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A Novel Hybrid Model for Technology Strategy Formulating in High-tech Industries under Uncertainty: A Case Study

N. Kazemifard[a], L. Bashir[a,b], D. Rahmani*[c]

[a] Technical Affairs and Network Development Department, Mobile Telecommunication Company of Iran, Tehran, Iran
[b] Department of Management, University of Tehran, Tehran, Iran
[c] Department of Industrial Engineering, K. N. Toosi University of Technology, Tehran, Iran

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ABSTRACT

Globalization and increased virtual communication have posed many challenges to high-tech companies; hence, such companies are sparing efforts to detect the best technologies in this field to solve new and emerging challenges addressing traffic load, communication system security, and infrastructure optimization. Telecommunications companies deal with a highly dynamic and uncertain environment, where their relevant technologies are changing and developing at an increasing speed. Regarding such an environment in telecommunications companies, the present study aimed to present an efficient model for formulating technology strategies for these companies. The proposed model is a hybrid method of attractiveness-capability matrix and, multi-criteria decision-making approaches in an uncertain and dynamic environment. The model provides the attractiveness-capability evaluation factors and criteria regarding the requirements of dynamic and uncertain environments in these companies. This approach provides a more accurate picture of the rapidly changing technologies in formulating technology strategy. The model also used the fuzzy TOPSIS to control the uncertainty aroused by widespread emerging technologies in such organizations. The proposed model is implemented concerning the requirements of the Mobile Communications Company of Iran (MCI), and its results are discussed in detail.

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1. INTRODUCTION

Nowadays, enhanced traffic load, exacerbated by the COVID-19 pandemic, has imposed much more pressure on public, cloud infrastructures, edges and access points serving residential areas. As such traffic load is also incurred on the edges and access points of service provider networks, some innovative solutions are mandatory to match bandwidth and traffic control demands. New technologies and digital ecosystems' multi-layered structure, encompassing network, software, and services, determine how new values are defined, thereby setting the grounds for communication service providers to offer practical and novel solutions [1].

Managers of large and high-tech industries are constantly faced with the question of which decisions should be selected and which should be left to company-level managers. Technology planning is one of those cases that its process of making decisions and the degree of attention is unclear, especially at the level of a large-scale industry [2]. These reasons have caused it essential and, so difficult to attain challenging technologies.

Accordingly, telecommunications companies are sparing efforts to detect the best technologies in this field and develop Technology Strategy Formulating (TSF) models to solve new and emerging challenges addressing traffic load, communication system security, and infrastructure optimization. In this regard, technology development and acquisition projects are the main components affecting enterprises' modernization, sustainability, and competitiveness [3]. In a similar vein, the technology portfolio is introduced to determine decisions about technology combination and Technology Strategy (TS), achieve investment goals,

*Corresponding Author Email: drahmani@knru.ac.ir (D. Rahmani)

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and establish a balance between risk/performance and asset allocation. Framing TS mainly aims to limit some technologies balancing risks, benefits and matching with organizational strategies.

This paper is outlined as follows: Section 2 considers the related literature. Section 3 presents a framework based on the attractiveness- competitiveness evaluation matrix. In section 4, the proposed TSF model is described, and section 5 analyses the proposed methodology using the fuzzy TOPSIS for MCI. The last section contains the results and suggestions for future research.

2. LITERATURE REVIEW

In this section, the relevant literature is reviewed in separate parts, as follows:

2. 1. Technology Strategy Formulation Models

Researchers have proposed many approaches and models to TSF, the most appropriate of which is compatible with the industry's features and flexible in the face of changes. A literature review revealed two main approaches to TSF [4] in the past years. The first approach is concerned with organizations or companies' position includes Poret's model, Hax and Mahluf's model and Little's model. The second one is a resource-oriented approach regarding key organizational capabilities and includes Kieza, Prahalad, and Hamel's Core Competency model and D'Oney's Super Competition model, and others [5]. Little's model deals with the market and its determinants and focuses on competition and success in the market. In this model, technologies associated with critical determinants should be specified to formulate TSs to detect future investments by recognizing the company's technology-related priorities. Poret's model considers decisive attitudes toward technology development and exploitation as a critical factor in promoting competitiveness. According to Poret's model, there are six steps to formulate TS. Hax and Mahluf developed their model based on Poret 's conceptual TSF model. In their proposed model, the key inputs of the TSF process are considered the organization's macro strategies. According to this model, the strategy of the selected technologies is formulated when the attractiveness of the selected technologies affecting TSF is determined, and the organization's capabilities regarding the concerned technologies are assessed. Arasti et al. [6] presented an integrated TSF model using the positioning approach. Ebrahimi et al. [7] presented a new TSF model for Iran's petrochemical industry. Nezhad et al. [5] also proposed a seven-stage TSF model underpinned by Hax and Mahluf's and Little's model using the positioning approach for the Auto Parts Manufacturing Industry. Alvarado et al. [8] developed a comprehensive and economic Technology Selection and Operation (TSO) model, which allowed decision makers to optimally select technology from the existing options and simultaneously optimize technology selection and usage. Mohammadzadeh et al. [9] used attractiveness-capability matrix of Technology to strategic technologies selection for oil production.

