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Identifying and analyzing open innovation strategies and providing a relative model in small and medium-sized manufacturing enterprises using fuzzy cognitive mapping (FCM) technique

Mohammad Heydari Maybodi[a], Hassan Dehghan Dehnavi[a,*], Mozhde Rabbani[b], Mohammad Reza Dehghani Ashkezari[b]

[a]*Department of Industrial Management, Yazd Branch, Islmic Azad University, Yazd, Iran*
[b]*Department of Management, Yazd Branch, Islamic Azad University, Yazd, Iran*

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Abstract

Today, globalization, the growth of technological complexity and environmental changes have encouraged the organization to change their attitude from closed innovation to open innovation and prioritize open innovation as a developing approach to gain competitive advantage. This study identifies and analyzes open innovation strategies and provides a model for that in small and medium-sized manufacturing enterprises. This research is practical in terms of purpose and descriptive survey in data collection and mixed in the method. First, effective factors were identified according to the literature review and confirmed by 15 experts in the field of innovation. Then, a matrix questionnaire was prepared and given to 83 experts of small and medium-sized manufacturing enterprises in Yazd city in Iran. Data analysis was done using Fuzzy Cognitive Mapping (FCM) techniques, and the final model was depicted using social networks. The findings related to analyzing data obtained from the experts' opinions indicate that the strategies of external relationships, internal relationships, support infrastructure systems, and technology absorption are more central than other ones because the effectiveness and susceptibility of these strategies are more than other factors. Thus, these strategies should be more emphasized.

Keywords: Open innovation strategy, Small and medium-sized manufacturing enterprises, Fuzzy cognitive mapping analysis, Social networks analysis
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1 Introduction

At this time, the researchers are turning their attention to studying innovation at the enterprise level because of the growing importance of innovation in different societies. Identifying effective factors for innovation of the enterprises is of great importance from at least two aspects. On one hand, enterprises especially small and medium-sized or

*Corresponding author
Email addresses: A007.heydari@gmail.com (Mohammad Heydari Maybodi), Denavi2000@yahoo.com (Hassan Dehghan Dehnavi), Mrabbani@iauyazd.ac.ir (Mozhde Rabbani), Mr.dehghani@ut.ac.ir (Mohammad Reza Dehghani Ashkezari)

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technology-oriented ones should evaluate the effective factors on their innovation performance so that they ensure their decisions, strategies and investments made in this field are effective. On the other hand, the governments should be aware of the effective factors on the innovation of the enterprises in order to take necessary actions to design appropriate and effective policies needed for promoting innovation in enterprises which, in turn, can promote innovation at the national level [3]. Innovation plays a key role in the contemporary world. It brings new products and services to the market while exploring new ways of production, distribution and marketing. In addition, it influences all other aspects of organizations including human behaviour using hard and soft methods [33]. Innovation as a term is widely used in nearly all countries. So far, the studies carried out in the developed countries indicate that there is a significant development in the area of innovation but the developing countries have been starting some measures to identify their weakness in this regard. Moreover, In addition, the limited number of studies performed on innovation and the lack of statistical and measurement related to innovation have shown that sheer commitment to promoting innovation to compete in the global context is inevitable. The lack of innovation studies to enrich decision and policy making has been considered as a major weakness in many developing countries [35].

Therefore, not so much research on open innovation has been done in developing countries. Open innovation as a new paradigm in innovation management has been used as a widespread innovation strategy at organizational and national levels. This approach has promoted innovation in both developed and developing countries. Not only has open innovation offered numerous advantages to commercial organizations, but also it has attracted academic attention. In addition, it has had a significant impact on industrial practices and performances in developed countries [30].

In Iran, although several studies have been done on innovation, they were judged to be of low quality by findings and statistical databases, so they are not sufficient to improve the foundations of innovation. The researchers have studied different aspects of organizational innovation. However, most of these studies focused on innovations in small and medium-sized enterprises, and enough attention has not been paid open innovation strategies. Some researchers have only investigated the effective internal factors of the innovation. Some others have only investigated the effective external factors on innovation, and others have investigated mutual factors affecting open innovation. According to this literature, it can be said that the researchers have not been able to design an integrated model of measures related to open innovation strategy in small and medium-sized enterprises where internal, external and bilateral factors are classified and framed, and the cause and effect relationships of these variables are extracted. The present research tries to summarize and classify the factors and variables related to open innovation and present them in a causal framework in the form of cause and effect relationships. In addition, since no model has been introduced to show how to use open innovation, especially in small and medium-sized enterprises in Iran, this research aims at discovering and designing such a model to fill the gap of studies in this case. It also provides insights for managers involved in industrial innovation processes, encourages them to use open innovation strategies in enterprises and improves cooperation with foreign enterprises to ensure mutual benefits. It also aims at increasing the awareness to open innovation and interest in it in industrial and academic communities.

