mean and standard deviation of nonlinear features at different stages of sleep.

Feature Type	Stage 1	Stage 2	Stage 3	Stage 4	REM	WAKE
Lmean	10.76±2.72	11.12±2.71	6.84±1.89	6.55±1.92	13.55±3.65	17.57±4.98
Lmax	56.70±18.55	91.50±26.78	36.05±10.43	41.41±12.14	105.73±42.87	154.85±48.21
REC	27.80±11.32	21.407±7.61	15.17±4.76	14.58±3.23	32.09±14.29	36.04±11.91
DET	95.88±24.56	94.64±24.54	92.04±23.98	92.18±24.00	96.77±2.10	97.31±1.66
ShanEn	2.80±0.58	2.72±0.51	2.33±0.34	2.36±0.42	3.047±0.48	3.29±0.52
LAM	34.23±8.6	33.71±8.3	31.09±7.38	31.62±6.97	43.76±9.32	52.12±12.53
TT	2.32±0.52	2.27±0.48	2.26±0.48	2.42±0.56	2.14±0.38	2.65±0.74

Table 3. The mean and standard deviation of nonlinear features at the first four stages of sleep.

Feature Type	Non-REM	REM	WAKE
Lmean	8.81±2.87	17.57±4.98	13.55±3.65
Lmax	56.42±17.10	154.85±48.21	105.73±42.87
REC	19.74±9.30	36.04±11.91	32.09±14.29
DET	93.68±2.92	97.31±1.66	96.77±2.10
ShanEn	2.55±0.43	3.29±0.52	3.047±0.48
LAM	32.67±7.67	52.12±12.53	43.76±9.32
TT	2.37±0.53	2.65±0.74	2.14±0.38

Changes in the values of the RP nonlinear features in the various stages of sleep are shown in *Figs. 6* to *9*. *Figs. 6-8* depict the features of Lmean, REC, DET, and ShanEn in the different stages of sleep as a boxplot, respectively. In *Fig. 5*, the Lmean feature values show a significant difference in the REM and non-REM stages. Due to this feature's property, it can be inferred that structures are more systematic when individuals are in the REM sleep stage, and the dynamics of the changes are reduced at this stage. This also represents an increase in the deterministic and predictability of the system in individuals' REM sleep stage. *Fig. 6* also shows that the REC feature, a measure of recurrence rate, has increased in REM mode compared to the non-REM mode, indicating a decrease in this sleep state's signal dynamics. Therefore, a recurrence to a point is more in REM conditions. The value of DET when people are in REM sleep mode has had a significant mutation compared to the non-REM mode. Increasing the value of DET represents the ability to predict the behavior of the signal after the non-REM mode. *Fig. 8* shows variations in the value of DET in different stages of sleep. The number of entropy of the diagonal lines in the RP is shown in *Fig. 9*. As shown in this Figure, when the individual is at the REM stage, the degree of entropy has a significant mutation, which can be argued that this feature creates a good

distinction between the REM and non-REM stages. Also, this feature shows that as the person reaches the REM sleep stage, the dynamics of the EEG signal are reduced.

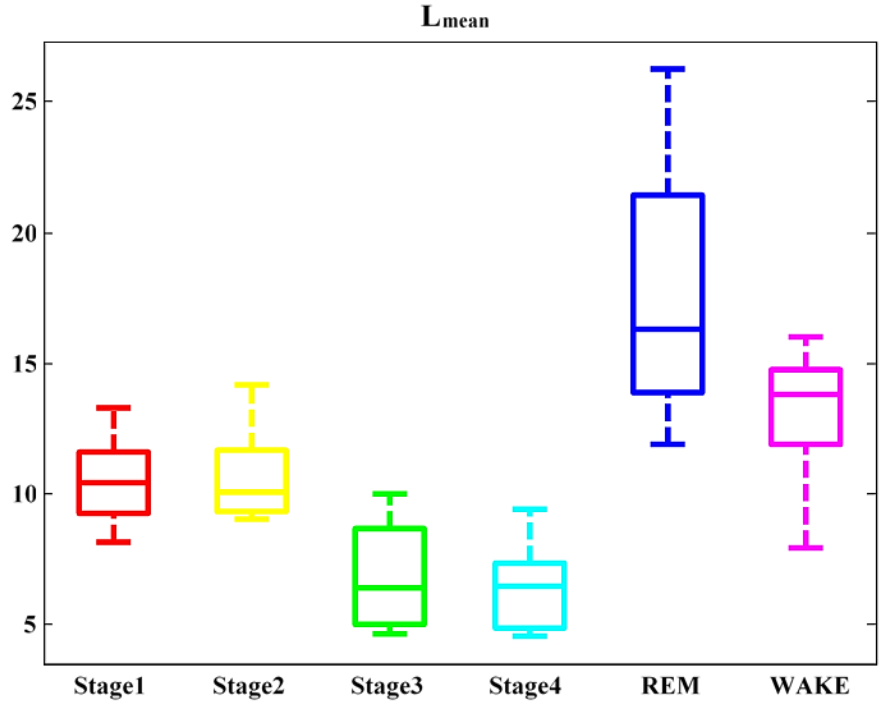

Fig. 6. Compare the sleep stages in L_{mean}.

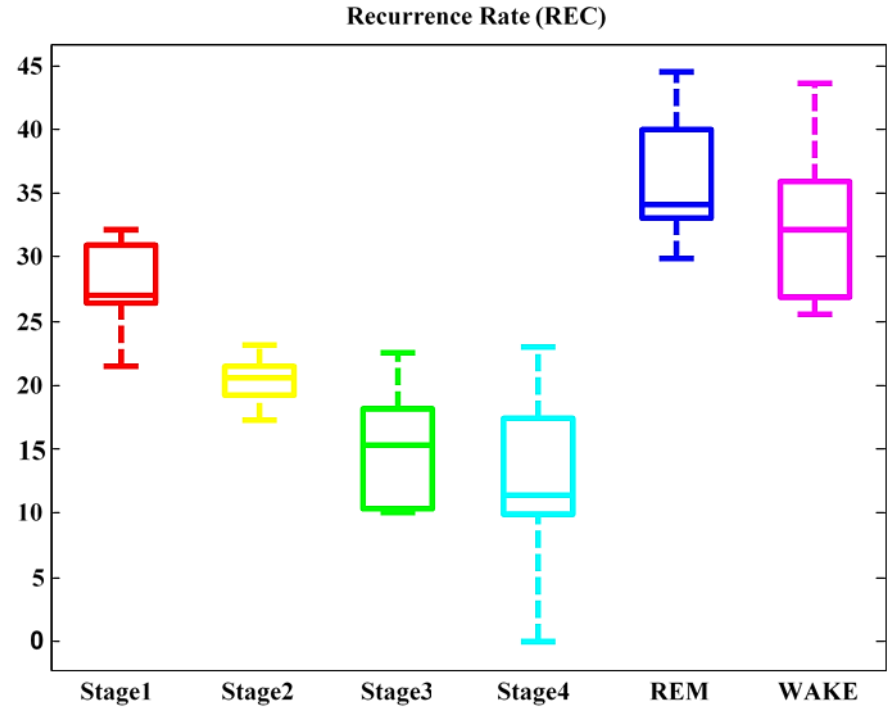

Fig. 7. Compare the sleep stages in Recurrence Rate (REC).

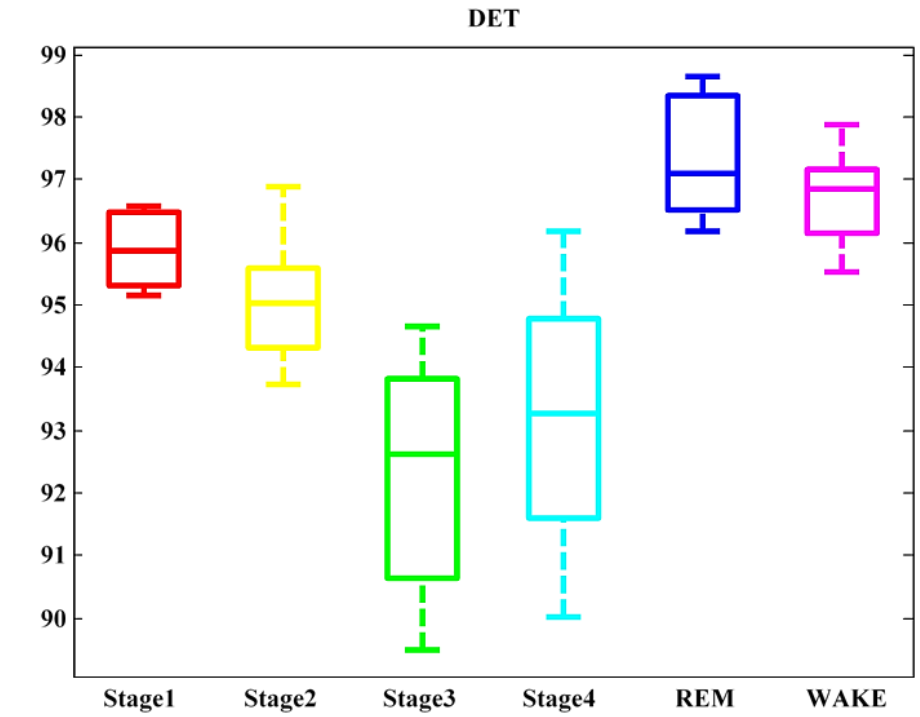

Fig. 8. Compare the sleep stages in DET.

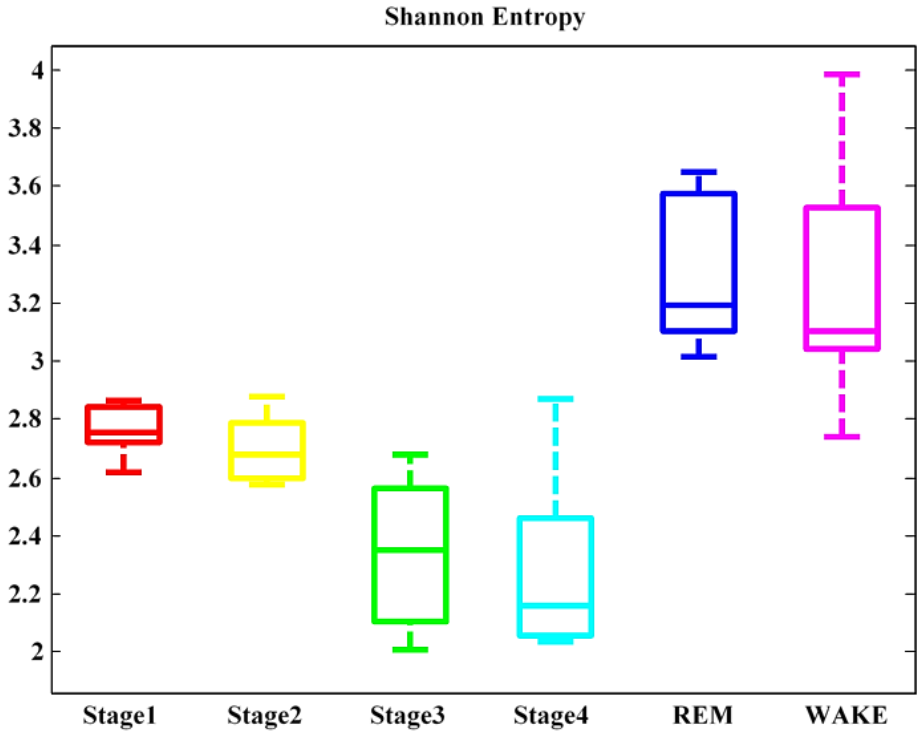

Fig. 9. Compare the sleep stages in ShanEn.

As shown in *Table 2* and *Figs. 6-9*, the separation of sleep stages cannot be easily addressed by these features. Still, the combination of these features together brings us to a correct diagnosis. Many features in the separation of the REM and AWAK stages have similar and close values together. To better distinguish these two states, we require to use intelligent systems for more accurate identification. Then, to determine the most proper number of hidden layers and neurons of each layer, the neural network performance accuracy was calculated for the layer change and the number of hidden layer neurons. The

structure of the neural and MLP layers optimized for the number of different features and the neural network's accuracy in the test mode has been shown in *Table 4*.

Table 4. Structure of optimal network for some different features.

N0. Features	N0. Input Layer 2	N0. Hidden Layer 1	N0. Hidden Layer 2	N0. Output Layer	Accuracy (%)
7	7	14	10	2	91.43±5.89
6	6	12	9	2	93.66±6.78
6	6	9	7	2	92.78±6.43
5	5	8	7	2	95.34±3.81
5	5	7	5	2	92.90±8.98
4	4	8	6	2	88.45±11.64
4	4	6	5	2	83.67±10.32

In MLP, the number of neurons in the input layer is equal to the number of features, and the number of neurons in the output layer is considered to be two. The number of hidden layers and neurons in each of them was determined by trial and error. Because the MLP training process begins with random weighting and the network converges to a different local minimum for each time, a fixed network's performance with a certain structure differs for different performances. To overcome this problem in optimization, the average accuracy rate of a network was used in 100 different performances for comparison. The sigmoid function was also selected as the activation function in neurons. As can be seen, the proposed system with 5 features, 8 neurons in the hidden layer 1, and 7 neurons in the hidden layer 2 is the best-achieved result, and the value of standard deviation is lower in this case. Finally, considering the network's desired structure based on the obtained accuracy, the neural network was trained 100 times, and the mean and standard deviation of specificity, sensitivity, and accuracy of the system were calculated according to the testing data. The results are presented in *Table 5*.

Table 5. Neural network performance using optimal structure.

Sleep Stages	Accuracy (%)	Sensitivity (%)	Specificity (%)
Non-REM-REM	98.32±2.11	99.03±1.43	98.54±1.88
Non-REM-Wake	97.76±2.34	98.71±1.95	98.02±1.23
REM-Wake	93.62±3.14	94.16±2.71	93.77±2.57

5 | Discussion

One of the methods considered by many investigators to determine the different stages of sleep is the use of brain signals. Despite extensive studies performed in the field of sleep stage detection using brain signals, recognizing sleep stages is still considered an interesting and serious issue for researchers. The first step to designing an automatic system for classifying sleep stages is quantifying recorded biological signals. Then, the quantified features achieved should be classified by a suitable system. The most important signal used in the classification of sleep stages is the EEG signal.