Besides the aforementioned classical models in the literature, some quantitative technology portfolio selection (TPS) methods have also been proposed to the model selection. Heidenberger and Stummer [4] classified quantitative TPS methods into six categories. Schuh et al. [10] tried to conceptualizing a turbulence-induced initiation phase for technology strategy development. Ghazinoory et al. [2] presented cascade roadmaps as a tool for technology strategy formulation in Oil Industry .

2. 2. Technology Portfolio under Uncertainty and Conflict Criteria

Evidently, in line with developing a technology portfolio, the selected technologies need to be evaluated using different criteria; however, their evaluation is challenging. As some of emerging technologies are new and vague for decision makers to evaluate, it seems that applying techniques based on the uncertainty and ambiguity of the input information is essential. Such techniques greatly reduce the evaluation error and increase the validity of the results rather than using traditional qualitative methods. In the evaluation of recognized technologies, experts often should provide assessments based on intangible and conflicting criteria. For example, in analyzing the strategic nature of new technology, it is possible to be better in some criteria and be weaker in others, and the analysis of such a contrast in the traditional approaches caused a higher averaging error. The conflict between various criteria is managed using Multi-Criteria Decision Making (MCDM) methods to address such issues.

Shen et al. [11] adopted an MCDM approach developing a technology selection model regarding organizations' economic and industrial perspectives. Since the preferences of experts regarding these criteria are frequently descriptive and qualitative rather than quantitative; therefore, such issues frequently lead to mental uncertainty especially because these technologies are essentially new and have a lot of uncertainties for the expert. Fuzzy set theory is one of the most effective methods for addressing the uncertainty caused by the complexity of the features of options and the decision-making behaviour of experts. In this project, the high uncertainty of technology analysis and the inherent conflict between criteria are managed using a fuzzy multi-criteria decision-making approach. Fuzzy TOPSIS technique is one of the famous and reliable methods of fuzzy multi-criteria decision-making, which is used in this project to rank options under uncertainty.

Moazenzadeh and Hamidi [12] developed a model for mobile banking; they proposed the TOPSIS (Technique for Order Preference by Similarities to Ideal Solution) method, the underlying concept of which is that the selected alternative should have the smallest and the largest distance from the positive and negative ideal solutions, respectively. A positive ideal solution maximizes profit and minimizes cost; however, a negative ideal solution maximizes cost and minimizes profit [12]. In the classic TOPSIS method, the weights of the criteria and the ratings of the alternatives are precisely specified. This is, while exact data are insufficient to model real decision-making problems in some other cases. Accordingly, the fuzzy TOPSIS method is proposed where the weights of criteria and the ratings of alternatives are evaluated by linguistic variables represented by fuzzy numbers to deal with the deficiency in the traditional TOPSIS [13, 14].

Cil et al. [15] proposed an integrated evaluation model using fuzzy AHP and fuzzy TOPSIS to select the positioning technology offering advanced services in the SEDEF shipyard. Aliakbari et al. [16] also developed a hybrid model using Fuzzy TOPSIS to evaluate and rate technologies appropriately in a company.

2. 3. Research Gap and Novelty There has been an increase in environmental dynamism and uncertainty in technology-oriented companies over the past years. A TS mandates maintaining and expanding sustainable competitive advantage by establishing technological capabilities. However, the established methods for this purpose are highly time-consuming and rarely adapt to the situation because of their discrete sequential approach combined with extensive analyses [17]. Organizations have been increasingly experiencing volatility, uncertainty, complexity, and ambiguity in their environment, which were posed by various factors, including globalization, digitalization, and industry convergence [18]. Telecommunications industry organizations operate in highly dynamic and uncertain environments, and technologies associated with their operations (e.g., Emerging Technologies (ETs)) are remarkably changing and developing for such organizations worldwide. Valinejad et al. [19] developed a hybrid model for telecommunication industry to assess the supply chain risk management based on five-dimensional sustainability approach.

ETs have become one of the main fields of global competition, and their complicated features challenge managers to formulate TSs encompassing both systematic theories and methods. According to Zhao et al. [20], the core content of ETs is technology selection and formulation. Accordingly, TSF is more complicated in telecommunications organizations; hence, more precise approaches are required to develop their TSF model and determine benchmarks and technology evaluation techniques.

A review of the literature reveals no efficient TSF model compatible with the dynamic and uncertain environment of such companies. In fact, by examining the case study, it was observed that there are three requirements for telecommunications companies to formulate :

1. Since the technologies in this field are extremely diverse and rapidly changing, they need a model that not only conceptually, but also determines the exact characteristics and criteria for evaluating the technologies. To the best of our knowledge, there is no comprehensive research in the telecommunications industry that has comprehensively and accurately determined criteria and sub-criteria for evaluating emerging technologies .
2. Since many of these technologies are emerging and there is no complete information about all of them by experts, so the uncertainty in the evaluation is quite evident. Therefore, the proposed model should have the power to manage uncertainty.
3. The existence of many operational, social and political restrictions such as transaction means that the evaluation of technologies should not be based solely on their capabilities and attractiveness, therefore, a model is needed that, in addition, measures the ability of the organization to use each technology.