After reviewing the theoretical foundations and background of the research comes the method. Then the opinions of the statistical community are analyzed using the fuzzy cognitive mapping method, and the final model is depicted using social networks. Finally, practical suggestions will be given based on the findings.

2 Literature review

In a dynamic economy, innovation has a decisive relationship with economic growth, the creation of competitive advantages and the sustainability of organizations under the influence of deep social changes and technological developments. Innovation can be defined as a process of continuous learning and research that leads to the discovery of new ideas in the market. Consequently, these ideas can result in the introduction of new goods or services or improvement in offering goods or services which improve performance in new types of associations and markets [2].

In the traditional innovation model, which is based on the closed innovation paradigm, enterprises rely mainly on internal knowledge and skills to develop new innovations. In this regard, organizations invest in highly qualified human capital and internal research and development processes to create competitive advantages. According to this model, it is required to control organizational processes in order to protect internal intellectual property and avoid or severely limit interactions and exchanges of internal resources and knowledge with external factors [19]. However, dynamic and evolutionary economics and markets have led to greater competitiveness among enterprises and the emergence of a global market. This new paradigm needs new methods to organize internal processes. It also has led to the emergence of a more open and collaborative innovation model. Today, new communication technologies, increasing the mobility of highly skilled workers and the need to reduce costs related to research and development can easily be

seen. As a result, optimizing internal processes and integrating external processes are of high importance to ensure the competitiveness of organizations [11].

Following the above, the concept of open innovation proposed by Chesbrough in [10] is addressed, which is defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. This definition does not consider innovation as a personal action but as an action that depends on the exchange of knowledge flows between different external sources to increase the value of innovation. A challenge that organizations are facing is to find a balance between coordination and integration of internal and external knowledge and competencies [34]. In the new paradigm of open innovation, the projects may use different knowledge and technology resources with various output possibilities in the market. In open innovation processes, organizational boundaries are not complicated. Thus, enterprises can interact with their surrounding environment. This process includes multiple sources of internal and external technologies and several internal and external commercialization channels [2]. In the open innovation paradigm, intellectual property is an important asset for an enterprise because it is regarded as an additional income and boosts the business model. In addition, in this paradigm, the management of knowledge spillovers requires two directions of knowledge flow along the boundaries of the enterprise, including movement from outside to inside and from inside to outside. A new movement called a coupled composed of the elements of previous movements has been presented [18].

The outside-in approach consists of opening a company's innovation process to contributions from various sources from the outside. In practice, this approach involves leveraging the discoveries of third parties, which prevents the company from being exclusively dependent on its own internal R&D activities. There are several sources of external knowledge that the company can use, such as suppliers, competitors, universities, and startups, among others [32]. In the inside-out approach, the companies should allow unused internal knowledge to spread outward. This paradigm helps companies bring their innovations to market in a faster manner. It is a growing need due to the shortening of the product life cycle. Companies can adopt several strategies in the inside-out model, such as licensing intellectual-property rights, creating spinoffs based on previously developed technologies or products, or outsourcing innovation [5]. Coupled open innovation requires that a combination of internal and external flows of knowledge arise in the company to collaboratively develop and/or commercialize an innovation. Two or more agents can be involved in this process, generating mutual knowledge flows between their organizations. This is intended to ensure that the company gains additional knowledge while, on the other hand, it is able to bring ideas to market more effectively [2]. Many researchers have investigated the role of open innovation in improving the performance of organizations. Their studies have described dimensions that are very important in developing and enriching the theoretical framework of the present research. In the rest of the paper, some studies done on pen innovation in small and medium-sized enterprises have been presented in Table 1.

Table 1: A literature review on small and medium-sized enterprises

Author and year	**Method**	**Purpose**	**Key findings**
Spithoven et al. [31]	Quantitative approach	Investigating the impact of open innovation, the innovative performance of small and medium-sized enterprises compared to large companies	The effect of open innovation practices in small and medium-sized enterprises is often different than that in large enterprises. Small and medium-sized enterprises that simultaneously use open innovation methods are more effective in introducing new products to the market
Crema et al. [5]	Quantitative approach	Analyzing the relationship between enterprise strategy, open innovation and innovation performance, with a focus on small and medium-sized enterprises	Companies that follow an innovative strategy invest more in technical skills and core competencies, and companies that choose a diversification strategy are more likely to exclusively choose open innovation management practices.
Pervan et al. [26]	Quantitative approach	Investigating a number of effective environmental factors (government support, financial resources, scientific, industrial collaborations and market dynamics) in supporting open innovation in emerging SMEs in the United Arab Emirates market.	The importance of government support and market dynamism on innovation in these companies does not support financial resources and scientific and industrial cooperation. Finally, innovation is related to local economic development and is supported by specific policies and programs