Recently, the use of nonlinear methods in processing physiological signals has gained much popularity due to the nonlinear nature of biological systems [42]. This paper aims to provide a new method based on the nonlinear analysis of the EEG signal to identify the various stages of sleep. RQA is a nonlinear algorithm that uses a RP of a dynamic system and quantifies the system's phase space features. Given the brain as a nonlinear system and an EEG signal as a manifestation of this system, some of the changes made in the EEG signal caused by mental state change can be realized through applying this algorithm.

As mentioned, the intuitive classification of sleep stages is time-consuming and tedious, and on the other hand, results depend on the level of experience of specialists. Thus, the automatic classification of sleep stages can facilitate this time-consuming and tedious work. This paper attempted to automatically separate the three Non-REM, REM, and Wake general modes using the EEG signal. To do this, the extraction of nonlinear features from different sleep stages was addressed using the EEG signal and reconstructing the

RP. Then, an Error Back Propagation Learning algorithm and an MLP neural network were used to classify the feature vectors. The results showed that the designed automatic system with a relatively good accuracy could separate these three modes. As stated in the definition of sleep stages, there is a similarity between the EEG signal in the REM sleep and stage 1 of NREM sleep. Therefore, the complete separation of sleep stages by the EEG signal alone is not possible, and EMG and EOG signals are required to recognize the sleep stages better. Researchers conducted in the field of automatic detection sleep stage, which are referred to in the introduction part to some of them, confirm this. In general, the research results in the field of sleep analysis are highly dependent on the way of data recording and the result of intuitive analysis by a specialist. *Table 6* shows the results of research carried out using different methods in recent years. A comparison of the results shown in *Table 6* clearly confirms the effectiveness of this paper's proposed method to separate the sleep stages with high accuracy. The use of fuzzy logic to quantify stress in each case is also a suggestion that researchers interested in this field may consider in the future [43]-[45].

Table 6. Compression techniques applied to EEG data for sleep stages detection.

N0.	Author(s)	Year	Method(s)	Channel Type	Accuracy
1	Ebrahimi et al. [35]	2008	ANN	Pz-Oz	93%
2	Li et al. [36]	2009	KNN	Fpz-Cz , Pz-Oz	81.7%
3	Güneş et al. [8]	2010	KNN and DT	-	82.21%
4	Vatankhah et al. [37]	2010	SVM	Fpz-Cz, Pz-Oz	98%
5	Jain et al. [48]	2012	ANN	-	93%
6	Huang et al. [4]	2013	SVM	-	70.92%
7	Hsu et al. [7]	2013	Elman Network	Fpz-cz	87.2%
8	Phan et al. [16]	2013	KNN	Fpz-Cz	94.49%
9	Şen et al. [15]	2014	DT	-	71.88%
10	Rodríguez-Sotelo et al. [39]	2014	ANN	Fpz-Cz, Pz-Oz	80%
12	Zhu et al. [46]	2014	SVM	Pz-Oz	87.5%
13	Obayya1 et al. [47]	2014	FCM	-	92.27%
14	Theodoridis et al. [40]	2015	Stacked sparse auto encoders NN	Fpz-Cz	78%
15	Hassan et al. [5]	2015	NB and LDA	Fz-Oz	88.62% , 90.11%
16	Aboalayon et al. [41]	2016	DT	Fpz-Cz	93.13%
17	Hassan and Subasi [18]	2017	TQWT	Fpz-Cz, Pz-Oz	95.35%
18	Rahimi et al. [20]	2019	SVM	ECG-HRV	81.76%
19	Tăutan et al. [21]	2020	RF	EEG-ECG-EMG	93%
20	Surantha et al. [19]	2021	SVM	HRV	82.1%
21	Sharma et al. [22]	2021	WD	EEG	85.1%
22	This Work	2021	RQA	Pz-Oz	98.32%

6 | Conclusion

The correct and accurate separation of each human sleep stage was performed in this paper using EEG data from the Physionet database. This separation was conducted by selected nonlinear features extracted from the Electroencephalography (EEG), whereas many of the proposed and raised methods by different researchers used time and frequency features. In the paper, after selecting the target data, we divided the signal to separate the sleep stages using the database tag. Then, to detect better identification of the algorithm, the extraction of features from different sections was performed using nonlinear features. To classify the data, features extracted from the various stages are separated into training and testing data. Using the MLP neural network and nonlinear features, results were obtained that made acceptable separation of sleep stages. Also, the separated stages for training include NREM, REM, and WAKE that the separation is also recognized for testing in this way.

Given that 6 to 8 hours of sleep at night is almost a standard rate, it can be said that the most common sleep disorders include disorders in the sleep cycle of people, which, due to living conditions and cultural changes, reduce or increase this standard rate. The incidence of sleep disorders is associated with a sleepless night, insomnia, apnea, etc., as well as neurological disorders such as stroke, Alzheimer's, or Parkinson's. The proposed algorithm of this paper can be very helpful in the field of timely clinical diagnosis and various diseases. The result of this paper could identify and distinguish all stages of sleep at an acceptable level. In addition to saving time, automatic analysis of sleep stages can help better and more accurate diagnosis and reduce physicians' workload in analyzing sleep data through visual inspection. As mentioned, the intuitive classification of sleep stages is time-consuming and tedious, and on the other hand, the results depend on expert experience. Thus, automatic classification of sleep stages can be time-consuming and tedious.

Separating sleep stages with the help of EEG signals alone cannot achieve 100% results. Therefore, using other signals such as EOG and EMG can help to diagnose sleep stages. Also, in general, the research results in the field of sleep analysis have been strongly correlated with the way it is recorded and the result of intuitive analysis by an expert. It is suggested that researchers pay attention to cardiac signals in future research to study the sleep stage. Using more data and deep learning techniques can also be an exciting topic for future research by researchers.

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Conflicts of Interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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Status of Quality Improvement Initiatives in Manufacturing Industry of Madhya Pradesh State in India

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Abstract

The objectives of this work are to investigate the status of implementation of quality initiatives by manufacturing firms in Madhya Pradesh, India, and to compare large and small-medium scale industries. Very few researchers have attempted to compare large scale and small-medium scale firms in order to know the extent of implementation of quality initiatives for a state like Madhya Pradesh. In this study, the survey questionnaire method was used for the collection of data. Nine quality initiatives were selected for the study. The obtained data are grouped into two groups: 1) large scale firms, and 2) small-medium scale firms. Descriptive and inferential statistics are used for analysis and the results are presented. Hypothesis testing was used to investigate for any significant difference between the two groups of firms in implementing each quality initiative. Results from inferential statistics reveal that there is a significant difference in the implementation of quality initiatives in large and small-medium scale industries. The findings of the present work will guide firms to identify areas where improvement is required at each quality initiative level. The study will help small-medium scale firms in the Madhya Pradesh state of India to conduct training programs in the areas of relevant quality initiatives for improving their quality of products.

Keywords: Small, Medium and large-scale firms, Quality initiatives, Quality assurance, TQM, Kaizen, Quality function deployment, Manufacturing industry.

1 | Introduction

Indian manufacturing industry occupied 17.4% of GDP in fiscal year 2020. In order to increase the contribution of the manufacturing sector to 25% or more, it is important to focus attention on the improvement of the quality of products, which is one of the important drivers in order to compete locally and globally. Quality is considered very significant in highly competitive markets for any product or service. Often it becomes the market differentiator for products. Quality Initiatives (QI) help a firm or industry to meet or exceed customers' expectations and contribute to its success in the long run. It also contributes to making an organization efficient by minimizing material wastage and in turn raises the levels of productivity. Due to this reason, all manufacturers aim to improve their product quality.

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For maintaining and enhancing the quality of products, many QI, viz. 1) Total Quality Management (TQM), 2) Kaizen, 3) Quality Assurance, 4) Quality Standards, and 5) Testing methods have been introduced. These initiatives have proved in many organizations that the end product meets or exceeds the quality expectations and standards defined for the product.

There are many QI other than listed above which were followed by various firms for achieving and maintaining the required quality level in their organizations. Some organizations believe in the concepts of Quality Function Deployment (QFD) and some others believe in statistical process control and acceptance sampling. Implementation and maintaining QI in a firm may require substantial investment at the beginning. This may be one of the reasons why large-scale firms are ahead of small and medium scale firms in implementing and maintaining QI. It is also true that small and medium scale industries focus more on following ISO as an initiative and they are content with meeting their business needs. However, many researchers focused their attention on factors related to organizational, cultural, and project differences. The effect of these factors is never compared in the implementation of Quality Management (QM) practices. Along with this, cases from developed countries, such as the United States, Britain, and Japan were taken up and examined the dissemination of QM tools and techniques but similar studies are lacking in developing economies such as India. Hence, it is important to study the implementation of QI in manufacturing firms in India and to compare them by taking a case study in one of the states in India.

Madhya Pradesh is chosen as the state where a comparative study of the implementation of various QI /techniques is taken up in this study in order to highlight the areas where there is scope to improve the quality of products in small-medium enterprises. The objectives of the study are to present a descriptive statistical analysis of selected QI and inferential statistics, to identify the QI that need to be implemented in small-medium scale firms for improvement of quality of product and successfully meet the market demands. A brief account of the review of literature is presented in Section 2, the methodology adopted for conducting the survey and analysis is given in Section 3. Section 4 covers the results and statistical analysis. Conclusions are given in Section 5.

2 | Literature Review

Jain and Samrat [1] used the interview method to collect the data and analyze real quality practices of Gujarat based manufacturing industry. Their focus was on quality planning, testing, and recording, supplier assessment, consultants, and certification practices. Chakraborty [2] devised an approach based on a survey for analyzing selected QM practices, implemented in SMEs in Tiruchirappalli, India. They found that 60% of firms implemented QI successfully, but 25% of firms were unsuccessful. The rest needs to be educated about the importance of quality in a competitive market. Limited knowledge and the high cost of training limit the implementation of QM practices in SMEs.

Maguad [3] proposed a system for implementing the Quality Management Initiatives (QMS) and they concluded that every organization should have its own model for QMS based on its strengths and weaknesses. Bhatia and Awasthi [4] conducted a study investigating the efficacy of QMS in Canadian context. They analyzed data collected from 32 organizations from across. The results of the research indicated that implementation of QMS acted as an impetus for change and hence, firms used it in daily practice.

Sandström and Svanberg [5] used force field analysis to find factors for and against change. They recommended considering some factors, such as the quality department, its goals, and their policies independently, as they cannot be categorized as a force for change. Prajogo et al. [6] concluded that a positive correlation exists between operational performance measures and supplier management practices. Further, flexibility, delivery, and cost performance were identified to be key factors for logistic integration and strategic long-term relationships. Martínez-Costa et al. [7] studied the effect of internal

motivation on successful implementation of the ISO9000 standard resulting in high performance and found that external motivation did not have much effect.

Majumdar and Manohar [8] studied SMEs in India for implementation of TQM practices using the interview method, analyzed the data, and identified their weakness/difficulties in adopting TQM. They recommended some guidelines for overcoming barriers to implementation after arranging the practices in order of importance. Kumar et al. [9] studied small and medium-scale firms in Australia and the U.K and compared them with reference to QM practices. They reported that six-sigma and lean initiatives contribute significantly to the success of QM practices. They also found that SMEs in the U.K reported significant improvement when compared with firms in Australia, in the implementation of QI. Singh et al. [10] used a questionnaire survey to investigate the impact of QM practices, such as, Just in Time (JIT), 5S's tools, suggestion schemes, etc. on inventory management, cost, etc. They concluded that QMS contributed to the performance output of the firms. Mandal et al. [11] used questionnaire survey and interview methods to collect data from quality professionals of Australian manufacturing firms. They studied the effectiveness of QI that were implemented and found that the awareness towards quality has gone up in these firms and quality became a priority initiative for improving customer satisfaction.

Similar studies have been conducted in countries such as, Pakistan by Abbasi et al. [12], Namibia by Mutingi and Chakraborty [13], etc. Chakraborty et al. [14] compared the QM practices in India and Namibia for SMEs. In all these cases, the status of implementation of QMS in either SMEs or the entire industry of a specific region was studied. Gutierrez et al. [15] proposed a solution for choosing alternatives among quality control, European Foundation for Quality Management (EFQM), Six Sigma, and ISO 9000 in accordance to the degree of development required for the elements that structure the alternatives. They involved 234 organizations in Europe, used Analysis of Variance and mean comparison t-test, and concluded that quality control is the simplest initiative, followed by ISO 9000, the EFQM model, and Six Sigma. Assarlind and Gremyr [16] emphasized on implementation of successful QM initiatives from large-scale firms gradually in Small and Medium-sized Enterprises (SMEs). They analyzed five categories of critical factors for QM initiatives in SMEs viz. 1) contextualization, 2) gradual implementation using realistic goals, 3) involvement and training of employees, 4) involvement of external support; management involvement, and 5) fact-based follow-up. Thawesaengskulthai [17] provided a holistic framework for selecting a QM initiative in Thailand for improvement which is carried out in three phases. They proposed a holistic model involving four selection views of fashion setting, pay-off, strategic fit, and organization fit to assist managers undertaking selection decisions. Nguyen et al. [18] compared the impact of QI on the operational capabilities of Vietnamese and Japanese manufacturers. The study provides empirical evidence on the implementation of QM practices in different countries by offering insights into performance improvement in both countries.

Gandara et al. implemented QFD approach for the implementation of the right design in improving the service of selling formaldehyde products in a chemical industry according to the customer requirements. They used a customer satisfaction questionnaire survey form for the data collection. Saputra et al. [20] used the statistical process control to determine the capability of the molding machine. They obtained a process capability of the machine to be 0.63 and they improved it to 1.65 by applying Poka-Yoke. Hernadewita et al. [21], studied a large-scale firm that prints magazines that often faces the problem of quality defects in its printouts and thus causes losses due to production defects. They determined the current sigma value of production to be 3.6 and the occurrence of various defects. They proposed necessary steps to achieve Six Sigma using the results of their study.

Very few researchers have made an attempt to compare the implementation of these initiatives in large-scale and small-medium manufacturing firms. In this work, the industries which come under small-medium and large scale are taken into consideration for Madhya Pradesh state. The micro-scale industry is not taken into consideration for the study. Implementation of QI in both these sectors is surveyed and QI that have significant differences in implementation between the two groups are identified. This helps small-medium

enterprises in focusing their management's attention on these initiatives and improves their quality standards.

3 | Methodology

A cross-sectional online questionnaire survey was used in this study. The questionnaire was administered during the period from December 2020 to April 2021. Consent to participate was implied by the completion of the survey. The questionnaire tool is a 68-item instrument using a nominal scale for most of the questions. A questionnaire survey is one of the best tools that can be appropriately employed to study the implementation of QI in large and small-medium scale industries. The first part of the questionnaire is general in nature and questions are designed to seek details about the firm, such as name of the firm, investment in the last three years, name and designation of the person participating in the survey, etc.