The proposed model of this study, to cover the above requirements, proposes a hybrid model that, to cover the first requirement, determines the analysis steps in detail and especially the evaluation criteria and sub-criteria. For the second requirement, it uses the fuzzy approach to control the uncertainty, and to cover the third requirement, it uses the attractiveness-capability matrix.

Accordingly, the present study aimed to provide a new analytical framework compatible with the uncertain environment of such organizations to illustrate telecommunications technologies clearly. This new analytical model mixes the existing quantitative models and uses the fuzzy approach for non-deterministic technology analysis and evaluation.

3. ATTRACTIVENESS-COMPETITIVE CAPABILITY MATRIX

The attractiveness-competitive capability matrix (ACM) is used to detect technological priorities and their appropriate strategies. This matrix is developed based on Porter's conceptual model. When allocating resources, including capital resources, human resources, equipment, and physical facilities, to strategic plans, some internal competition exists to overcome resource limitations [21]. The results of this matrix facilitate specifying the strategic position of technologies and the key technologies [22]. Using this matrix, however, mandates the definition and development of factors and criteria facilitating a multi-dimensional and comprehensive evaluation [23].

Technology assessment models are underpinned by a two-dimensional framework. In these models, one-dimension deals with internal factors, which are mainly controlled by companies and are intertwined with their behaviour and decisions. Such factors are known as technological competitiveness [24, 25]. On the other hand, external factors, including the behaviour of customers, competitors, governments, and other stakeholders, are beyond the organization's control. They explain the status of technology outside the organization; hence, they are called technological attractiveness [23]. To detect appropriate TSs, both the attractiveness of each technology and the organization's competitive capability should be addressed. To this end, the attractiveness-competitive capability matrix is drawn for technologies, according to which a decision can be made to determine the appropriate strategy for the concerned technology. The ACM has four distinct districts, as presented in Figure 1. A strategic approach can be adopted for each of the technologies existing in these four districts:

District (1): The attractiveness of the technologies in this district is not high, and the organization's competitive strength is also low. Accordingly, these technologies are not necessary, and the organization's appropriate strategy is to hand them over to other companies or not focus on them.

District (2): The attractiveness of the technologies in this district is high; hence, they are necessary. However, the organization's competitive strength is low. Accordingly, two different TSs can be adopted: (a) The organization can use the services of successful organizations, or (b) The organization reinforces its competitive capability for these technologies.

District (3): The attractiveness of the technologies in this district is low; however, the organization's competitive strength is high. Due to the organization's mastery of these technologies, the appropriate TS is either to transfer them to other organizations or to use them in other products.

District (4): The technologies of this district are of paramount importance since they are highly attractive, and the organization's competitive strength is also high in this district. Accordingly, the appropriate TS is to be prioritized in the acquisition list. Moreover, regarding the organization's highly competitive strength, these technologies should be acquired as internal or collaborative research and development.

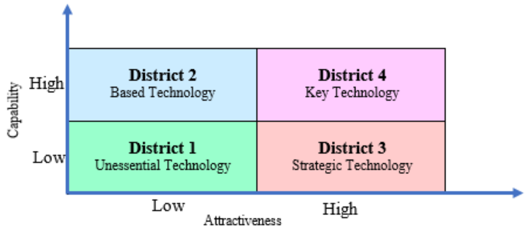


Figure 1. Attractiveness-Competitive Capability Matrix

4. METHODOLOGY: A MODEL FOR TECHNOLOGY STRATEGY FORMULATION IN THETELECOMMUNICSTION INDUSTRY

Organizations have been increasingly experiencing volatility, uncertainty, complexity, and ambiguity in their environment, which were posed by various factors, including globalization, digitalization, and industry convergence [18, 19]. Such organizations require a TSF model tailored to their dynamic and uncertain conditions. In this section, according to Figure 2, the hybrid TSF model for telecommunications companies is proposed. To this end, after detecting the technologies, the following steps were taken:

(1) Designing decision matrices for competitive strength and attractiveness separately;

(2) Prioritizing technologies using the fuzzy TOPSIS technique for competitive strength and attractiveness separately;

(3) Designing the attractiveness-competitive matrix and positioning each technology;

(4) Analysis and Strategy formulation.

In Step 2, the fuzzy TOPSIS technique was used to control the uncertainty aroused by evaluating technologies. This is briefly explained below:

- Fuzzy TOPSIS

The steps of fuzzy TOPSIS used for ranking the technologies are as follows [26]:

First Step:

Firstly, k experts are defined as $D_k = \{1, 2, ..., K\}$. Then, each team is asked to evaluate m technologies based on each n criteria, which is defined (for each attractiveness and competitive capability index, separately) based on fuzzy linguistic variables according to the following Table 1. Each linguistic variable has an equivalent triangular fuzzy number in the form of $\tilde{A}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ in which, after replacement based on verbal variables, a primary decision matrix will be formed.