Hossain and Kauranen [14]	Misanalysis	Open innovation in SMEs: a systematic literature review	SMEs improve their overall innovation performance by choosing open innovation. They found that a large number of studies were conducted with a quantitative approach. Surprisingly, unlike many other disciplines, North American researchers have made limited contributions; But European scientists, along with some researchers from Korea, China and developing countries, have been active in this field
Popa et al. [27]	Quantitative approach	Examining the empirical literature related to evaluating the effect of organizational records and innovation climate on open innovation and also the effect of its consequences on the performance of small and medium-sized enterprises	The results showed that organizational factors such as Commitment-based human resource practices have a positive effect on the innovation climate, which, in turn, helps innovation methods (inside-out and outside-in processes)
Santoro et al. [29]	Qualitative approach	Internet of Things: Creating a Knowledge Management System for Open Innovation and Knowledge Management Capacity	Investigating small and medium-sized enterprises in open innovation shows that these enterprises have a closed approach to this concept and use customers only as a source of external information
Asada et al. [4]	Quantitative approach	Open innovation and knowledge management in small and medium-sized enterprises	External knowledge and internal innovation have a significant contribution to increasing performance in SMEs. In addition, it was found that external knowledge mediates the relationship between external knowledge and internal innovation with the performance of an enterprise
Almeida [2]	Quantitative approach	Open innovation strategies: diversity in Portuguese SMEs	The most common outside-in methods were the integration of external knowledge from suppliers and customers. In the inside-out model, licensing processes were more important. While in the coupled (hybrid) model, joint ventures and consortium networks were important. Increasing the innovation capacity of these organizations was considered the most relevant advantage, while the lack of resources and problems in knowledge integration were raised as challenges.
Khosropour et al. [16]	Quantitative approach	Investigating and ranking the effective factors in the mechanism of applying the open innovation approach	The ranking of the effective factors on the open innovation approach showed that the factors including understanding and exchange, identification of innovative opportunities and networking capability are the most important and the factors including the specific design of structure and process, cooperation from outside to inside and vice versa and internal cooperation are less priority
Manteghi et al. [20]	Quantitative approach	Investigating the success factors of open innovation intermediary enterprises	The success factors include (in order): nano business sector policies, institutions and laws, specialized services, economic factors, cooperation networks, features of the business model of nano companies and structural factors of the network of nanotechnology companies

Molaei et al. [21]	Quantitative approach	Integrating customers in innovation initiatives using open innovation approach	Opening the primary stage of innovation and then integrating different customers in this stage in order to generate innovative thoughts can have a positive effect on the success of the new product; Also, providing a model of customer integration in innovation preparations with the help of open innovation approach
Poursadeq [28]	Quantitative approach	Identifying and prioritizing effective factors on the open innovation in insurance companies	Individual factors: tolerance for ambiguity; courage; risk-taking; independence; self-confidence; locus of control; motivation; perseverance. Organizational factors: structural variables; cultural variables; human resource variables; Other factors, environmental factors: competitive environment; suitable economic conditions; organizational dynamics; technological infrastructure; attention to the customer; technological complexity; Material factors
Babaei et al. [6]	Mixed approach	Designing an open innovation model in small and medium-sized companies using a mixed approach	The highest predictability of the open innovation model is related to facilitation strategies, and the lowest percentage is related to technological opportunity strategies
Jamipour et al. [15]	meta-synthesis method	A framework of open innovation implementation success factors using a meta-synthesis method	The success dimensions of open innovation implementation include internal and external participation, knowledge management, information technology capabilities, human resources, strategic factors, support and organizational infrastructure.
Hakaki et al. [13]	Mixed approach	Providing a multi-level structural back model for the successful implementation of open innovation	Economic factors (the most influential index), universities, research institutes, and information technology support systems in the basic layer were the most important of all. Competitors, colleagues, organization strategy, organizational learning, employees and reward system were categorized in the strategy layer and suppliers, organizational structure and environmental issues were categorized in the operation layer
Bakhsham et al. [7]	Qualitative approach	Identifiing open innovation challenges in small and medium-sized businesses based on the stages of innovation projects	Lack of planning of project partners, inappropriate innovation strategy, unknown partners, inconsistency of goals, lack of social trust, time pressure, lack of financial resources, inappropriate information and control systems, redefinition of goals, ignoring the efforts of partners, bureaucracy and administrative burdens, lack of inappropriate policies for adoption of advanced innovation and failure to achieve the intended goals are the key challenges of small and medium-sized companies to accept open innovation

As a review of the previous literature shows, there was no study that could investigate open innovation strategies to provide a comprehensive model in small and medium-sized enterprises, which includes all dimensions, factors and relationships among them. Thus, all open innovation strategies are necessary to investigate in a cohesive way. In other words, investigating key factors such as internal, external and combined factors and innovation strategy regarding all

dimensions is essential.