At the beginning of the questionnaire, definitions of QI are included to ensure that respondents were able to distinguish the intervention from others that may have been occurring in their workspace. Industries that have registered with Micro, Small & Medium Enterprises (MSME), Madhya Pradesh, India, were invited to participate in the online survey. Large scale industries which are located in Madhya Pradesh are also contacted for participating in this survey. The number of small and medium-scale firms in Madhya Pradesh is 531 and the large-scale firms are 287. Some of the questions were repeated so as to verify consistency in answers. The questionnaire consists of three parts. The first part was designed to know whether various QI, such as TQM, JIT, Kaizen, etc. Were implemented in manufacturing firms or not. The second part was at the micro level for the QI in which tools and techniques of each quality initiative were included. The third part of the questionnaire was designed to collect implementation details of the basic quality control and inspection activities in the firms. The online questionnaire was pilot tested with ten professionals using QI in the manufacturing industry. Revisions were made to the questions based on their feedback before sending it by e-mail to sample firms.

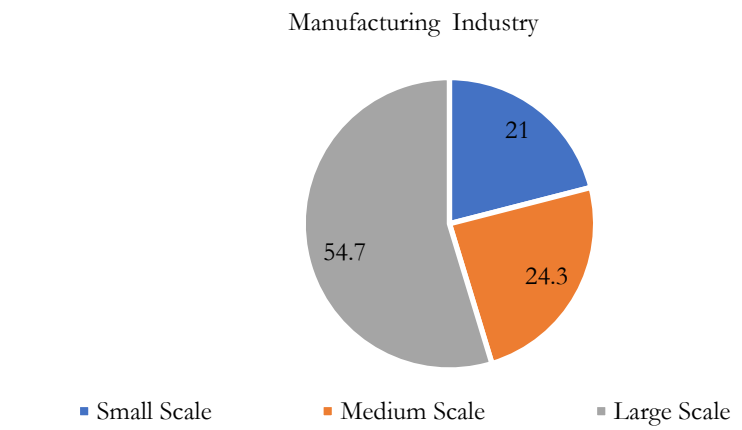
The questionnaire was sent to 400 firms by e-mail, inviting them to participate online through Google forms. Reminders are sent once in 15 days. At the end of 140 days, a response from 106 firms was obtained. Of these, 58 firms are large scale firms and the rest 48 are small-medium scale firms. Some firms have given responses to all the questions, but some others partially answered them. They were contacted on the phone to obtain answers by clarifying some of their queries for the rest of the questions in order to get the questionnaires filled out completely. For analysis, the firms are divided into large scale and small-medium scale firms. For descriptive statistics, Microsoft Excel 10 is used to construct bar graphs for comparison purposes. For inferential statistics, the chi-square test applicable to nominal scale data is adopted. Chi-square tests are used to examine differences between two groups, such as large and small-medium scale industries, in implementing QI and their tools and techniques.

4 | Findings from the Survey

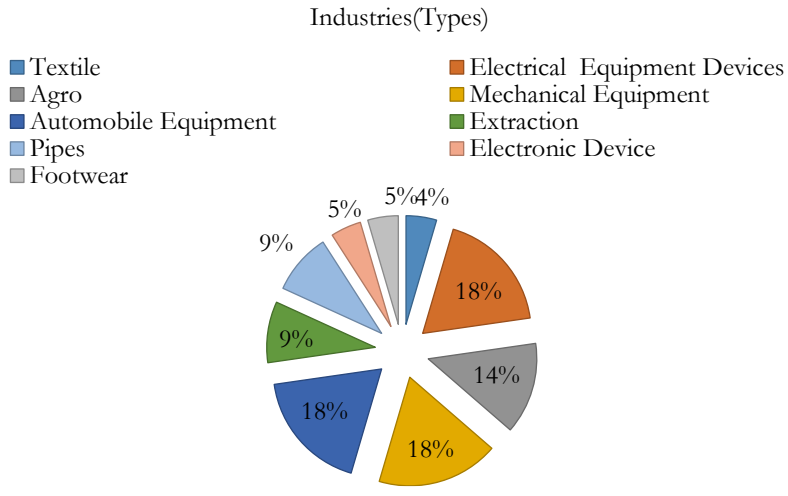
The data obtained from google forms are arranged with a Microsoft Excel sheet based on the investment made by the firms. Those firms which have made an investment up to INR 5crore (USD 670,000) are categorized into small-scale firms and those which have invested from INR 5 crore to INR 10 crore (USD 1,240,000) are categorized into medium-scale firms. Large scale firms are those firms that have invested more than INR 10 crores. The data are grouped into large scale and small-medium scale firms for analysis purposes. Comparison of implementation of QI is presented using descriptive statistics and hypothesis testing is carried out using inferential statistics.

4.1 | Descriptive Statistics

From the 106 responses obtained, 58 responses (54.7%) were from large scale firms and the rest 48 were from small-medium scale firms (45.3%) as shown in *Fig. 1.a.* The categories of firms who responded are shown in *Fig. 1.b.* The data collected represents all types of manufacturing enterprises in Madhya Pradesh state, India. Bar charts are used to compare the large and small-medium scale firms in implementing the QI and the result are shown in *Fig. 2.* Most large-scale firms are using all the initiatives such as, TQM, QA, QI, TM, Quality System (QS) etc. Very few small-medium scale firms are using these initiatives. This is a major difference between large scale and small-medium firms from Madhya Pradesh and the corresponding category of firms elsewhere in the world. Most small-medium scale firms are focused on implementation of TQM, QA, and QI methods only. This may be one of the reasons why they are lagging behind large scale firms which are implementing most of the QI. This will also affect the quality of output products from small-medium scale firms.

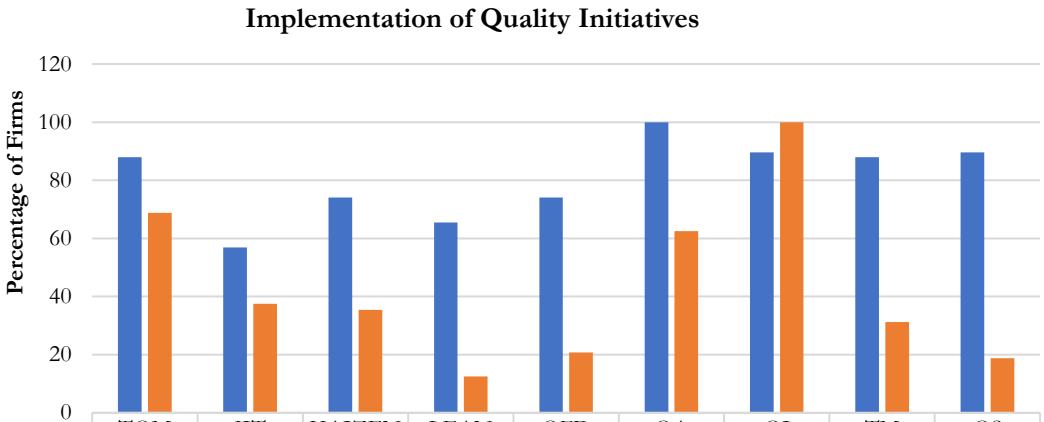


a.



b.

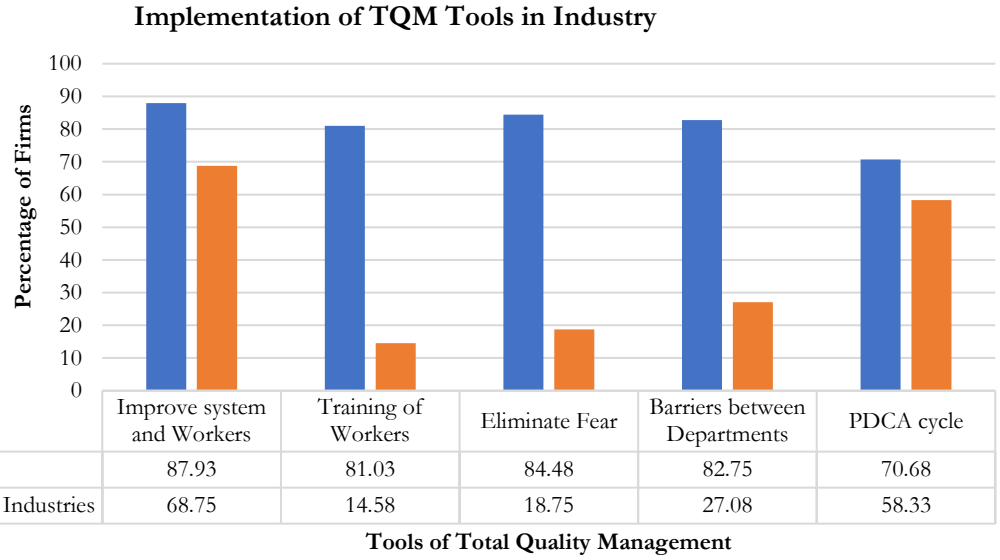
Fig. 1. Response diagrams: a. firms categorized based on investment; b. firms categorized based on product/type of product.



	TQM	JIT	KAIZEN	LEAN	QFD	QA	QI	TM	QS
Large Scale Industries	87.93	56.89	74.13	65.51	74.12	100	89.65	87.93	89.65
Small and Medium Scale Industries	68.75	37.5	35.41	12.5	20.83	62.5	100	31.25	18.75

Fig. 2. Comparison of quality initiatives between large and small-medium scale firms.

In *Fig. 3*, implementations of selected TQM tools are presented. From *Fig. 3*, it may be observed that small-medium scale firms are focusing their attention on improving the system and PDCA cycle. Very few of them are focusing on training of workers, elimination of fear, and removal of barriers between departments. It is important to improve skill level of workers by arranging training program from time to time, creating work environment which facilitates elimination of fear and insecurity among workers.



	Improve system and Workers	Training of Workers	Eliminate Fear	Barriers between Departments	PDCA cycle
Large Scale Industries	87.93	81.03	84.48	82.75	70.68
Small and Medium Scale Industries	68.75	14.58	18.75	27.08	58.33

Fig. 3. Comparison of TQM tools between two groups of firms.

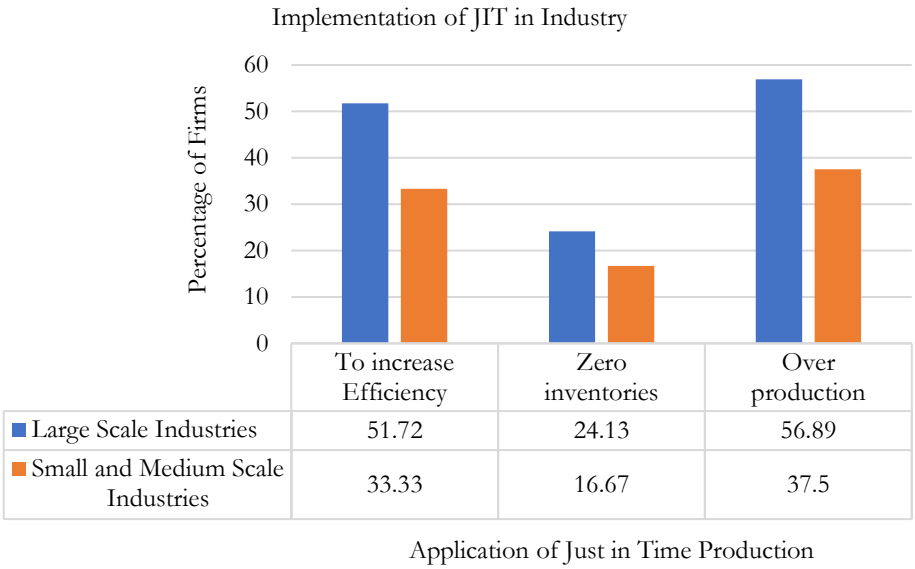


Fig. 4. Comparison of JIT tools between two groups.

From *Fig. 4*, it is clear that JIT implementation is poor at both large scale (max. 57%) as well as small-medium scale firms (max. 37.5%). Out of three factors of JIT taken into consideration, zero inventories concept is least used by the firms and this is a cause of concern and is identified as a barrier for enhancement of quality in the manufacturing industry of Madhya Pradesh state. Two factors are considered in the implementation of Kaizen as shown in *Fig. 5*, and both are found to be implemented in most of the large-scale firms but many of the small-medium scale firms need to implement Kaizen Gemba, which emphasizes on better communication and trust between employees and management. *Fig. 6* shows detailed analysis of Lean manufacturing tools. It is found from the *Fig. 6* that small-medium scale firms hardly use this initiative and there is need to educate them about importance of this tool. There is also scope to increase the number of large-scale firms using this initiative, which is helpful to improve productivity as well.

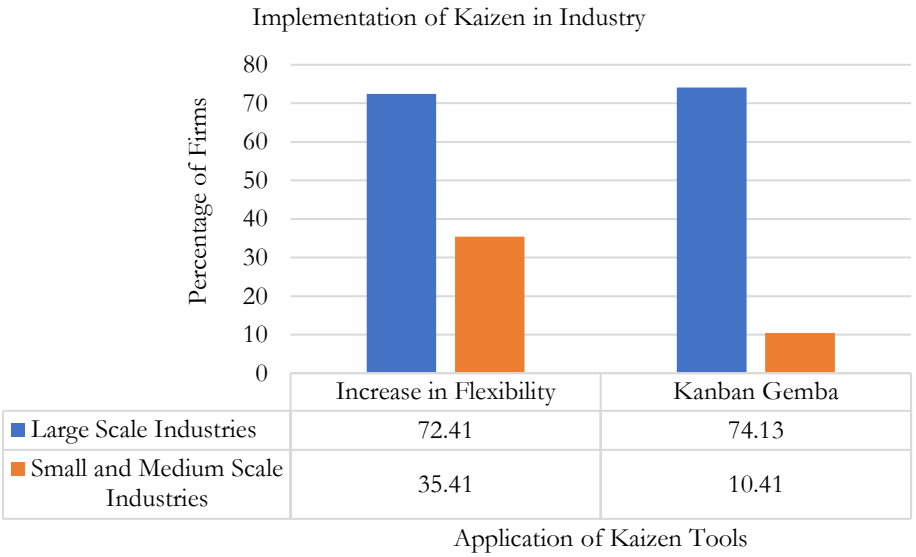


Fig. 5. Comparison of kaizen tools between two groups.