After creating the decision matrices for each expert team, the matrices should be normalized. The following equations are used for matrices normalization. The normal matrix of each expert team is defined as $\tilde{R}_k = [\,\tilde{r}_{ijk}\,]_{m*n}$: in which:

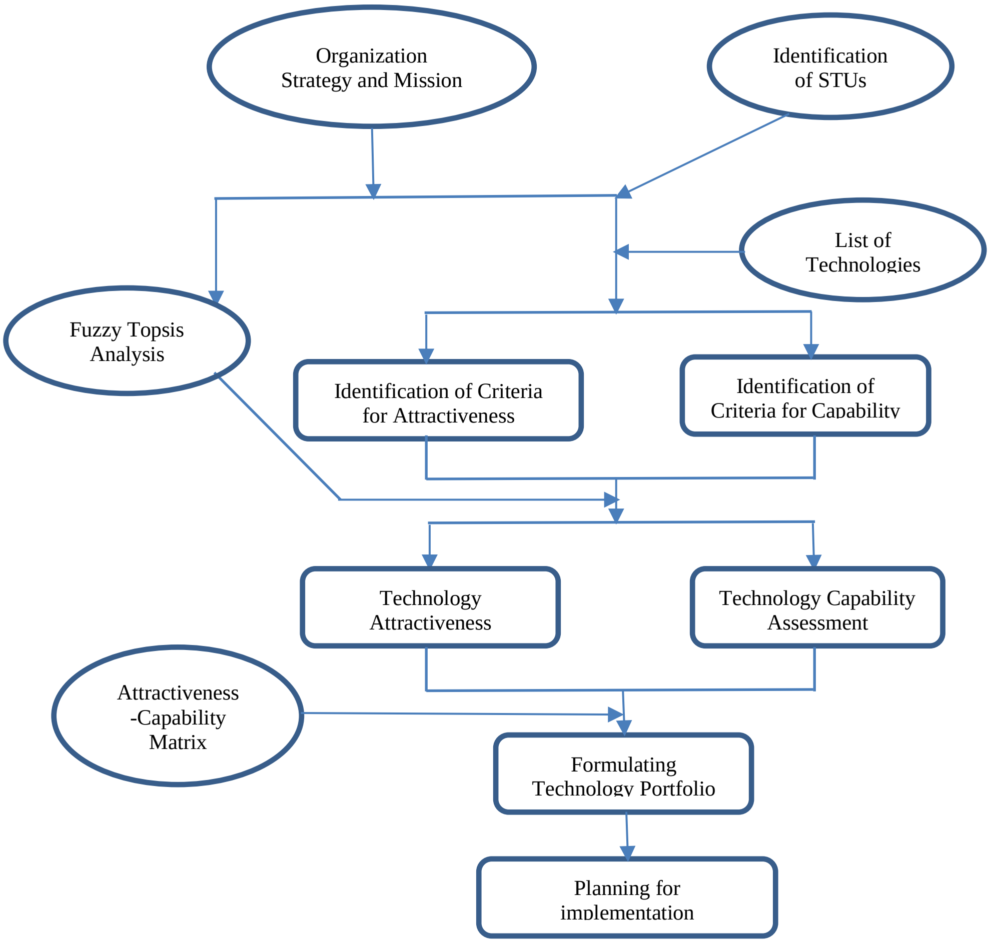


Figure 2. Proposed model for technology strategy formulation

TABLE 1. Linguistic variables for ratings

Linguistic Variables	Triangular Fuzzy Numbers
Very Poor	(0,1,2)
Poor	(1,2,3)
Medium Poor	(2,3.5,5)
Fair	(4,5,6)
Medium Good	(5,6.5,8)
Good	(7,8,9)
Very Good	(8,10,10)

$$\tilde{r}_{ijk} = \left(\frac{a_{ijk}}{c^*_{jk}}, \frac{b_{ijk}}{c^*_{jk}}, \frac{c_{ijk}}{c^*_{jk}}\right) \quad (1)$$

where:

$$c^*_{jk} = Max_k \left\{c_{ijk}\right\} \quad (2)$$

Second Step:

Since different criteria have different importance for each expert group, each team is asked to determine the importance of each criterion based on the fuzzy linguistic variables in Table 2.