3 Methodology

This research is practical by purpose because it aims at applying and testing theoretical concepts to investigate effective strategies of open innovation in the performance of small and medium-sized manufacturing enterprises. It is a descriptive-exploratory and mixed research In terms of how to obtain data because here, the description and interpretation of the existing conditions and relationships between different strategies in the field of open innovation in small and medium-sized enterprises are discussed so that a solution can be given to improve the performance of such companies. From the methodological point of view, a mixed method is used in this research because it uses a combination of different methods in several stages based on a predetermined plan, and the result is a combination of research methods, not a specific method [8]. Thus, the modelling process in this research is implemented in four steps in the context of a mixed research methodology. In the first and second steps, a qualitative approach and in the third and fourth steps, a quantitative approach are used. Documentary-survey method is sued. In the first stage, the initial conceptual framework of effective open innovation strategies for the performance of small and medium-sized manufacturing enterprises is extracted. In the second stage, the mental model of the experts is extracted, and the results are analyzed using the fuzzy cognitive mapping method.

Fuzzy cognitive mapping (FCM) is a directed graph with feedback consisting of nodes and connections between them. Nodes represent the concepts or variables which describe the behavior of the system, and the balanced directional arcs represent the causal relationship between these concepts [23, 24]. A fuzzy cognitive map F is a 4-tuple (N, W, C, f) where $C = \{C_1, C_2, ..., C_N\}$ denotes the nodes of the map and represents the concepts involved in the problem. $W : C \times C \longrightarrow [-1, 1]$ is an $N \times N$ matrix that includes W_{ii} or the weights of the causal relationships between the concepts. Causal relationships between C_i and C_i are determined numerically in the interval $[-1, +1]$. ($W_{ij} \in [-1, 1]$) indicated the intensity and direction that one concept influences other concepts [17]. Function $A : C \longrightarrow A_2^{(t)}$ calculates the degree of activation of each of the concepts C_i in discrete times $t = \{1, 2, ..., T\}$.

Since the fuzzy cognitive method is the main analysis method in the present study, its basics are explained in detail in the rest. Accordingly, the fuzzy cognitive map is a technique that Kosoko [17] created for quantitative modeling based on the knowledge and experience of experts. It is also an efficient fuzzy graph that shows nodes, concepts and arcs, as well as the relationships between concepts. A fuzzy cognitive map consisting of n concepts is displayed in an $n \times n$ matrix (proximity matrix) [25]; in this way that $W_{ij} > 0, W_{ij} < 0$ and $W_{ij} = 0$ mean, respectively, positive, negative and no relationship between two concepts. Moreover, the values of W_{ij} show how much concept C_i affects another concept C_j. In addition, the centrality of a concept C_j in a cognitive map is determined by the sum of the number of concepts influencing C_j (directly and indirectly) and the number of concepts dependent on C_j. These numbers are determined by the number of edges in the paths leading to C_j and leaving it. In the fuzzy cognitive map, the number and the influence of cause and effect relationships can be considered to define a more accurate view of the concept of centrality using the following relationships:

$$C(C_i) = IN(C_i) + OUT(C_i) \tag{3.1}$$

where $IN(C_i)$ is the sum of the weight of the causal relationships, including all connecting paths from nodes C_j, $(I \neq j)$ to node C_i calculated using relation (3.2):

$$IN(C+_i) = \sum n_j = 1W_{ij} \tag{3.2}$$

It should be added that in relation 3.1, $OUT(C_i)$ is the sum of the weight of the causal relations, which includes all the paths connected from node C_i to all nodes C_j calculated using relation 3.3:

$$OUT(C_i) = \sum_{j=1}^{n} W_{ij} \tag{3.3}$$

In the summation of causal weights, absolute values are used for assigning equal importance to positive and negative relationships. In addition, a fuzzy cognitive map based on imprecise fuzzy expressions shows mutual relationships in concepts. The experts are asked to describe the relationship between two concepts using a fuzzy rule describing the cause and effect relationship and explain the degree of influence of one concept on the other concept using the linguistic

concept. Then, their responses are converted into numbers between negative ones and positive on. Once the data are gathered, the linguistic variables are transformed using the table of fuzzy numbers, and then their averages are obtained according to equation (3.4) (n is the number of experts).