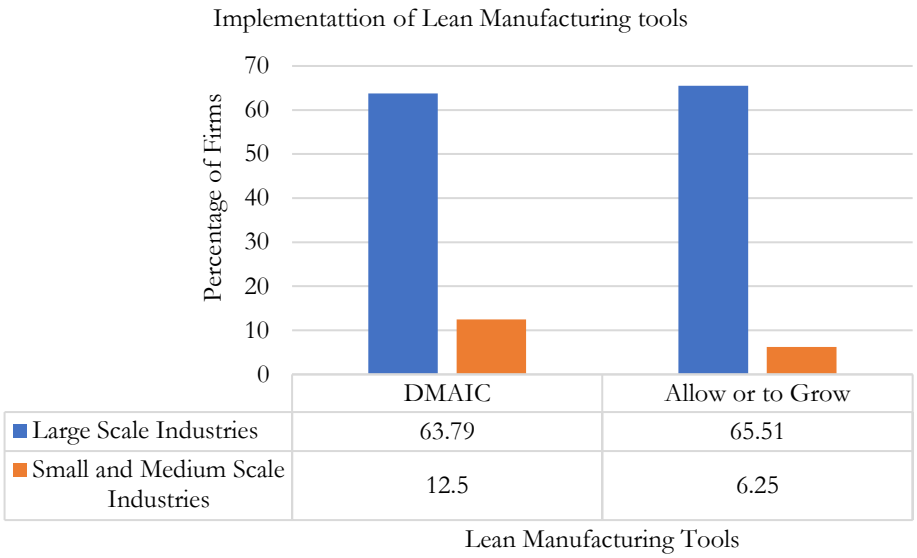


Fig. 6. Comparison of LEAN Manufacturing tools between two groups.

Fig. 7 shows the implementation of the QFD initiative in both categories of firms. Even though large-scale firms perform better in the three factors that are considered, small-medium scale firms have a lot of scope for improvement, especially in implementation of house of quality tools in design. This helps them in converting the customer requirements into design specifications in the most effective manner. *Fig. 8* shows details related to the implementation of quality assurance tools by both groups of firms. Written procedures are maintained by more than 50% of both the firms and quality assurance tools are used by large scale firms. Small-medium scale firms need to improve complaints, handling and documentation procedures which will improve goodwill of firms and quality of product.

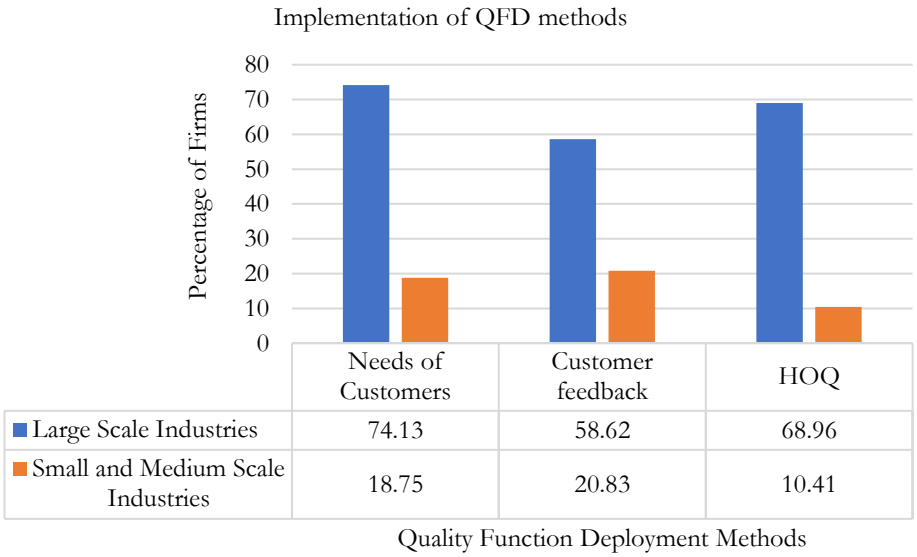


Fig. 7. Comparison of QFD methods between two groups.

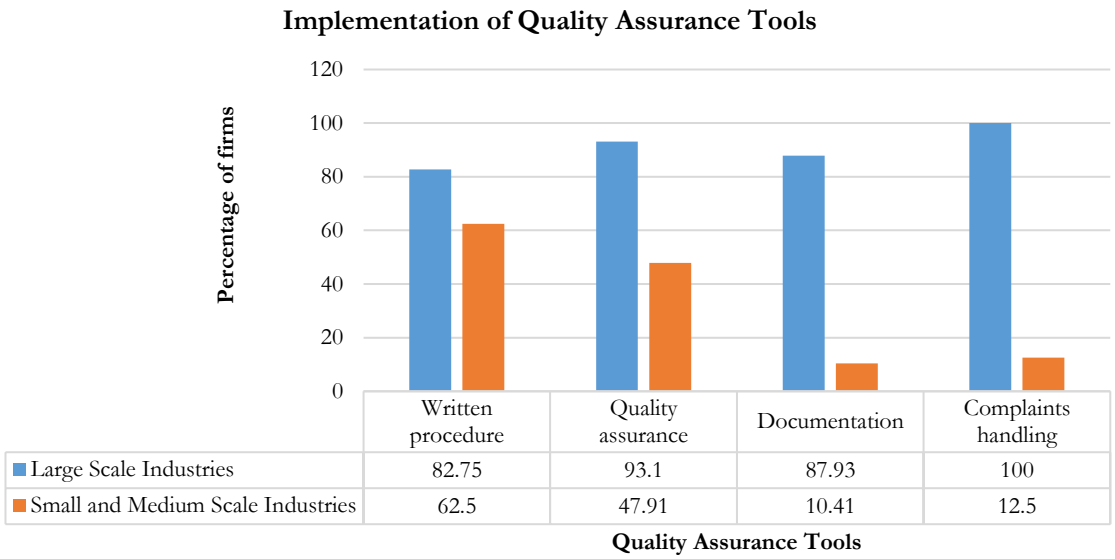


Fig. 8. Quality assurance tools: a comparison between both groups of firms.

However, in Quality Inspection (QI) activity (shown in *Fig. 9*), both groups are firms that use all the tools and techniques. This shows that basic quality control and inspection activities are carried out by most of the firms. As shown in *Fig. 10*, quality standards, such as, ISO9000, ISO9001 is implemented by most of the firms, whereas, OHS-AS, MS-ISO-14001, and HAC-CP, are used by very few firms. Out of these, implementation of Operational Safety and Health Standards needs to be considered as a primary requirement by small-medium scale firms. Small-medium scale firms also need to adopt environmental management systems which are need of hour in regulating pollution of the environment. Implementation of advanced testing procedures in small-medium scale firms received low response when compared to large scale firms. Reasons for this may be attributed to the non-availability of funds with small-medium scale firms.

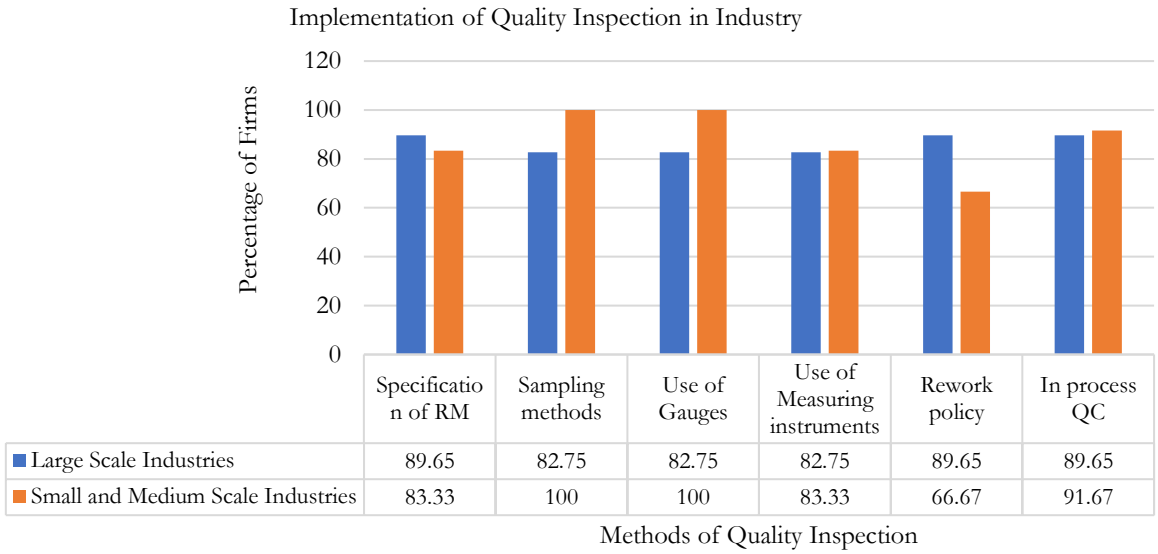


Fig. 9. Methods of quality inspection: comparison between both groups of firms.

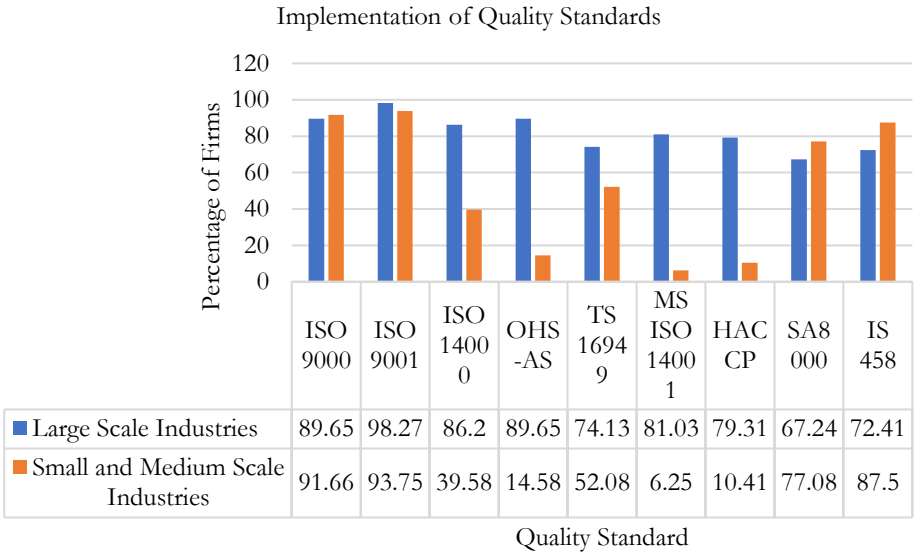


Fig. 10. Methods of quality standards: comparison between both groups of firms.

4.2 | Inferential Statistics

Hypothesis testing and test of significance methods are used in this paper to find out whether implementation of QI in large scale and small-medium scale industries is significantly different. For a test of significance, Chi-square test is used as most of the data is nominal data comprising 'yes,' or 'no' type responses. From *Fig. 11*, it is observed that there is a difference in the implementation of QI between the two groups. In order to test the significance of it using the Chi-square test, the following null and alternative hypothesis are framed.

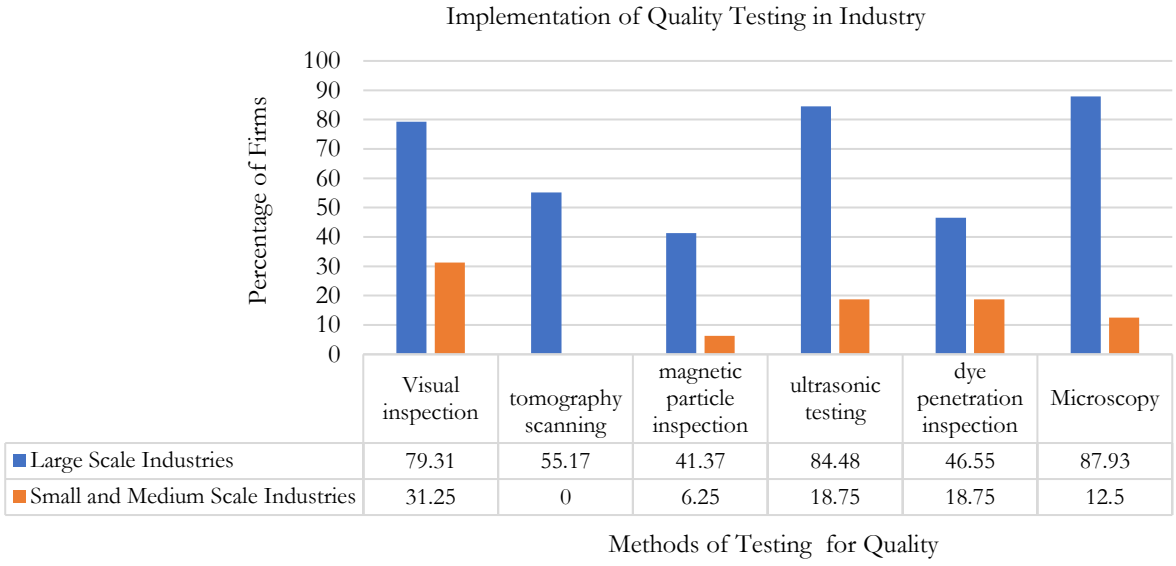


Fig. 11. Comparison of methods of testing for quality between the two groups.

Hypothesis H0: there is no difference between large and small-medium scale enterprises in the implementation of quality improvement initiatives.

Hypothesis H1: large and small-medium scale enterprises differ significantly in the implementation of quality improvement initiatives.

Data from *Fig. 2* is reproduced in *Table 1* to illustrate the computation of expected values. The total expected value (36.93) is calculated using *Eq. (1)*, which is shown in *Table 2*. Chi-square tables are referred to find out p-value. If a p-value is less than 0.05 (confidence level), it may be concluded that the difference between the two groups is significant; otherwise, the difference between the two groups is insignificant.

Table 1. Responses from firms in implementation of quality initiative.

Quality Initiative	TQM	JIT	Kaizen	Lean	QFD	QA	QI	TM	QS	Total
Large Scale Industries	51	33	43	38	43	58	52	51	52	421
Small and Medium Scale Industries	33	18	17	6	10	30	48	15	9	186
Total	84	51	60	44	53	88	100	66	61	607

Table 2. Expected values of responses for quality initiatives.

Quality Initiative	TQM	JIT	Kaizen	Lean	QFD	QA	RM	TM	QS
Large Scale Industries	58.26	35.37	41.61	30.52	36.76	61.03	69.36	45.78	42.31
Small and Medium Scale Industries	25.74	15.63	18.39	13.48	16.24	26.97	30.64	20.22	18.69

4.2.1 | Chi-square test for nominal data

Step 1. Compute expected value using the following equation.

$$\text{Expected Value}\left(E_{ij}\right) = \frac{\sum_{j=1}^{n} O_{ij} * \sum_{i=1}^{m} O_{ij}}{N}, \tag{1}$$

where Eij is expected value of ith row and jth column (calculated and shown in *Table 2*); Oij is observed value of ith row and jth column (given in *Table 1*); $\sum_{j=1}^{n} O_{ij}$ is sum of ith row and $\sum_{i=1}^{m} O_{ij}$ is sum of jth column; N is the total value of above two sums.