Based on the fuzzy numbers in Table 2, the weight of the criteria is defined as a fuzzy number $\tilde{W}_{jk} = (w_{jk1}, w_{jk2}, w_{jk3})$. Then, the following equations

TABLE 2. Linguistic variables for importance weight of each criterion

Linguistic Variables	Triangular Fuzzy Numbers
Very Low	(0,0,0.2)
Low	(0.1,0.2,0.3)
Medium Low	(0.2,0.35,0.5)
Medium	(0.4,0.5,0.6)
Medium High	(0.5,0.65,0.8)
High	(0.7,0.8,0.9)
Very High	(0.8,1,1)

are used to the union the weights, which are determined by the expert to define them as $\tilde{W}_j = (w_{j1}, w_{j2}, w_{j3})$ according to the following equations:

$$w_{j1} = Min_k \{w_{jk1}\} \quad (3)$$

$$w_{j2} = \frac{1}{K}\sum_k w_{jk2} \quad (4)$$

$$w_{j3} = Max_k \{w_{jk3}\} \quad (5)$$

Since this problem is a group decision problem, it is necessary to integrate the matrix of all k experts. The following equation are used to create the final integrated matrix is defined as $\tilde{R} = [\tilde{r}_{ij}]_{m*n}$ in which $\tilde{r}_{ij} = (a_{ij}, b_{ij}, c_{ij})$.

where:

$$a_{ij} = Min_k \{a_{ijk}\} \quad (6)$$

$$w_{ij} = \frac{1}{K}\sum_k w_{ijk} \quad (7)$$

$$c_{ij} = Max_k \{c_{ijk}\} \quad (8)$$

Third Step:

The weight of each criterion should be multiplied in the normalized matrix to get the final normalized weighted matrix as $\tilde{V} = [\tilde{v}_{ij}]_{m*n}$ in which $\tilde{v}_{ij} = \tilde{r}_{ij} * \tilde{W}_j$.

Fourth step:

In this step, the positive (FNIS, A^*) and negative (FNIS, A^-) ideals for each criterion are calculated by the following equations and known as the "calculation of ideals".

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_n^*) \quad (9)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^-) \quad (10)$$

where:

$$\tilde{v}_j^* = Max_i \{v_{ij3}\} \quad (11)$$

$$\tilde{v}_j^- = Max_i \{v_{ij1}\}, \quad i=1,2,..,m \; j=1,2,..,n \quad (12)$$

Fifth step:

At this step, the distance of each technology from the positive and negative ideals is calculated through the following equations, which are known as "calculation of the distance to the negative ideal" and "calculation of the distance to the positive ideal", respectively.

$$d_i^* = \sum_j d(\tilde{v}_{ij} - \tilde{v}_j^*) \quad i=1,2,\ldots,m \quad (13)$$

$$d_i^- = \sum_j d(\tilde{v}_{ij} - \tilde{v}_j^-) \quad i=1,2,\ldots,m \quad (14)$$

D is the distance between two fuzzy numbers, (a_1, b_1, c_1) and (a_2, b_2, c_2) are two fuzzy numbers. The distance is calculated as:

$$d_v(\tilde{M}_1, \tilde{M}_2) = \sqrt{1/3((a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2)} \quad (15)$$

Sixth step:

The following equation is used to compute the relative closeness to the ideal solution, and the results are presented on a sheet, Index of Similarity calculation.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad (16)$$

Seventh step:

The calculated CC_i score for each technology in the previous step should now be scaled between 0 and 1, as these scores will be used to create the attractiveness matrix. Then the final scores are used in the analysis and provision of decision matrices.

5. TECHNOLOGY STRATEGY FORMULATION FOR MCI

The first step of this model is to detect telecommunications technologies and their position in the hype cycle. To this end, the telecommunications technologies were first examined according to the world's most prestigious institutions. As result, 191 technologies were selected according to international reports and approved by specialized experts. Moreover, seven main fields of the STU (App, Device, Smart Network, Service Support, Security, Management, People and Process) technology were detected by and the opinions of experts and specialists in the field. During meetings with them, the extracted 191 technologies were classified into the seven fields regarding their applications.

5. 1. Designing a Decision Matrix for Attractiveness Index (A)

Evaluation indicators should first be specified to analyze technology attractiveness. Hax and Mahluf attributed technology attractiveness to the effect of technology outside the organization and introduced factors facilitating the external analysis of each technology. Some of those criteria are as follows: the potential to reinforce competitive advantage in the product and the process, the technological change rate, the added value potential, the long-term effect of technology on costs, performance, and quality, and the effect on industry standards. Jolly [23] classified attractiveness indicators into four categories, namely market potential, technical potential, competitive capability, and socio-political situation.

The present study considered four main criteria to evaluate attractiveness. Given the significance of the accuracy and specialization for each of these four criteria, some sub-criteria were also introduced.

5. 1. 1. Strategic Attractiveness Index (A1) The extent the technologies affect the realization of the organization's strategic goals determines the strategic attractiveness (A1) of technologies. As shown in Table 3, 10 sub-criteria are specified for A1. Moreover, the expert uses linguistic variables in Table 1 to evaluate the technologies in each sub-criterion.

5. 1. 2. Market/economic Attractiveness Index (A2) The market/economic attractiveness (A2) is the second evaluation criterion measured by the amount and significance of technology use in the company's current and future services/products. To this end, we need a service-technology matrix to detect the most attractive technologies using the intersection of services and technologies.