$$W = (w_i^1, w_m^1, w_u^1) \quad i = 1, 2, ..., n \tag{3.4}$$

$$W_{avf} = \sum n_i = 1(wi(i)_i, wm(i), wu(i))/n \tag{3.5}$$

Then comes defuzzification. For this stage, the weighted average defuzzification method is used:

$$W_{\max} = w_1 + 2w_m + w_u/4 \tag{3.6}$$

In the third stage, the integration map for effective strategies on open innovation to improve the performance of small and medium-sized enterprises is extracted, and the necessary analysis of the qualitative model for it is done. Then, some scenarios for its development are simulated according to the model, and their results are investigated using analysis of social networks. Fcmapper and Ucinet softwares are used to perform, respectively, fuzzy cognitive mapping and social network analysis. A discussable topic in the field of cognitive mapping is the analysis of concepts and the calculation of the effectiveness of each concept in the mapping structure. Kosko introduced the concept of centrality to calculate the importance and weight of a node in a fuzzy cognitive map. Özesmi and Özesmi used degree centrality to analyze the structure of social FCMs by characterizing their most important nodes [22], but in general, few researchers have used this criterion to identify important concepts in the structure of a cognitive map. In the present study, the central conformity index has been used in order to analyze the nodes and identify the most effective node in the fuzzy cognitive mapping structure. This index is obtained from three indices, including centrality degree ($Cen_D(C_i)$), closeness degree ($Cen_C(C_i)$) and betweenness degree ($Cen_B(C_i)$):

$$Cen_{Cons}(C_i) = Cen_D(C_i) + Cen_C(C_i) + Cen_B(C_i) \tag{3.7}$$

$$id(c_i) = \sum_{j=1}^{N} |W_{ji}|$$

$$od(c_i) = \sum_{j=1}^{N} |W_{ij}|$$

$$Cen_D(C_i) = id(c_i) + od(c_i) \tag{3.8}$$

In these relations, $id(c_i)$ is equal to the input degree of the node, c_i. N is equal to the number of nodes connected to c_i node in the cognitive mapping, and W_{ji} is the weight of the input edge from node c_j to node c_i. $od(c_i)$ is the output weight of the nth node, which is the net sum of the weights of the output edges from the node to the neighboring nodes.

$$Cen_B(C_i) = \sum_{i \neq S \neq T \in C} \frac{\sigma_{ST}(C_i)}{\sigma_{ST}} \tag{3.9}$$

relation (3.9) is used to obtain the betweenness degree, where σ_{ST} represents the number of shortest paths between T and S. In addition, $\sigma_{ST}(C_i)$ is the number of shortest paths between node T and node S that passes through node C_i.

$$Cen_C(C_i) = \frac{1}{\sum d_G(C_i, t)}; \ (t \in C \backslash C_i) \tag{3.10}$$

Relation (3.10) is used to calculate the closeness degree where $d_G(C_i, t)$ is the shortest path between node t and the node C_i in the structure of a map. The statistical population of this research is experts in the field of innovation in small and medium-sized enterprises in Yazd city and university professors. Since the method used was qualitative,

the snowball method was used for sampling. In addition, some highly experienced experts were identified during several stages. After data gathering, they were asked to introduce other experts, and finally, the number 83 experts from the statistical community were selected to participate in building the final model. The privacy of people and the confidentiality of the information obtained from the respondents were protected. The validity of this qualitative research was evaluated using methods including long-term participation, continuous observation, holistic view, peer review or feedback as well as member control method. In qualitative research, reliability often refers to the stability of responses of multiple coders to the data set [1]. In the present research, the agreement between the coders was reached, which confirmed its reliability.

4 Findings

First, effective open innovation strategies for the performance of small and medium-sized manufacturing enterprises were identified and extracted by reviewing the research background and library study. In this step, 14 factors were identified. The next stage included semi-structured interviews with 15 experts. Consequently, a number of factors were removed, merged or added from the prepared list. The criterion for the agreement was the meaningfulness of the concepts related to open innovation in small and medium-sized enterprises, and finally, all the experts approved a total number of 11 factors. The refined list of strategies related to open innovation in small and medium-sized manufacturing enterprises can be seen in Table 2.