Expected values are computed from *Eq. (1)* from observed values of QI are shown in *Table 2*.

Step 2. Compute $\chi 2$values in order to test of independence between two groups of variables.

$$\chi^2 = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}. \tag{2}$$

The values of $\frac{(O_{ij}-E_{ij})^2}{E_{ij}}$ are calculated and shown in *Table 3*. The grand sum of all these values is obtained as 36.93.

Table 3. Chi-square values computed for quality initiatives.

Quality Initiative	TQM	JIT	Kaizen	Lean	QFD	QA	QI	TM	QS	Total
Large Scale Industries	0.90	0.16	0.05	1.83	1.06	0.15	4.34	0.60	2.22	11.32
Small-Medium Scale Industries	2.05	0.36	0.10	4.15	2.40	0.34	9.83	1.35	5.03	25.61
Total	2.95	0.52	0.15	5.99	3.46	0.49	14.18	1.95	7.25	36.93

Number of degrees of freedom = (number of rows-1)*(number of columns-1) = 1*8=8.

For $\chi 2$= 36.93, from statistical tables, the p-value obtained is 0.000012 and the result is significant at $p<0.05$.

The null hypothesis is rejected, indicating the significant difference between large and small-medium scale firms in the implementation of QI. Analyzing further, each quality initiative is taken into consideration and from the data, $\chi 2$ values, degrees of freedom and p-values are computed. The results obtained are shown in *Table 4*. Take for example, at the next level, the factors of TQM are taken into consideration and the following hypotheses are framed.

Table 4. Hypothesis testing for quality initiatives.

Quality Initiative	TQM	JIT	Kaizen	Lean	QFD	QA	QI	TM	QS
χ^2	22.79	4.30	5.49	0.86	2.13	25.32	3.57	13.67	71.31
DOF	8	2	1	1	2	3	5	5	8
p-value	0.000139	0.116	0.019	0.32	0.34	0.00003	0.61	0.017	0.00001
$p<0.05$ (yes/No)	Yes	No	Yes	No	No	Yes	No	Yes	Yes
Null Hypothesis	Rejected	Not Rejected	Rejected	Not Rejected	Not Rejected	Rejected	Not Rejected	Rejected	Rejected

Hypothesis H0: there is no difference between large and small-medium scale enterprises in the implementation of TQM tools.

Hypothesis H1: large and small-medium scale enterprises differ in the implementation of TQM tools.

Number of degrees of freedom = (number of rows-1)*(number of columns-1) = 1*8=8.

$\chi 2$ = 22.79. The p-value is 0.000139 and the result is significant at $p<0.05$. The null hypothesis is rejected in this case and hence the difference in the implementation of TQM tools is significant.

From the above results (refer to *Table 4*), it may be concluded that QI, viz., 1) TQM, 2) Kaizen, 3) QA, 4) TM, and 5) QS have significant different implementation between large scale and small-medium scale firms in Madhya Pradesh. This indicates that small and medium scale firms should focus on the implementation of these techniques for improving the quality of their products and in turn competitiveness in the market. Take for example, small and medium scale firms should focus on improvement of the system, training of workers, eliminating fear, barriers between departments, and implementation of plan–do–check–act (PDCA) cycle, etc. in order to improve their efforts towards implementation of TQM initiative. Similarly, the null hypothesis is not rejected in the case of QI, such as, JIT, LEAN, QFD, QI etc. which indicates that large and small-medium scale firms do not differ much with regard to implementation of these techniques. This proves that either both groups have implemented these initiatives to some extent or are actively practicing them.

5 | Conclusions

In this paper, a questionnaire survey was conducted for two groups of firms (large and small-medium) in Madhya Pradesh state in India in order to know the status of implementation of QI in those firms. The results are presented using descriptive statistics and inferential statistics. For descriptive statistics, a comparative study of both groups of firms is made using bar graphs. By analyzing the bar graph in terms of percentage of firms, small-medium scale firms are found to implement initiatives such as, TQM, JIT, Kaizen, and QA at par with the large-scale firms in initiatives. However, they are far behind in implementation of initiatives such as, LEAN, QFD, TM and QS in comparison with that of large-scale

firms. But in the area of QI, small-medium firms are performing better than large firms as shown in *Fig. 2*. In quality standards, in some of the quality standards such as, ISO 9000, ISO 9001, SA8000, and IS458, small-medium scale firms are matching with large scale firms. However, in most of the other criteria, small-medium scale firms are lagging behind large-scale firms. Especially in TQM, small-medium scale firms are lagging behind in the areas of providing training to workers and eliminating fear among them, as compared to large scale firms as revealed from *Fig. 3*. For providing adequate training to workers, they need skilled trainers and adequate training facilities, which needs greater investment.

In inferential statistical analysis, χ-square tests and hypothesis testing are used. Test of significance for the overall implementation of QI indicates that there is a significant difference between the two groups of firms. As there is a significant difference, each quality initiative is taken up and χ-square test is used to study the level of significance for each of them. The results indicate that some of the areas of TQM, Kaizen, QA, TM and QS need improvement for small-medium scale firms in order to improve their quality and compete with market leaders. Although the percentage of small-medium scale firms using TQM and QA is high, their implementation is not good enough to match the level of large-scale firms. For implementation, they need more funds in order to improve their infrastructure, and also local as well as central government support. Government needs to promote the use of modern techniques and provide opportunities for small-medium scale firms to grow. In addition to this, they need to train their employees in order to upgrade their skills. They need to focus on improving the quality of product, efficiency of the firm, and fulfilling the customer needs. Government support is also required in terms of establishing proper markets for the products from small-medium scale industries till they grow to a certain level.

The drawback of this study is that the authors are very selective in their studies regarding the factors in each of the QI. Future researchers may consider an exhaustive list of factors for each of the QI and conduct similar studies in other countries. This helps a firm to know and highlight the areas in which they need to focus in order to improve their quality in both design and production areas.

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Paper Type: Research Paper

Analysis of Factors Affecting Brand Strengthening Drivers in E-Commerce: A Study of the Iranian Tourism Industry

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Abstract

In the last decade, Information and Communication Technology (ICT) was used as the most effective tool to help businesses gain a competitive advantage by attracting customers. Thus, ICT has significantly contributed to the growth of e-commerce. Internet access allows e-commerce to spread globally and cheaply. However, many organizations did not realize the potential value created by e-commerce. Since the provision of information and branding at the destination necessarily involves the focused attention of all tourism companies in the destination, e-commerce can lead to the development of a new distribution channel in a virtual network and connects the producer with the customer. To this end, the present study analyzed the factors affecting brand strengthening drivers in e-commerce in the Iranian tourism industry. Brand strengthening drivers were ranked using Shannon's entropy method. The results indicated that advertising and brand communication are the most effective brand strengthening drivers.

Keywords: Brand strengthening, E-commerce, Tourism industry.

1 | Introduction

Tourism is a relatively long value chain industry [1] and is considered one of the largest sectors in the world. The tourism industry has generated about 11% of Gross Domestic Product (GDP), employed 200 million people, and serves 700 million tourists worldwide [2]. Searching for information on booking, transportation, accommodation, and destination is a process in which suppliers, intermediaries, and customers have traditionally played their part using their information systems. However, the whole structure of the tourism industry is changing [1] and this may be easily understood [3]. Thus, the internet can promote tourism products and services offered by tourism companies because it provides an unprecedented level of connectivity and enables direct and low-cost communication with tourists. The capacity of the internet to access, organize, and transmit information more efficiently provides new formulas for communication between tourism customers

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and tourism companies, leading to the emergence of new types of economic factors and new business models. Some scholars believe that the development of e-commerce provides good opportunities for both tourists and tourism companies, but presents significant challenges for organizations that require in-depth analysis of marketing strategies and consumer knowledge. Since the internet is a new shopping channel, tourism is often seen as a clean e-commerce industry without security issues [2].

Over the past decades, advances in Information and Communication Technology (ICT) have dramatically changed the way the "ordinary businesses" operate in the tourism sector. Moreover, transactions have become cheaper and faster due to the processing and exchange of information, and business processes are re-engineered to achieve the integrated coordination of a company's value chain activities. E-commerce reduces management costs, facilitates the accuracy and quality of information for decision making, and facilitates strategic collaboration between businesses [4]. Different schools of thought have also come up with different business strategies and policies for the implementation of e-business at the operational level. Porter's theory, for example, implied that every business has to implement a technological strategy to "survive" in a turbulent competitive world [5]. However, some businesses seem to be more advanced and innovative than others that find the following drivers to be more cost-effective, more efficient, and more risk-averse. For example, tourism agents who provide quality services and vacation packages to their customers do not apply innovative strategies by imitating competitors' practices. One problem with this approach is that customers may have become loyal to other businesses that offer similar products and services [6]. However, this approach can be more applicable and successful for many tourism agents who want to achieve low-risk goals.

However, it should be noted that insufficient acceptance of ICT is considered an obstacle to equal opportunities for business activities. Individuals and businesses without access to the internet and related technologies fail to benefit from the electronic services provided and have to gradually leave global markets [7]. ICT has contributed to developing business activities and has become the most effective tool to help businesses gain a competitive advantage by attracting customers. According to Daud Norzaidi et al. [8], the advent of ICT has contributed to the significant growth of e-commerce. In addition, internet access allows e-commerce to spread globally and cheaply. However, Gibbs and Kraemer [9] argued that many organizations did not realize the potential value created through e-commerce. Swati and Kamal [10] reviewed various studies on the impact of e-commerce on the tourism sector at the national level. By comparing British and German tourism organizations, Williams et al. [1] measured the factors that contribute to website access and proposed a set of e-commerce applications that create a more effective online environment. Sigala [11] also measured the impact of e-commerce productivity on tourism hospitality in the UK and found that factors such as payroll systems, ICT infrastructure, and distribution channels were associated with business performance.

Furthermore, in addition to the importance of ICT, branding at the destination has attracted the attention of all tourism companies, and thus e-commerce connects tourism companies with the customer by creating a new online distribution channel [12]. Since the branding strategy focuses on strengthening the brand of the product or even the business, brand strengthening is essential to describe a product in the form of visual designs. These visual designs include brands, logos, words, or things that can attract customers. In addition, the visual design of a brand should be developed in line with the brand identity and brand image of the product and business [13]. Thus, given the importance of brand strengthening through branding in the tourism sector, brand strengthening has been addressed in various studies. For instance, many studies have focused on strengthening the brand image [8], [14], [15], strengthening brand equity [16] and [17], strengthening brand association [18], strengthening brand identity [19], strengthening brand loyalty [20], strengthening brand value [21], strengthening brand awareness [22], strengthening brand communication [23], and strengthening brand trust [24]. Furthermore, a review of the literature on business-related issues indicates that brand strengthening is associated with many factors such as brand awareness, advertising, brand association, trust, loyalty, brand communication, and perceived quality [25], [26]. Accordingly, the present study seeks to identify brand strengthening drivers and to find out the drivers that are more effective in brand strengthening.

2 | Literature Review

A review of the literature on business-related issues indicates that brand strengthening is associated with many factors such as brand awareness, advertising, brand association, trust, loyalty, brand communication, and perceived quality [25], [26]. Advertising, brand awareness, perceived quality, brand association, brand communication, brand trust, and brand loyalty are considered brand strengthening precedents in tourism e-businesses. KaffashPoor et al. [27] examined the effects of these factors on each other in tourism businesses and showed that advertising affects brand awareness. Chi et al. [23] also showed that brand awareness affects perceived quality. Furthermore, Rahahleh et al. [28] concluded that advertising as an effective factor in sales promotion influences brand association. Schivinski and Dabrowski [29] found that brand association has a significant effect on perceived quality. According to Kia [30] and Hadadian et al. [31], brand awareness affects brand communication. Zehir et al. [32] also showed that brand awareness and perceived quality can promote customers' trust in the brand. Furthermore, building trust can improve brand loyalty [33].

In addition, since a business brand can differentiate it from other brands, a good branding strategy can be developed by understanding brand strengthening drivers. This section summarizes the most important studies conducted in Iran and other parts of the world. Akbari et al. [20] examined how Corporate Social Responsibility (CSR) affects brand loyalty, hotel positioning, and the intention to revisit, and concluded that there was a significant direct relationship between CSR with hotel brand positioning and an indirect relationship between CSR and intention to revisit through identification, loyalty. Drewniak and Karaszewski [21] examined brand management in a situation of an economic crisis to identify brand value strengthening methods in the scope of emerging markets and concluded that competitive conditions force companies to use newer marketing techniques to create a positive brand image. Latif [34] examined the influence of brand communities on strengthening brand association and concluded that community members believe that advertising activities are necessary for brand positioning and strengthening the relationship between brand and consumers. Rahman et al. [35] studied destination brand equity and tourists' revisit intention towards health tourism and concluded that destination brand equity affects a tourist's intention to revisit health tourism through destination brand association. Feng et al. [36] examined the external impact of international tourism on the brand equity development process of Multinational Firms (MNFs) and concluded that increasing the number of international tourists in the country of origin of MNFs significantly increases the brand equity of the company. This finding was interesting because the impact of international tourism on the brand equity of MNFs has a significant effect even after controlling other key brand drivers such as advertising, research and development (R&D), and dynamic brand equity. The results also indicated that international tourism is a very effective tool to improve the brand equity of MNFs and is 2.5 times more effective than advertising.