5. 1. 3. Technical Attractiveness Index (A3) This criterion assesses the technical features of technology. It is determined by some sub-indices, including the level and the potential effect of technology on business regarding positioning indices on the HYPE cycle, benefit rating (extent of the effect on industry), penetration in the market, acceptance time, and life cycle maturity. Table 4 presents the decision matrix regarding this index and its sub-criteria.

5. 1. 4. Environmental Attractiveness Index (A4) This criterion determined the extent of access to technologies regarding the following issues: sanctions on access to suppliers, legal and regulatory requirements, the effect of technology on the organization, and environmental requirements. Table 5 shows the matrix for A4 and its sub-criteria.

5. 2. Developing a Decision Matrix for Competitive Capability Index (B) The following four criteria are suggested to evaluate an organization’s competitive capability strength for a given technology: Competitive strength of HR, competitive strength of equipment (existing hardware and infrastructure), competitive strength of technical knowledge, and competitive strength of orgaware (Table 6).

TABLE 3. Decision matrix for Environmental attractiveness criterion according to four sub-criteria

Technology	**Sub-criteria f or strategic attractiveness**									
	Maintaining and reinforcing a unique architecture consistent with the future of information technology;	Promoting customer experience at all contact points;	Offering a customer-oriented product portfolio	Acquiring and developing technologies of priority	Having effects on regulatory organizations' telecom programs	Ensuring the provision of efficient information technology services	Institutionalizing security in organizations from the first steps of design	Ensuring network efficiency and reliability	Establishing a future-oriented network	Ensuring income growth and diversification

TABLE 4. Decision matrix for technical attractiveness criterion according to five sub-criteria

Technology	**Sub-criteria for technical attractiveness**																								
	Position on the HYPE cycle					Benefit Ratings				Penetration in the market					Acceptance time				Maturity in the life cycle						
	1	2	3	4	5	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	5	6	7

TABLE 5. Decision matrix for environmental attractiveness criterion according to four sub-criteria

Technology	**Sub-Criteria for Environmental attractiveness**			
	Access to suppliers regarding some issues (e.g., sanctions)	Effect of technology on organization	Environmental effects, with higher values indicating being more destructive	Legal/regulatory requirements and obligations

TABLE 6. Decision matrix for competitive capability criterion according to four sub-criteria

Technology	Sub-Criteria for Environmental attractiveness			
	The competitive strength of HR (B1)	The competitive strength of equipment (hardware and infrastructure) (B2)	The competitive strength of technical knowledge (B3)	The competitive strength of orgaware (B4)

5. 3. Step 2: Prioritizing Technologies Considering the designed matrices, 191 technologies were completed by six expert teams using fuzzy numbers. In the following, the matrices are aggregated to evaluate the technologies in terms of attractiveness and competitive capability.

5. 3. 1. Prioritizing Technologies by Attractiveness Index Adopting the Fuzzy TOPSIS technique, the matrices completed by six expert groups were aggregated regarding attractiveness. Due to space limitations, the aggregate matrix results are reported only for the first 10 technologies (out of 191 technologies) in Tables 7-11.

Following aggregation, the technologies were rated in terms of attractiveness using the fuzzy TOPSIS technique (Table 8).

5. 3. 2 .Prioritizing Technologies by Competitive Capability Index In the next step, the matrices should be aggregated in terms of competitive capability. In Table 9, the aggregate matrix results are reported concerning competitive capability only for the first 10 technologies.

Following aggregation, the technologies were rated in terms of competitive capability using the fuzzy TOPSIS technique (Table 10).

TABLE 7. Fuzzy aggregate matrix of experts' opinions on attractiveness for the first 10 detected technologies

Code	Technology	STU	A1			A2			A3			A4		
T1	DigitalOps	Service support/ Apps	0.08	0.57	0.85	0.00	0.29	0.88	0.44	0.46	0.48	0.51	0.76	1.00
T2	Total Experience for CSPs	People & process	0.11	0.57	0.81	0.00	0.54	1.00	0.02	0.13	0.52	0.14	0.59	1.00
T3	CSP Data Monetization	Management	0.26	0.62	0.94	0.04	0.30	0.70	0.33	0.34	0.35	0.40	0.75	1.00
T4	Converged Cloud Management	Infrastructure	0.17	0.68	0.98	0.00	0.18	0.50	0.41	0.43	0.44	0.50	0.71	0.88
T5	Intercarrier Service Automation	Infrastructure/ service support	0.18	0.59	0.96	0.00	0.14	0.37	0.25	0.26	0.27	0.45	0.70	0.93
T6	B2B Service Platform	Service support/ Apps	0.54	0.76	0.95	0.07	0.32	0.44	0.40	0.41	0.43	0.47	0.78	0.98
T7	5G Charging	Service support	0.52	0.81	1.00	0.09	0.37	1.00	0.48	0.50	0.52	0.45	0.73	0.97
T8	Data Literacy	People & process	0.00	0.56	0.90	0.00	0.39	0.86	0.51	0.53	0.55	0.50	0.80	1.00
T9	Service and Resource Orchestration	Service support	0.51	0.73	0.96	0.02	0.14	0.48	0.53	0.56	0.58	0.55	0.78	1.00
T10	Platform Operating Models	Apps	0.03	0.60	0.93	0.00	0.46	0.92	0.06	0.09	0.19	0.51	0.72	0.94