Table 2: Refined list of strategies related to open innovation in SMEs by experts

Row	Factor
1	Organizational context
2	Organizational structure
3	Cultural strategy
4	Continuous learning strategy
5	R&D strategy
6	Internal relationships
7	External relationships
8	Economic strategy
9	The central strategy of the organization
10	EO strategy
11	Support infrastructure system and technology absorption

The second stage of the qualitative modeling process is extracting and analyzing the experts' causal map. Once coordination was made, and one or two in-depth interviews with experts based on a pre-prepared form were held, the table of factors was again given to the experts, and after the final approval, a matrix of effective factors and strategies for innovation to improve the performance of small and medium-sized manufacturing was prepared and given to experts. By scoring from -1 to $+1$, the experts showed the relationship between the factors and the intensity of each of the strategies. In this way, they completed the matrix and thus, the mental model of each expert was obtained. In the next step, the causal map of each expert was depicted using Fcmapper software. To ensure the accuracy of the process of recording and to extract the mental model of the experts, the relevant experts approved the causal map. After the mental model of the experts was determined, the possibility of extracting an integrated causal map for the model of the effective factors and strategies for open innovation to improve the performance of small and medium-sized enterprises was investigated. Table 3 shows the integrated matrix of experts, which reflects the impact of each variable (strategy) on another based on the summation of experts' opinions.

After combining the opinion of the experts, the effectiveness and susceptibility of each strategy were analyzed using Fcmapper software. The results are shown in table 4. The higher the degree of centrality of a strategy and factor, the more influential it is in the network of factors and strategies.

Considering Table 4, it can be said that the higher the degree of centrality of a factor, the more important it is in the network of factors. Based on Table 5 and its evaluation, the role of the effective factors in improving the condition of other factors and scenarios was investigated. In the first scenario, all the factors are in an active state, which remains unchanged in comparison to compare the other two scenarios. In the second scenario, a situation is simulated where external relationships are considered, but no effort is made to improve internal relationships, the support infrastructure system and absorb technology. In the third scenario, two strategies of internal relationships and

Table 3: The final diffusion matrix resulting from the integration of mental maps of experts

	Organizational context	Organizational structure	Cultural strategy	Continuous learning strategy	R&D strategy	The central strategy of the organization	External relationships	Economic strategy	The central strategy of the organization	EO strategy	Support infrastructure system and technology absorption
Organizational context	0.00	0.80	0.20	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.60
Organizational structure	0.65	0.00	0.15	0.75	0.95	1.00	1.00	0.40	1.00	0.50	1.00
Cultural strategy	1.00	0.80	0.00	0.90	0.80	0.90	0.90	0.10	1.00	1.00	0.50
Continuous learning strategy	0.20	0.40	0.30	0.00	0.80	0.50	0.50	0.20	0.70	1.00	0.60
R&D strategy	0.00	0.20	0.00	0.10	0.00	0.20	0.40	0.60	0.30	0.90	1.00
Internal relationships	0.50	1.00	0.60	0.80	0.70	0.00	1.00	0.70	1.00	0.50	0.50
External relationships	1.00	1.00	0.70	0.70	0.80	1.00	0.00	0.90	0.70	1.00	1.00
Economic strategy	0.70	0.70	0.50	0.50	0.80	0.60	0.70	0.00	1.00	0.80	1.00
The central strategy of the organization	0.30	0.50	0.50	0.70	0.80	0.90	0.90	0.60	0.00	0.90	0.90
EO strategy	0.50	0.30	0.20	0.70	0.80	0.70	0.80	0.50	0.30	0.00	0.70
Support infrastructure system and technology absorption	0.60	0.50	0.50	0.50	0.80	0.80	0.70	0.70	0.50	0.80	0.00

Table 4: The amount of effectiveness, susceptibility and centrality of each strategy

Factors	**Centrality**	**Susceptibility**	**Effectiveness**	**Rank**
Organizational context	12.55	5.45	12.55	7
Organizational structure	13.60	6.20	13.60	5
Cultural strategy	11.55	3.65	11.55	11
Continuous learning strategy	11.85	6.65	11.85	10
R&D strategy	11.95	8.25	11.95	9
Internal relationships	14.90	7.60	14.90	2
External relationships	16.70	7.90	16.70	1
Economic strategy	12.50	5.20	12.50	8
The central strategy of the organization	14.00	7.00	14.00	4
EO strategy	13.40	7.90	13.40	6
Support infrastructure system and technology absorption	14.20	7.80	14.20	3

the support infrastructure system and absorption of technology are considered, but no attention is paid to improving external relationships. Table 5 shows the results of the second and third scenarios.

If enough attention is paid to the external relationships, but no attempt is made to improve the internal relationships, upgrade the support system and attract technology, all factors move in a negative direction to a low or moderate extent. It means that all factors will drop. Thus, it can be concluded that improving factors including external relationships, internal relationships, the support system and technology absorption are not able to develop

Table 5: The results of the simulation of the proposed scenarios based on the model