Rahahleh et al. [28] examined the effect of electronic service quality on relationship quality in the tourism industry and showed that electronic service quality has a significant effect on relationship quality. Their findings also indicate that ease of use, privacy, and accountability have a positive and significant effect on relationship quality. Sanjari Nader et al. [24] examined the effect of social network-based brand communities on brand evangelism through strengthening brand trust. The results showed that consumer relations with brand components (product, brand evangelism, company, and other customers) in social network-based brand communities have a positive and significant effect on brand evangelism through the mediating role of brand trust. Cheng et al. [37] investigated the relationship between brand value and strengthening with the customer brand engagement in a social networking brand community. The results showed that information search and social interactions are related to customer brand engagement and as a result, customer brand engagement is correlated with brand strengthening. Shirmohammadi et al. [38] examined the effect of social interaction, appearance, and credit value of tourism brands in cyberspace and its impact on the choice of European tourism destinations. They concluded that social network capabilities affect the process of tourist experience of social networks and interaction with tourists. Besides, tourist satisfaction also affects their travel intentions. Moro and Rita [39] examined

brand strategies in social media in hospitality and tourism and concluded that there is a strong relationship between social media and branding, and social media are the most important issue in advertising branding. Ahmadizad et al. [40] examined the effectiveness of e-marketing in the tourism industry and concluded that organizational, environmental, technological, and ease of use have a positive and significant effect on the acceptance and use of e-marketing, with perceived ease of use having the greatest effect and technological factors having the smallest effect. Otilia-Elena [41] examined the role of social media marketing in strengthening the brand image and concluded that creating a successful brand is a goal pursued by every business but requires constant attention to any interaction and experience with consumers. Abdolvand and Honarisharif [42] identified the factors affecting brand loyalty and commitment on social media. The results suggested that improving customer relationships with the company, product, and other customers will improve customer trust in the brand and ultimately increase customer commitment and loyalty to the brand.

3 | Research Methodology

This study is an applied study in terms of its objectives and an analytical-descriptive study in terms of the research design and procedure. A researcher-made questionnaire with 7 components and 40 items was used to collect data and identify the research variables. The research sample included 17 managers and faculty members who were selected using purposive sampling. Shannon's entropy method was used to analyze the factors affecting brand strengthening drivers in e-commerce. For this purpose, a questionnaire was distributed among subject-matter experts using the expert judgment system. The validity of the questionnaire was confirmed through the face and content validity, and its reliability was measured and confirmed with the alpha coefficient of 0.939.

4 | Shannon's Entropy

One of the methods to extract the weight/importance of criteria in multi-criteria decision-making problems is Shannon's entropy. The entropy weighting method considers more weight for indices that have more variability. As a result, the indices are differentiated through the different weights produced by entropy. According to information theory, entropy represents the measure of uncertainty in the expected information content of a message. In other words, entropy is a measure of the amount of uncertainty expressed by a discrete probability distribution, so that this uncertainty is greater if the distribution is sharper than the frequency distribution [43]. The concept of entropy was introduced by the American mathematician and electronics engineer Claude Elwood Shannon, who is referred to as the father of information theory:

Step 1. The Shannon's entropy for each random phenomenon of a probability distribution is measured as follows:

$$E = S\begin{pmatrix} P_1 \\ P_2 \\ 0 \\ 0 \\ P_n \end{pmatrix}, \sum_{i=1}^{m} P_i = 1. \quad (1)$$

The entropy of the phenomena that include indices due to the uncertainty of the numbers within the matrix is estimated as follows:

$$E_j = -K \sum_{i=1}^{m} [P_i . L_n P_i], K = \frac{1}{L_n m}. \quad (2)$$

Where Ej is the index entropy; m is the number of options; Pi is the probable value of the index for option i, Ln is the Napier or natural logarithm, and K is a constant that adjusts the entropy between zero and one.

Note that in decision matrices m≥3, indicating such matrices are not applicable for less than 3 options. Thus, we have

$$M = 3 > e = \frac{2}{7} \rightarrow L_n m > 1 \rightarrow \frac{1}{L_n m} < 1, \quad (3)$$

where, the closer the value of Ej, the closer entropy of index j, to 1, the effect of the index on the prioritization of the options will decrease to 0. Thus, if a phenomenon or an index is equal in probability for all options, its entropy is 100% or equal to 1. Thus, such an index will have no role in choosing the option. Mathematically, this is to say that if an index for option m has the same value, its entropy is:

$$E_j = -K \sum_{i=1}^{m} [P_i . L_n P_i] \ = E_j = 1. \quad (4)$$

In other words, such an index is perfectly entropized and has no role in the choice of options, and as will be shown, its weight is zero. At this stage, the current status matrix is descaled with a clockwise norm.

Step 2. The variation or deviation from full entropy for each indicator is calculated as follows:

$$d_j = 1 - E_j \quad , \quad j = 1,2, \dots , n. \quad (5)$$

Step 3. The weight of each index is obtained using the following equation:

$$W_j = \frac{d_j}{\sum_{i=1}^{m} d_j}, j = 1,2, \dots , n. \quad (6)$$

If a matrix is formed based on the experts' opinions and the decision-maker has a subjective judgment for the weight vectors of the indices and wants to involve it in the weighting of indicators, the adjusted weights ($\acute{W}_j$) are calculated as follows:

$$\acute{W}_j = \frac{\lambda_j W_j}{\sum_{j=1}^{m} \lambda_j W_j}, \lambda = (\lambda_1, \lambda_2, \dots \lambda_n), \sum_{j=1}^{m} \lambda_j = 1. \quad (7)$$

4.1 | Formation of the Decision and Normalization Table

Table 1. Frequency of the responses to the questionnaire items (to form the decision table).

Criteria / Experts	Brand Awareness	Brand Association	Brand Trust	Brand Communication	Perceived Brand Quality	Brand Loyalty	Advertising
4	4		4	4	4	4	4
2	4	4	4	4	4	4	4
3	3	4	3	2	4	3	3
4	1	2	3	2	2	3	1
5	3	3	3	2	3	3	2
6	4	3	3	3	4	4	2
7	3	3	2	3	4	3	2
8	4	5	4	5	4	4	3
9	4	4	4	5	4	4	5
10	5	2	3	2	5	5	5
11	3	4	3	4	4	4	5
12	3	3	2	2	2	3	2
13	2	2	1	3	4	5	3
14	4	4	4	4	5	4	5
15	4	4	4	4	5	4	5
16	5	4	4	3	3	5	2
17	4	4	3	4	4	3	3

Table 2. Normalization of the decision table.

Criteria Experts	Brand Awareness	Brand Association	Brand Trust	Brand Communication	Perceived Brand Quality	Brand Loyalty	Advertising
1	0.0667	0.0678	0.0741	0.0714	0.0615	0.0615	0.0714
2	0.0667	0.0678	0.0741	0.0714	0.0615	0.0615	0.0714
3	0.050	0.0678	0.0556	0.0357	0.0615	0.0462	0.0536
4	0.0167	0.0339	0.0556	0.0357	0.0308	0.0462	0.0179
5	0.05	0.0508	0.0556	0.0357	0.0462	0.0462	0.0357
6	0.0667	0.0508	0.0556	0.0536	0.0615	0.0615	0.0357
7	0.050	0.0508	0.037	0.0536	0.0615	0.0462	0.0357
8	0.0667	0.0847	0.0741	0.0893	0.0615	0.0615	0.0536
9	0.0667	0.0678	0.0741	0.0893	0.0615	0.0615	0.0893
10	0.0833	0.0339	0.0556	0.0357	0.0769	0.0769	0.0893
11	0.050	0.0678	0.0556	0.0714	0.0615	0.0615	0.0893
12	0.050	0.0508	0.037	0.0357	0.0308	0.0462	0.0357
13	0.0333	0.0339	0.0185	0.0536	0.0615	0.0769	0.0536
14	0.0667	0.0678	0.0741	0.0714	0.0769	0.0615	0.0893
15	0.0667	0.0678	0.0741	0.0714	0.0769	0.0615	0.0893
16	0.0833	0.0678	0.0741	0.0536	0.0462	0.0769	0.0357
17	0.0667	0.0678	0.0556	0.0714	0.0615	0.0462	0.0536

4.2 | Calculating Shannon's Entropy for each Index

Table 3. Calculating the entropy for each index.

(-K *Pij * LN(Pij))	Brand Awareness	Brand Association	Brand Trust	Brand Communication	Perceived Brand Quality	Brand Loyalty	Advertising
1	0.0637	0.0644	0.068	0.0665	0.0606	0.0606	0.0665
2	0.0637	0.0644	0.068	0.0665	0.0606	0.0606	0.0665
3	0.0529	0.0644	0.0567	0.042	0.0606	0.0501	0.0553
4	0.0241	0.0405	0.0567	0.042	0.0378	0.0501	0.0254
5	0.0529	0.0535	0.0567	0.042	0.0501	0.0501	0.042
6	0.0637	0.0535	0.0567	0.0553	0.0606	0.0606	0.042
7	0.0529	0.0535	0.0431	0.0553	0.0606	0.0501	0.042
8	0.0637	0.0738	0.068	0.0761	0.0606	0.0606	0.0553
9	0.0637	0.0644	0.068	0.0761	0.0606	0.0606	0.0761
10	0.0731	0.0405	0.0567	0.042	0.0696	0.0696	0.0761
11	0.0529	0.0644	0.0567	0.0665	0.0606	0.0606	0.0761
12	0.0529	0.0535	0.0431	0.042	0.0378	0.0501	0.042
13	0.04	0.0405	0.0261	0.0553	0.0606	0.0696	0.0553
14	0.0637	0.0644	0.068	0.0665	0.0696	0.0606	0.0761
15	0.0637	0.0644	0.068	0.0665	0.0696	0.0606	0.0761
16	0.0731	0.0644	0.068	0.0553	0.0501	0.0696	0.042
17	0.0637	0.0644	0.0567	0.0665	0.0606	0.0501	0.0553

The table and figure below show the data for weighting the criteria using Shannon's entropy. After preparing the table, the respondents normalized all these numbers. Then, by replacing the Pij values in *Eq. (4)*, the Ej values were obtained. Afterward, the estimated values were replaced in *Eqs. (5)* and *(7)*, and the Wj and dj values were estimated for each index as shown in *Table 4*.

As can be seen, advertising with a weight of 0.2841 has the highest rank as a factor affecting brand strengthening drivers in e-commerce in the tourism industry, and brand loyalty has the lowest weight.

Table 4. Ranking the indices using Shannon's entropy method.

Indices	Brand awareness	Brand association	Brand trust	Brand communication	Perceived brand quality	Brand loyalty	Advertising
Entropy (Ej)	0.9844	0.9887	0.9853	0.9829	0.9903	0.994	0.9705
Deviation (Dj)	0.0156	0.0113	0.0147	0.0171	0.0097	0.006	0.0295
Weight (Wj)	0.1503	0.1083	0.1415	0.1651	0.0931	0.0576	0.2841
Rank	3	5	4	2	6	7	1
Total weight	1	K = 0.3530					

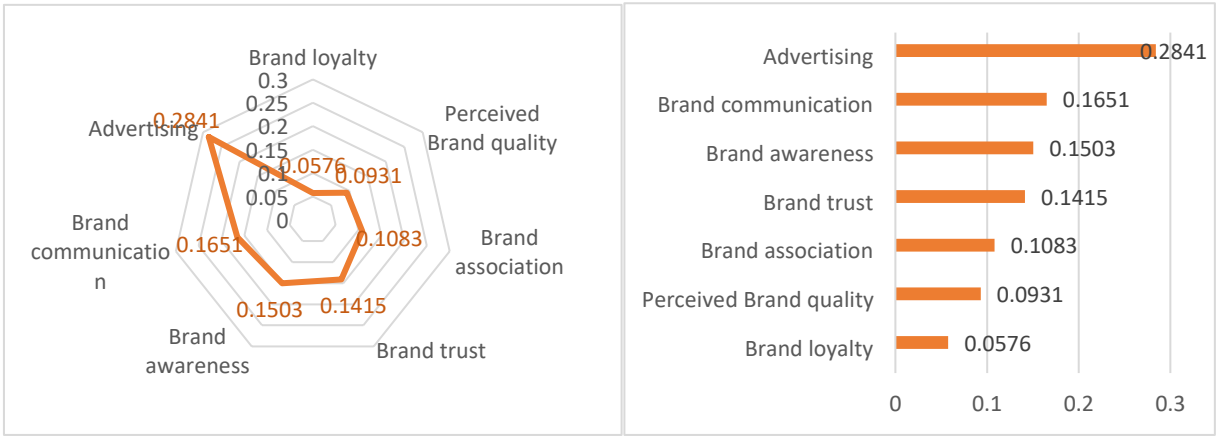

Fig. 1. Ranking the indices using Shannon's entropy method.

5 | Conclusion

The present study analyzed the factors affecting brand strengthening drivers in e-commerce in the Iranian tourism industry. The findings indicated that advertising is one of the effective brand strengthening drivers. Advertising involves visual-verbal messages that, through paid advertising, make people interested in a particular product, service, thought, idea, or brand. Advertising can help build brand strengthening as long as the consumer relates human characteristics to the advertised product. Accordingly, the results of this study showed that advertising as one of the effective sales promotion drivers is effective in brand strengthening. Thus, it should be noted that the development of tourism and advertising in a specific process are closely linked because tourism in the development process is part of the economic production structure that can play a fundamental role in expanding production and income and creating employment in countries. The results also indicated that brand communication is the second most important factor affecting brand strengthening. Psychologically, customers can develop reciprocal relationships with brands, which take the form of human relationships through advertisers. These relationships allow tourists to evaluate the brand personality. Similar to the process that involves the formation and maintenance of interpersonal relationships, brand communication affects the tourists' behavior toward a brand through cognitive behaviors and emotional communication with the brand. Besides, given the rank of brand awareness, it can be argued that social media can have a positive impact on tourists. Sharing memories may be the most important factor affecting the tourism industry. Social media enables tourists to share the most important memories of their travels with many audiences. When those involved in the tourism industry become aware of the potential benefits of social media for the prosperity of the industry, they will pay more attention to the prominent role of e-commerce in increasing brand awareness in e-tourism.

Following the findings of this study, the tourism industry needs to create a mechanism to improve the current situation. Thus, an effective program must be developed and implemented based on the marketing approach and attention to branding strategies. Consequently, a wide range of e-tourism services should be promoted to help improve brand loyalty. Thus, marketing principles and issues that lead to brand strengthening need to be revised quickly through further studies and investments. A prerequisite for brand strengthening includes identifying and ranking effective drivers to implement specific strategies for marketing development. The government must also supervise national tourism organizations and take effective measures to facilitate branding efforts and ultimately strengthen the brand through an electronic mechanism in business processes.

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Identifying and Ranking the Factors of the Foreign Investment in the Development of Iran's Free Trade Zones Using MCDM Approach

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Abstract

Considering the position of free zones in the country's commercial development, the present study identifies and ranks the factors affecting the attraction of domestic and foreign investments in the development of Iran's free trade zones and is customized in Amirabad port free zone. The present study is in the group of descriptive-survey research in terms of applied purpose and data collection method, which used statistical tests and Multi-Criteria Decision Making (MCDM) approach. In this regard, the statistical population of the study includes all actual and potential investors and managers of economic units located in the Amirabad Behshahr Free Zone, of which 385 people were analyzed using a questionnaire. The results obtained in the present study at the second level show that the first and the most important criteria is the management issues, followed by strategic planning, infrastructure, economic policies, laws and regulations, and finally location. Next, the most important factor is related to facilities and infrastructure, followed by the existence of natural resources and public budget allocation.