TABLE 8. Final rating of technologies in terms of attractiveness index using fuzzy TOPSIS technique for the first 10 detected technologies

Code	Technologies	STUs	d_i^-	d_i^*		Score
T1	DigitalOps	service support/ Apps	2.37	2.16	0.523648	0.577359
T2	Total Experience for CSPs	People & process	2.21	2.57	0.462445	0.398191
T3	CSP Data Monetization	Management	2.20	2.23	0.496796	0.498752
T4	Converged Cloud Management	Infrastructure	2.14	2.23	0.489049	0.476073
T5	Intercarrier Service Automation	Infrastructure/ service support	1.86	2.48	0.428713	0.299441
T6	B2B Service Platform	service support/ Apps	2.27	1.95	0.537576	0.618134
T7	5G Charging	Service support	2.66	1.79	0.597352	0.793125
T8	Data Literacy	people & process	2.48	2.09	0.542652	0.632994
T9	Service and Resource Orchestration	service support	2.40	1.87	0.561735	0.688857
T10	Platform Operating Models	Apps	2.10	2.48	0.459269	0.388893

TABLE 9. Fuzzy aggregate matrix of experts' opinions on competitive capability for the first 10 detected technologies

Code	Technology	STU	B1			B2			B3			B4		
T1	DigitalOps	Service support/ Apps	0.00	0.38	0.67	0.00	0.35	0.67	0.00	0.26	0.75	0.00	0.31	0.63
T2	Total Experience for CSPs	People & process	0.00	0.43	0.89	0.00	0.48	0.89	0.00	0.39	1.00	0.00	0.41	0.80
T3	CSP Data Monetization	Management	0.10	0.36	0.67	0.10	0.39	0.89	0.00	0.34	0.75	0.10	0.45	0.80
T4	Converged Cloud Management	Infrastructure	0.10	0.51	0.89	0.10	0.51	1.00	0.10	0.48	1.00	0.10	0.57	0.90
T5	Intercarrier Service Automation	Infrastructure/ service support	0.00	0.40	0.89	0.00	0.38	1.00	0.00	0.34	0.75	0.00	0.33	0.80
T6	B2B Service Platform	Service support/ Apps	0.00	0.43	0.89	0.00	0.35	0.89	0.00	0.34	0.75	0.00	0.28	0.80
T7	5G Charging	Service support	0.00	0.45	0.89	0.00	0.43	0.89	0.00	0.47	1.00	0.00	0.30	0.80
T8	Data Literacy	people & process	0.00	0.40	0.89	0.00	0.38	0.89	0.00	0.34	1.00	0.00	0.28	0.63
T9	Service and Resource Orchestration	Service support	0.00	0.38	0.67	0.00	0.35	0.67	0.00	0.26	0.75	0.00	0.31	0.63
T10	Platform Operating Models	Apps	0.00	0.43	0.89	0.00	0.48	0.89	0.00	0.39	1.00	0.00	0.41	0.80

TABLE 10. Final rating of technologies in terms of competitive capability index using fuzzy TOPSIS technique for the first 10 detected technologies

Code	Technology	STU	d_i^-	d_i^*	CC_i	Score
T1	DigitalOps	Service support/ Apps	1.74	2.89	0.375575	0.213178
T2	Total Experience for CSPs	People & process	2.29	2.68	0.461053	0.373605
T3	CSP Data Monetization	Management	2.01	2.63	0.433598	0.322077
T4	Converged Cloud Management	Infrastructure	2.51	2.36	0.514723	0.474334
T5	Intercarrier Service Automation	Infrastructure/ service support	2.16	2.76	0.438141	0.330604
T6	B2B Service Platform	Service support/ Apps	2.08	2.79	0.427922	0.311425
T7	5G Charging	Service support	2.28	2.70	0.457707	0.367326
T8	Data Literacy	People & process	2.13	2.79	0.43254	0.320091
T9	Service and Resource Orchestration	Service support	2.16	2.71	0.44294	0.33961
	Platform Operating Models	Apps	1.95	2.78	0.412197	0.281911

5. 4. Designing ACM ACM was finally developed after obtaining the final ratings of attractiveness and competitive capability for each technology (Table 11). Accordingly, Figure 3 illustrates ACM.

In the company's technology portfolio encompassing existing technologies or some technologies partially affecting existing/future services and products, 20 technologies were placed in District 4 of ACM, considered priority technologies. Attractive technologies consisted of 28 technologies in District 3 of ACM, and mature and essential technologies consisted of 41 technologies in District 2 of ACM.