Factors	Strategy 1	Strategy 2	Strategy 3	The results of strategy 1	The results of strategy 2	The results of strategy 3	Comparing strategies 2 and 1	Comparing strategies 3 and 1
Organizational context	1.00			0.99840	1.00	0.995595867	−0.00333262	−0.00280439
Organizational structure	1.00			0.99924501	0.99653609	0.99792251	−0.00270892	−0.00132250
Cultural strategy	1.00			0.990418952	0.971083256	0.980663618	−0.01933570	−0.00975533
Continuous learning strategy	1.00			0.999517981	0.998183393	0.999015473	−0.00133459	−0.00050251
R&D strategy	1.00			0.999902656	0.999551174	0.999780133	−0.00035148	−0.00012252
Internal relationships	1.00	1.00	1.00	0.999813462	0	1	−0.99981346	0.00018654
External relationships	1.00	1.00	1.00	0.999861772	1	0	0.00013823	−0.99986177
Economic strategy	1.00			0.997965	0.991700	0.994978914	−0.00626516	−0.00298587
The central strategy of the organization	1.00			0.999660	0.998428	0.999304232	−0.00123201	−0.00035560
EO strategy	1.00			0.999862	0.999477	0.999618575	−0.00038439	−0.00024317
Support infrastructure system and technology absorption	1.00	1.00	1.00	0.999848	0.000000	1.000000	−0.99984782	0.00015218

open innovation to improve the performance of small and medium-sized manufacturing enterprises alone. All these factors are dependent on each other.

After simulating different scenarios on the model, the data of the integration matrix of the experts was inserted into the Ucinet software, and a graph was depicted from the model. This graph actually shows the most important effective strategies for open innovation to improve the performance of small and medium-sized manufacturing enterprises. As it can be seen in this schematic graph, any strategy that is of a more important role in improving performance is located in the center of the graph (Figure 1).

5 Discussion and Conclusion

Today, globalization, the growth of technological complexity and environmental changes have encouraged the organization to change their attitude from closed innovation to open innovation and prioritize open innovation as a developing approach to gain competitive advantage. Although many studies have been done on open innovation, no one has investigated open innovation strategies to improve the performance of small and medium-sized enterprises. Thus, in the present research, first, the theoretical concepts were studied and then, a qualitative model was provided to clarify the effective strategies for open innovation using FCM and social media analysis techniques so that a proper map can be given to the manager to use open innovation in their organizations.

Since today's organizational resources are limited, small and medium-sized manufacturing enterprises can benefit from external relationships and inter-organizational cooperation to develop innovation. External relationships pave the way for enterprises to gain new knowledge sources and create a foundation for continuous learning. In external relationships, enterprises do their best to source technology in cooperation with service providers or by networking with advanced and innovative companies. External resources help reduce the time, risk and cost of innovation and increase flexibility and operationality. In the present research, the external relationships strategy was selected as the first important strategy to improve the performance of small and medium-sized manufacturing enterprises in

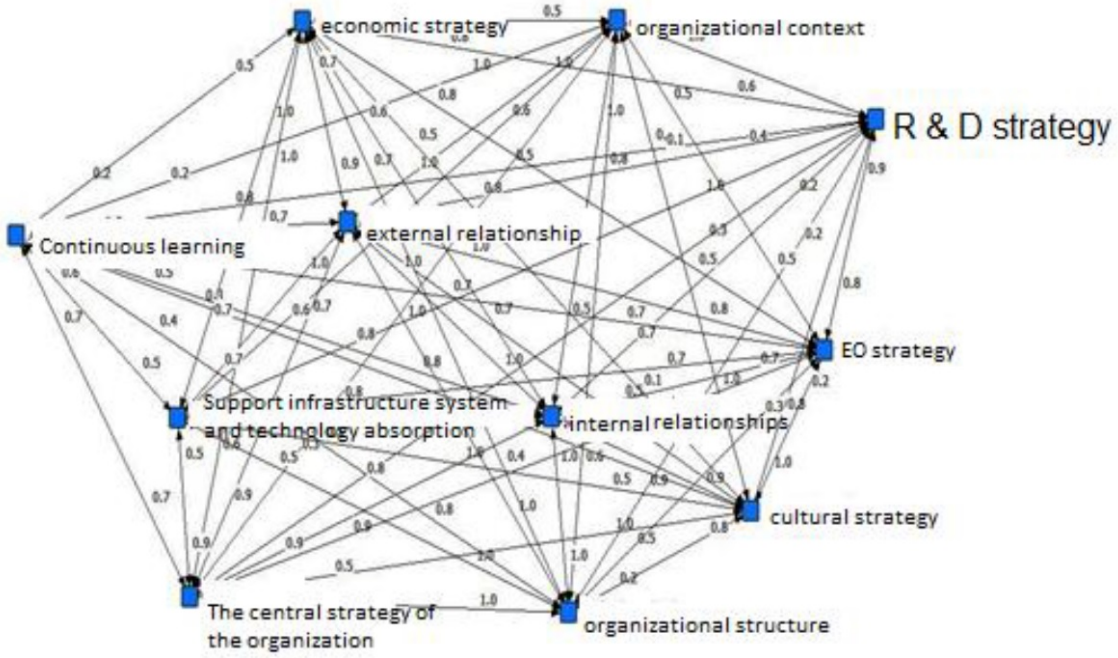

Figure 1: Fuzzy cognitive map of effective strategies for improving the performance of small and medium-sized manufacturing enterprises