Keywords: Investment attraction, Export development, Free trade zones, Amirabad port, MCDM approach.

1 | Introduction

Economic development requires investment in various sectors and economic activities. Without investing in infrastructure and superstructure projects, one cannot expect the expansion of employyment, production, and economic prosperity. Today, many countries in the world have a strong desire to attract foreign investment. The experience of using free zones in developing countries has been a key component of the export development strategy framework with the aim of attracting foreign investment, developing industrial exports, creating employment, and acquiring new technology. Therefore, different countries have tried to create industrial-commercial zones in different ways. One of the useful and suitable ways for this purpose is to create free trade-industrial zones. Since this program is at the top of our country's grand plans. The capital factor is one of the main factors in the growth and development of countries and other economic variables such as

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employment, GDP, supply of goods and services, etc. are directly affected by this factor [1]. The free trade zones are one of the most important items in the supply chain of different products [2], [3].

The rapid growth of free trade zones has led to the development of such zones in the country after the port of Hamburg (1888) and Ireland (1959). These include the Manaus Free Trade Zone (in Brazil), the Maritime Free Zone (in Mauritius), the Karachi Free Zone (in Pakistan), the Masan and Erie Wakumi Free Zone (in South Korea), the Candella Free Zone, and Santa Cruz Electronics In India), Shiko, Xiamen, Shenzhen, Zhuhai, Shanto, Hanyan and Pudong Free Zones (in China), Ataturk Airport Free Zones, Mersin, Antalya, Aegean, Istanbul Leather, Istanbul (in Turkey), Jebel Ali Free Zones, Ahmad Ibn Rashid (in Dubai), Jakarta Free Zone (in Indonesia), etc. in Asia.

Statistics show that from 1970 to 1994, 283 regions were established in the United States, 93 regions in Europe, 43 regions in Africa, 27 regions in the Middle East, 83 regions in the Far East, and a total of 526 free zones in the world. According to official statistics of international organizations, by 2003, more than 3,000 free zones have been established in 116 countries [4]. In Iran, the provisions and tasks of the Vision 1404 document have outlined Iran's position as the first developed country in the region, and in line with the objectives of the document, the country's five-year development plans, including the Fourth Development Plan, policies and programs have determined and specified clear provisions for different economic sectors of the country, including the provisions of article 35 of the Fourth Plan Law as tasks related to the development and expansion of infrastructure and infrastructure of free trade-industrial zones in order to realize capacity [5]. Mentioned the potential opportunities of these areas. Statistics show that the share of 6 free zones in the total amount of foreign investment attracted in the last 9 years has been less than 2 billion dollars [5]. Nearly 20 years have passed since the establishment and operation of the country's free zones.

Over the years, despite the costs and efforts made, the infrastructure and facilities needed to define a ready-made model developed and organized in accordance with international standards are still not available. Attracting investors is slow, and despite the abundant natural resources and reserves and the potential economic prospects of free zones, which puts them in the regional and global rankings in terms of this index, unfortunately, domestic and foreign investors tend to they do not have much to invest. Those who enter this field and are willing to bring their capital to these areas despite the existing shortcomings are so involved in bureaucracies that they either leave the job in half or are willing to leave without any eyes. They had to raise their capital and travel to a safer place. Reports indicate that during the 9 years of 80-88, the free zones of the country have attracted a total of less than $ 2 billion in foreign investment, which indicates the failure of these zones in attracting foreign investment.

Since foreign investment is directly related to the state of infrastructure in free zones; therefore, in the current situation, it is the only Kish Free Zone that has relatively better infrastructure and has been more successful in attracting foreign capital than other regions.

According to the presented materials, in the present study, the factors affecting the attraction of domestic and foreign investments in the export development of Iran's free trade zones (specifically the Amirabad Port Free Zone of Behshahr) have been identified and ranked.

For this purpose, several variables such as infrastructure, laws and regulations, management, economic policies, strategic planning, and location factor are considered as variables affecting domestic and foreign investment in the free zone of Amirabad port of Behshahr. It seems that studying this issue and presenting empirical evidence in this section can be useful and useful for many people and areas involved in free trade zones. Thus, the main question of the research is as follows: what are the factors affecting the attraction of domestic and foreign investments in the development of exports of Iran's free trade zones (Amirabad port free zone), and what are their prioritization?

The reaming of the paper is organized as follows: in Section 2 the research background is presented, in Section 3 the methodology and in Section 4 the numerical results are presented. Finally, in Sections 5 and 6 the discussion and conclusion are provided.

2 | Theoretical Foundations and Research Background

In today's world of societies, capital has a high opportunity cost. Hence, it settles in communities and plays a role in the process of economic value creation that has less risk and higher income. The emphasis on the importance of the issue is not only rooted in this issue, but many countries in the world are facing a lack of capital and capital resources, and today the role of capital is something more than this. Foreign capital does not only play the role of financing a country's shortage of financial resources. The key point here is that the investment management of any society can and should attract foreign capital with its own art, as well as capital belonging to the natives living abroad, in order to bring the said technical and technological knowledge with them. Publish it by working in the host community. Thus, technical knowledge and technology, in practice, experience the process of localization, i.e., adaptation to its environment, in order to be closer to the optimal point of factor productivity. Indigenous people's access to this technical and technological knowledge naturally determines the position of society in the international division of labor [5].

The World Bank aims to create free trade zones in the short term, increase exports, create employment opportunities, encourage investment and accelerate the development of the region and the host country in the long run, transfer technology, acquire and improve management skills and economic growth The country knows.

Evidence obtained in Azad and Rostamnya [6] research shows that among the variables considered staff training as the most important factor and then the variables of employee resistance, information technology acceptance and user behavior, organizational culture, low-level awareness of users about technological advances, and ultimately competition among different competitors are the next influential factors in this field. Behname [7] concluded that the ELG hypothesis (the hypothesis that exports lead to economic growth) was given only for the postwar period. The results of the analysis of the expropriation correction model provided an important determinant to explain the changes in GDP. In addition, both in the short run and in the long run, exports have been the cause of Granger relative to GDP.

Free Zones in Iran according to note 19 of the law on the first program of socio-economic development, the Islamic Republic of Iran more or less for reasons similar to what was proposed for other countries and considering the important principle in creating free zones, namely attracting foreign capital and export development to in order to achieve goals such as accelerating the implementation of infrastructure, development, economic growth and development, job creation, investment, production and export of goods was created. At that time, it was not possible to remove the many restrictions imposed on the Iranian economy in the first years of the revolution and during the war, all at once. Therefore, the formation of free zones was considered by the officials in order to remove economic constraints and attract foreign investment and export development. After the end of World War II, free trade zones expanded rapidly around the world [8]. Among these, free trade-industrial zones or export-import processing zones as one of the tools to expand industrial exports and facilitate countries' access to global markets have been considered by most governments and economists. Today, the experience of many countries, such as China, South Korea, and Taiwan, shows that by creating free trade zones, it is possible to attract foreign investment and increase the development of exports of industrial goods and, consequently, the country's foreign exchange earnings. These areas with tax and customs exemptions and avoidance of domestic deterrent laws, having appropriate infrastructure facilities and efficient executive organizations, etc. can attract foreign investment due to the use of comparative advantages such as cheap labor and Attract raw materials and proximity to consumer markets.

Alguacil et al. [9] stated that host governments should develop a set of policies that not only focus on increasing foreign direct investment but also develop their economic and political framework. Prasanna [10] concluded that the effect of foreign direct investment flows on the country's exports is significantly positive. Mijiyawa [11] showed that political factors, economic factors (infrastructure); Social and cultural factors are ranked first to fourth, respectively. The results of Pegkas [12] show that there is a positive relationship between foreign direct investment and economic growth.

The results of the study by Mosusavi Zadeh et al. [13] show the existence of a two-way causal relationship between foreign direct investment and exports. Abdollahzadeh and Mirbargkar [14] stated that indicators in the category of economic factors include tax cuts and financial risk, which increase the attraction of foreign direct investment, as well as trade agreements, market size, GDP growth, exchange rates, proximity to large markets, labor productivity, which is significantly effective in attracting expenditure investment. Indicators of country characteristics include political interference, ethnic, religious, and military tensions, common language, government instability, financial risk, corruption, and the red line of bureaucracy and political violence, which are significant in attracting foreign direct investment.

Rasyid [15] assessed the net impact of the free zones and uses an experimental approach. In this research, the implementation of the free zones presented as a natural influence on a decrease in prices of specific products. Chen et al. [16] proposed a development performance evaluation system for a typical free trade zone that was established on the basis of theoretical models and empirical research. Several free trade zones were selected in China and the assessed the proposed system on each of them. The development performances of these zones were evaluated using a system built by combining an Analytic Hierarchy Process (AHP) with a grey relational analysis. Fontalvo et al. [17] applied a methodology for evaluation and forecasting for companies located in the Industrial Port Zone of the city of Barranquilla, Colombia. Based on a comprehensive analysis, supported by the concepts of technical efficiency, purely technical efficiency, and additive efficiency, the efficiency of scale and of mixing, as well as in the algorithm. Mohamadzadeh et al. [18] assessed and evaluated some of the social outputs of the various investment applied in the Manaus Free Trade Zone. It was aimed to determine whether factors in labor standards and social conditions in the Manaus Industrial Pole are capable of generating positive spillovers in Manaus and surrounding areas. Teixeira [19] assessed the current and desirable strategies of development in university management and propose a development strategy for university management in accordance with the requirements of the Free Trade Zone Policy in Hainan of China.

According to the research literature as well as the backgrounds presented inside and outside the country to identify and rank the factors affecting the attraction of domestic and foreign investment in the export development of Iran's free trade zones (Amirabad port free zone) were identified. Accordingly, the variables considered are infrastructure, rules and regulations, management, economic policies and strategic planning, and location factor. In addition, each of these variables also includes subcomponents that are specified in the conceptual model. Thus, the conceptual model of the present study is as follows. The conceptual model of the present study is as *Fig. 1*.

3 | Research Methodology

The method of the present research is applied in terms of purpose. Also, in terms of research method, it is considered in the field research group. Finally, in terms of the inference method, it is considered as analytical (or inductive) inference. Also, in the present study, the statistical population includes all actual and potential investors and management of economic units located in the Amirabad Behshahr Free Zone. Amirabad Special Economic Zone, as the largest port on the Caspian Sea and the third generation port of the country, has opened a new horizon in the economic prosperity of the north of the country. Amirabad can be considered as one of the most successful ports in attracting private sector investment. Extensive support lands (1060 hectares) along with infrastructure facilities and economic costs resulting from the legal benefits of special economic zones and value-added tax exemptions have provided a suitable and safe platform for domestic and foreign private sector investment. Therefore, in other words, the statistical

population of the study includes all domestic and foreign investors (in manufacturing, industrial, service, and commercial sectors) in the Amirabad region of Behshahr. To select the sample size from the Cochran sampling formula and using random sampling method is available.

In order to find the importance of each of the indicators in *Fig. 1*, the AHP is used. This technique is a powerful and flexible method in the category of multi-criteria decision-making methods by which complex problems can be solved at different levels. For this reason, it is called a hierarchical model because it is a tree model and hierarchy. The AHP method combines both objective and subjective evaluation in an integrated structure based on scales with even comparisons and helps analysts organize the essential aspects of a problem into a hierarchical framework. Among the advantages of this method can be mentioned: measuring the consistency of decision makers' judgments, creating pairwise comparisons in choosing the optimal solution and option, the ability to consider criteria and sub-criteria in evaluating options, creating the ability to achieve the best option through Paired comparisons.

The AHP method is a way to help make decisions and emphasizes the importance of a decision maker's intuitive judgments as well as the stability of comparing alternative options in the decision process. Because a decision-maker makes his or her judgments based on knowledge and experience and therefore makes decisions based on this, the AHP approach is consistent with the behavior of a decision-maker. The strength of this approach is that it regularly organizes tangible and intangible factors and offers a structural but relatively simple solution to decision problems.

In addition, by breaking a large logical problem and then descending gradually, to smaller and smaller, one is able to connect the small to the large through simple pairwise comparison judgments. This study uses the following methods to collect data and information:

Documentary method: in order to present the basics of the research, specialized Persian journals (for example, Jihad Daneshgahi Journal) and international journals are used.

Field: a questionnaire tool will be used to collect data in this research. The present research questionnaire follows Mosusavi Zadeh et al. [13]. Finally, it should be noted that the questionnaire used in this study is standard and its validity has already been proven. However, Cronbach's alpha measurement method has been used in this study for its reliability or reliability. For this purpose, the first 30 questionnaires were distributed and Cronbach's alpha was prepared. Given that the value obtained for Cronbach's alpha coefficient is higher than 0.7, it can be said that it has an acceptable reliability test.

4 | Numerical Results

4.1 | Descriptive Statistics

The results for demographic characteristics are shown in *Table 1*.

Table 1. Summary of description population cognitive sample research.

Component-Display	Specifications	Number	Abundance
Gender	Man	363	94.3
	Female	22	5.7
Marital status	Married	385	100
Level of education	Bachelor's degree and lower	290	75.3
	Master degree and higher	95	24.7
Years of service	Less than 10 years	93	24
	10 years to 20 years	210	54.5
	20 years and older	82	21.5

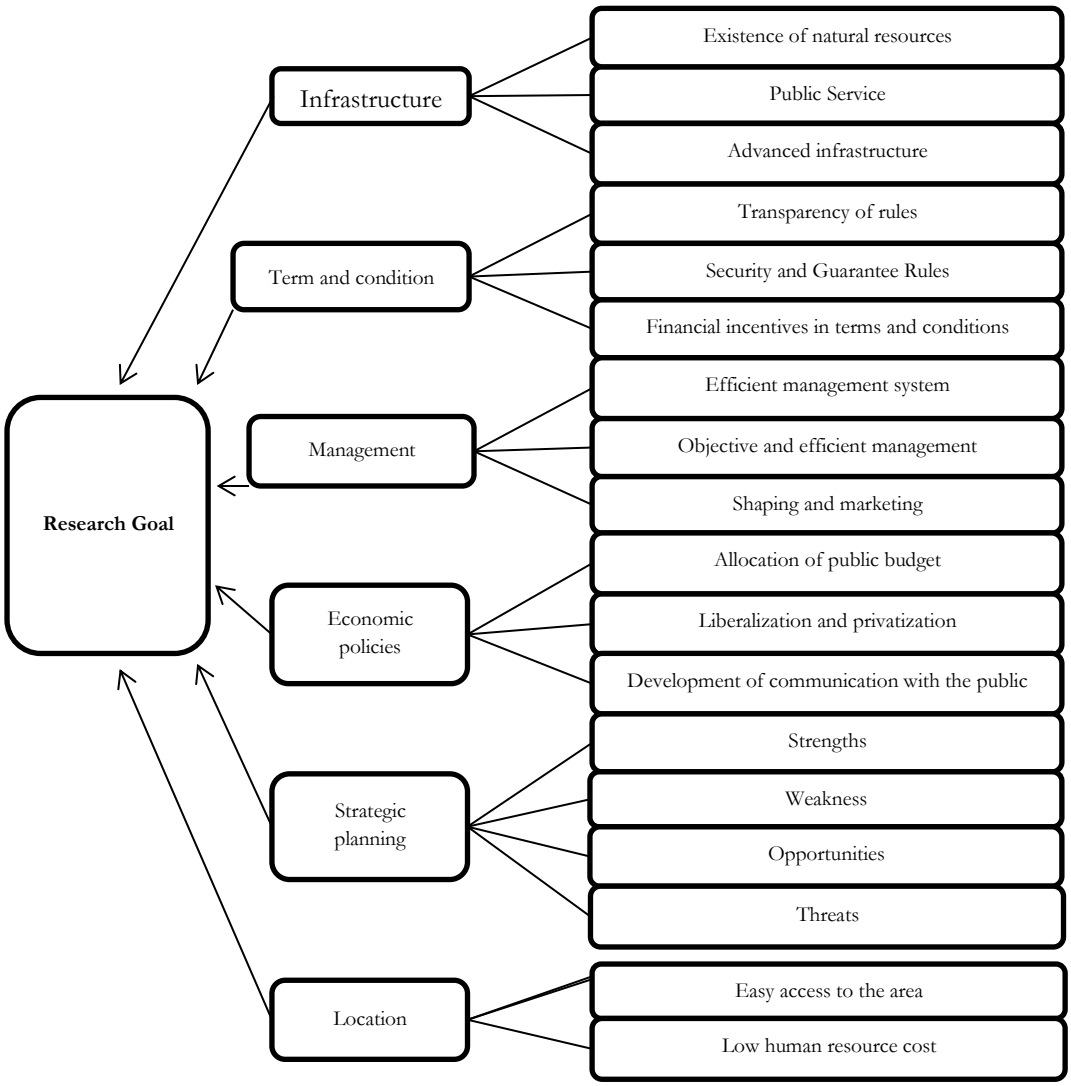

Fig. 1. The Proposed conceptual model.

In addition, in order to describe the data, the mean and standard deviation of the research data were used. A summary of descriptive statistics related to research variables is given in *Table 2*.

Table 2. The weight of each criterion and the range of results.

Weighted Average	Criteria	Minimum	Maximum	Average	Standard Deviation
4.1	Infrastructure	1	5	4.1	0.576
	Facilities and infrastructure	3	5	4.2	0.802
	Public Service	3	5	4.4	0.775
	Advanced infrastructure	1	5	4.1	0.803
3.8	Terms and conditions	1	5	3.8	0.795
	Transparency of rules	1	5	3.6	0.865
	Security and guarantee rules	1	5	4.1	0.776
	Financial incentives in terms and conditions	1	5	3.6	0.854
4.2	Management	1	5	4.2	0.963
	Objective and efficient management	2	5	4.6	0.971
	Useful management system	2	5	4.3	0.823
	Shaping and marketing	2	5	3.6	0.782

Table 2. Continued.

Weighted Average	Criteria	Minimum	Maximum	Average	Standard Deviation
3.7	Economic policies	1	5	3.7	0.756
	Allocation of public budget	2	5	3.9	0.795
	Free and Privatization	2	5	4.1	0.931
	Development of communication with the public sector	1	5	4.1	0.854
3.7	Strategic planning	1	5	3.7	0.756
	Strengths	2	5	3.8	0.751
	Weakness	2	5	3.9	0.767
	Opportunities	2	5	3.6	0.937
	Threats	2	5	3.8	0.867
3.5	Location	1	5	3.5	0.966
	Existence of natural resources	2	5	4.1	0.886
	Easy access to the area	2	5	3.6	0.711
	Low human resource cost	2	5	3.4	0.968

As can be seen, based on the opinions and professional experience of experts, the most important criterion is related to management because it has the highest weighted average among the criteria related to the management variable, which is equal to 4.2. On the other hand, the weakest criterion is location because it has the lowest weighted average among the relevant criteria, which is equal to 3.5.

4.2 | Normality Test of the Data

Kolmogorov-Smirnov test was used to evaluate the normality of the components of the pattern dimensions and in all tests, the statistical hypothesis is as *Table 3*.

Table 3. Kolmogorov -Smirnov test results.

Components	Significance Level (Sig)
Infrastructure	0.087
Terms and conditions	0.081
Management	0.0056
Economic policies	0.072
strategic planning	0.064
Location	0.096

As can be seen in *Table 3*, the Kolmogorov-Smirnov test is significant for the research data, i.e. the significance level is greater than 0.05, so the data have a normal distribution.

4.3 | Results Obtained in the Form of the MCDM Approach

In this section, we try to first display the information obtained from the AHP in the form of tables and then analyze the research hypotheses with respect to the research data which is provided in *Fig. 2*.

At the first level of the decision tree, the target is the factors that affect the attraction of domestic and foreign investors. At the second level, the main criteria affecting the attraction of domestic and foreign investments are presented. The relative weight and priority order of these criteria are in *Table 4*.

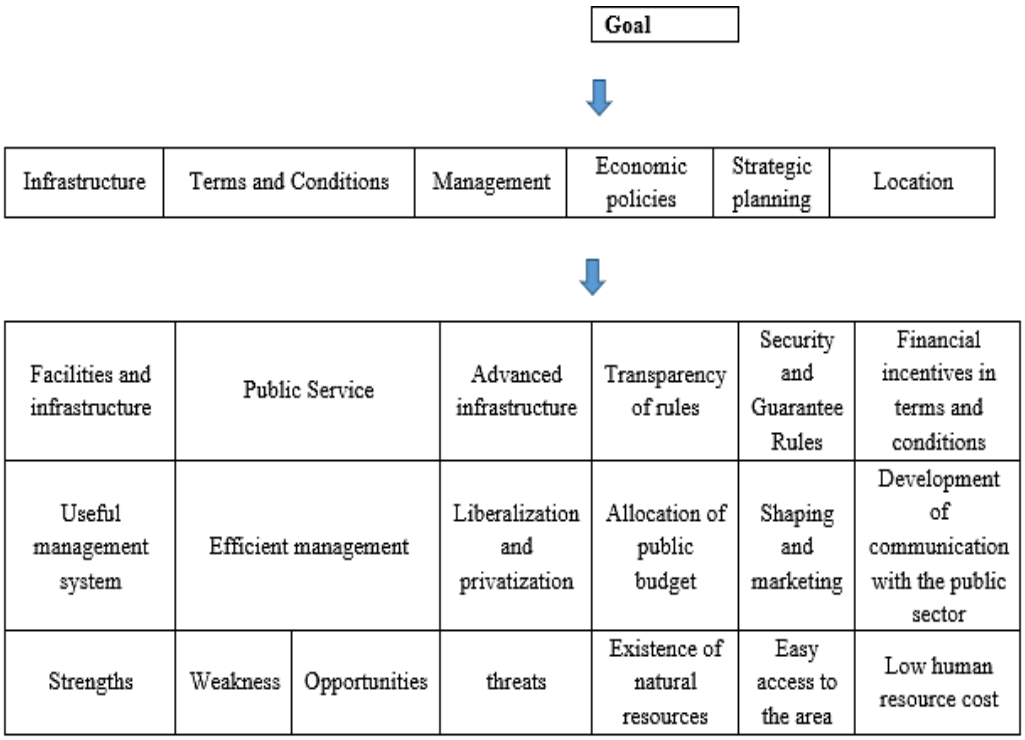

Fig. 2. The structure of the hierarchical process in the applied AHP.

Table 4. Interpretation of second-level priorities.

Main Criteria	Relative Weight	Priority
Management	0.2853	1
Strategic planning	0.1984	2
Infrastructure	0.1943	3
Economic policies	0.1585	4
Terms and conditions	0.0874	5
Location	0.0765	6

By analyzing the data in the table above, it can be concluded that management plays an important role in attracting domestic and foreign investments, followed by strategic planning, infrastructure, economic policies, laws and regulations, and location, respectively. The third level includes the following 19 criteria, which are regularly presented in *Table 5*.

Table 5. Interpretation of third-level priorities.

Sub-Crietria	Relative Weight	Final Weight	Priority
Facilities and infrastructure	0.434	0.149	1
Existence of natural resources	0.547	0.130	2
Allocation of public budget	0.545	0.121	3
Efficient management	0.400	0.101	4
Security and guarantee rules	0.400	0.084	5
Advanced infrastructure	0.387	0.072	6
Strengths	0.170	0.064	7
Useful management system	0.400	0.054	8
Development of communication with the public sector	0.181	0.047	9
Opportunities	0.270	0.035	10
Easy access to the area	0.264	0.029	11
Financial incentives in terms and conditions	0.400	0.024	12
Threats	0.423	0.018	13
Liberalization and privatization	0.272	0.015	14
Low human resource cost	0.187	0.014	15
Transparency of rules	0.200	0.013	16
Public service	0.162	0.011	17
Weakness	0.135	0.010	18
Shaping and marketing	0.200	0.009	19

In this way, the nineteen priorities were identified. Accordingly, facilities and infrastructure have the highest priority, and shaping and marketing have the lowest priority.

5 | Discussion

The general results obtained in the present study show that from the respondents' point of view, the most important factor influencing the attraction of domestic and foreign investments is management. This points to the important role of managers and their position in terms of respondents. It seems that if we rely on proper and efficient management, desirable results can be achieved in the field of free zones and trade in these sectors. Managers of Amirabad Free Zone should also rely on new systems and the design and marketing of Amirabad port in accordance with international standards.

The second factor considered by respondents in order to attract domestic and foreign investment is strategic planning. When it comes to planning, the emphasis is on long-term, medium-term, and short-term plans. But in the meantime, long-term planning shows a roadmap that can have a long-term impact on an organization's decisions. On the other hand, the second priority may be considered to follow the first priority. When respondents emphasize good management, their vision is to have a well-written and long-term plan that can ensure the efficiency and effectiveness of the organization. At the same time, relying on these programs can identify strengths and weaknesses as well as opportunities and environmental threats. Therefore, managers in this field should work harder on strategic planning and identify strengths and weaknesses. Taking advantage of environmental opportunities and reducing threats can bring many benefits to the region in the future.

The third important factor in attracting domestic and foreign investment from the perspective of respondents is infrastructure. Certainly, the existence of facilities and infrastructure such as water, electricity, advanced telephone networks, high-powered Internet of modern ports, usable ports, equipped airports in the region and the size of new urban areas, and in addition, facilities such as tourist areas and Recreation can add to the attractions of the Amirabad region of Behshahr. Fortunately, the Amirabad port of Behshahr, next to the Miankaleh wildlife tourist area, can provide many attractions for traders and even domestic and foreign tourists. In addition, due to its distance from the urban area, the Amirabad region has pristine and beautiful landscapes that can enclose any tourist. The use of these competencies requires proper management, which will make possible the commercial development of the region in the future. These findings are consistent with the results of Abdollahzadeh and Mirbargkar [14], Mosusavi Zadeh et al. [13].

The fourth important factor in attracting domestic and foreign investment is economic policies. In this case, the government and policymakers play an important role. For this, the public budget must be allocated and the liberalization and privatization of the region must be done more quickly. Meanwhile, the development of relations with the public sector can also be considered for the development of the Amirabad port. To do this, the managers of this region must make more efforts. At the same time, the government can consider different resources and budgets for these sectors. These findings are consistent with the results of research by Abdollahzadeh and Mirbargkar [14] and Mosusavi Zadeh et al. [13]. The fifth factor influencing the attraction of domestic and foreign investments in the Amirabad region of Behshahr is laws and regulations. Policymakers and legal entities operating in the international arena play an important role in this area. In order to do this, the transparency of the laws must be effective in providing the services, the security and the guarantee of the laws, and the financial incentives in the laws and regulations. Therefore, to do this, policymakers and managers in these areas should strive to provide legal requirements that will facilitate trade in the area. These findings are consistent with the results Abdollahzadeh and Mirbargkar [14], and Mosusavi Zadeh et al. [13].

Finally, the last factor in attracting domestic and foreign investment is location. It seems that the reason for selecting this variable as the last priority from the respondents' point of view can be considered in a

suitable place in the Amirabad region of Behshahr. The availability of natural resources, easy access to the region, and access to cheap labor are all indicators that exist in this region, and therefore, the basic infrastructure of the region is ready. These findings are consistent with the results of Aggarwal [8].

6 | Conclusion and Future Direction

In this research, a decision-making method for free trade zones was presented. Also, a complete analysis of the effectiveness of each foreign investment indicator in these types of regions was presented. This research can be raised as a basis for the sustainable development of free trade zones. The results of this research can be useful for both theorists and academics as well as for activists in the field of management. Therefore, the following suggestions are made:

1. It is suggested that the managers of Amirabad Free Zone try to expand the infrastructure of the region, including airports, railways, transportation routes, in order to provide the main facilities for the growth of the region. In addition, the use of modern ports, accommodation for merchants, multi-star hotels, and strong internet networks are among these factors.
2. It is suggested that the managers of free zones choose appropriate laws and regulations in order to improve trade in this zone. Transparency of laws, security, and guarantee of laws, and financial incentives in-laws and regulations can be among these issues.
3. It is suggested that the management of free zones be entrusted to experienced and highly educated people. The use of objective and efficient management, management systems, and shaping and marketing based on global standards are among these factors and solutions.
4. It is suggested that the government consider better conditions for free zones. Meanwhile, the governorate and managers, policymakers, and activists of the Behshahr region can also be involved in this sector. Allocation of public funds, liberalization, and privatization or development of relations with the public sector are among these strategies.
5. It is suggested that the managers of Amirabad port of Behshahr use strategic and codified planning in order to improve the future situation of the region. To do this, they can use academics and scientists to identify their strengths and weaknesses and take advantage of environmental opportunities to develop the region.
6. It is suggested that regional managers use the place where Amirabad is located with proper planning. Creating tourist areas and easy access using different ways can be among these cases.

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