the field of open innovation. Thus, it is suggested that such enterprises should consider external relationships with innovative companies, NGOs, research institutions, universities, customers, suppliers, competitors and public and private partners as their main goal to create, implement, disseminate ideas and improve the process of open innovation. Some researchers, such as Almeida [2] and Jamipour [15], have also emphasized the importance of external relationships and accelerating the innovation process through relationships with external partners in the field of open innovation studies in small and medium-sized enterprises.

The other result of the present research is that the internal relationship in an enterprise should be emphasized. In studies on open innovation, the approach to internal relationships and using capabilities within the organization is of great importance. Often, enterprises interested in open innovation pay more attention to external relationships and ignore the importance and necessity of participation and internal relationships. Internal relationships emphasize active cooperation and involving the organization's employees in the process of implementing open innovation. The cooperation between different units and employees has a positive effect on sharing tasks and knowledge in different departments of the organization and can bring about better insights into the existence of the specializations and capabilities in the organization. Intra-organizational relationships build a bridge between different stakeholders in the organization and different units so that they can better understand innovative opportunities. However, realizing internal relationships and creating partnerships within the organization is not so easy. It is suggested that small and medium-sized manufacturing enterprises in Yazd use technological infrastructures such as blogs, social networks, online forums and other communication technologies to boost their internal relationships and enrich the innovative activities of employees and shareholders. The results of the present study are consistent with the results of the studies carried out by Bigliardi et al. [9] and Hakaki [13] and their colleagues.

Technology can be developed based on values, beliefs, facilitating processes and flexible structure. It is why the support and absorption of appropriate technology infrastructure can have a significant effect on the innovation and open innovation environment. The promotion of open innovation strategies in small and medium-sized manufacturing enterprises necessitates organizational agility and flexibility to accept the necessary changes for adapting to the open innovation strategy. It can be realized with the support of new technology systems and their absorption. The implementation of open innovation is impossible if new and up-to-date technologies are not absorbed. On the other hand, information technology has become a key tool for developing innovation and changing traditional ways of doing work into new ones. Information technology capability (ITC) refers to organizational capabilities to acquire, implement, combine and reconfigure IT resources to achieve competitive advantages. Small and medium-sized manufacturing enterprises can upgrade their hardware and software systems to improve open innovation. Poursadeq [28] and Bakhsham [7] indicated in their studies on the same topic that companies with better infrastructure which can support and absorb innovative technology are more successful in using the open innovation approach.

According to the results obtained from fuzzy mapping analysis, external relationships are considered the most effective strategy on other strategies and factors. Thus, it can be said that the most effective factor in the open innovation approach is the external relations strategy. On the other hand, the significant effect of external relationships on other strategies and factors reflects that this factor has a great role in improving the performance of small and medium-sized manufacturing enterprises. The centrality of each of the open innovation strategies in the performance was calculated by summing up the values related to the effectiveness of various factors. The centrality of a factor represents its relative importance in terms of influencing other factors or being influenced by them. In other words, it can be said that the centrality of a node represents its activity level in the adjacency matrix. It is suggested that managers and trustees of small and medium-sized manufacturing enterprises pay enough attention to these three factors and prioritize the improvement and promotion of the mentioned strategies.

At the end of this paper, it should be noted that the present study suffers from some limitations despite its theoretical value. This problem can be mended in future quantitative and qualitative research. Of these limitations is the use of fuzzy logic, which still has the possibility of errors in recording opinions. Another one is the unfamiliarity of managers of small and medium-sized manufacturing enterprises with managing open innovation approach and their reluctance to share detailed information, which caused problems in the work preparation process. The limited availability of experts in the field of innovation due to the COVID-19 added to the problems. In general, this research can be used as a guide for additional research in this area. Using other strategies and factors and mathematical planning can help determine the best combination of strategic goals and implement them in the future in other industries and types of services. In addition, the present research has developed a framework of open innovation strategies at the theoretical level that has not been tested in a given company. Therefore, it is recommended to conduct a case study in a selected company and evaluate it using the proposed research framework. This research has identified open innovation strategies to improve performance. Carrying out other quantitative and qualitative research can help identify the effective factors and strategies for the open innovation approach in a more accurate way. Managers, trustees and activists of manufacturing industries in small and medium-sized enterprises can use the results of the present study to improve their performance.

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