5. 5. Result Analyses and Technology Acquisition Solutions The final step in TSF is to propose solutions to develop and acquire TSs regarding technological fields and technologies under investigation. To provide appropriate TSF for each technology, its technical features, along with the company's existing competitive strength in a concerned district, should be considered. For example, the company's existing competitive strength, along with the position of technology in the life cycle or its maturity extent, should be considered. In this regard, one should not ignore technological dimensions, which were also examined in evaluating the technical attractiveness of these technologies.

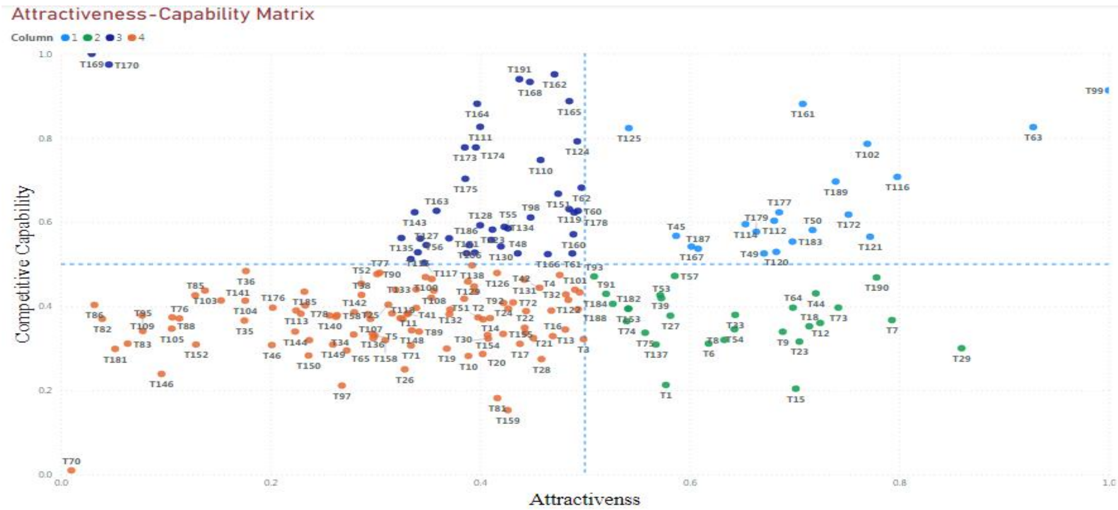
In this updating phase of the TSF project, a questionnaire addressing technologies identified in Districts 3 and 4 of ACM (priorities 1 and 2) and technology acquisition techniques was prepared and completed by the experts.

- **Suggestions to promote technological competitiveness and technology acquisition with priorities 1 and 2**

Tables A1 and A2 in the appendix present the attractiveness and competitive capability scores for some technologies as samples. As shown in this Table

TABLE 11. Final attractiveness and competitive capability scores and the district of the first 10 detected technologies

District	Competitiveness score	Attractiveness score	STU	Technology	Code
3	0.2132	0.5774	service support/ Apps	DigitalOps	T1
1	0.3736	0.3982	People & process	Total Experience for CSPs	T2
1	0.3221	0.4988	Management	CSP Data Monetization	T3
1	0.4743	0.4761	Infrastructure	Converged Cloud Management	T4
1	0.3306	0.2994	Infrastructure/ service support	Intercarrier Service Automation	T5
3	0.3114	0.6181	service support/ Apps	B2B Service Platform	T6
3	0.3673	0.7931	service support	5G Charging	T7
3	0.3201	0.6330	People & process	Data Literacy	T8
3	0.3396	0.6889	service support	Service and Resource Orchestration	T9
1	0.2819	0.3889	Apps	Platform Operating Models	T10



A1, the selected 5 technologies, a majority of which are infrastructure technologies. In this district, the technologies are of paramount importance since both their attractiveness and the company's competitive strength are high. Accordingly, the most appropriate strategy for these technologies is prioritized in the acquisition, maintenance, and promotion list. Moreover, regarding the company's high competitiveness, these technologies should be acquired as internal or collaborative research and development.

Table A2 lists some technologies with high attractiveness for which the company's competitive strength is low (technologies in district 3). They are the second priority of technology development or acquisition.

Although the company's general competitiveness is high for these technologies, some techniques to promote competitiveness are as follows:

- Cooperation in research and supporting technology companies, universities, and research centers;
- Employment and development of specialized HR;
- Promoting organizational knowledge by granting scholarships, holding specialized training courses, and others;
- Concluding consultation and educational contracts with natural and legal persons;
- Establishing or supporting centers for technological growth, acceleration, and development in affiliated companies;
- Developing existing hardware infrastructure in companies, equipment purchase, technical knowledge, infrastructure, and others;
- Possessing or purchasing some shares of small-sized enterprises /start-ups; and
- Maintaining and promoting existing competitiveness

- **Managerial insights**

When managers of a single and large industry such as telecommunications face the emergence of new and diverse technologies in a fast and dynamic manner, choosing among them and investing in them is a very complicated matter. Basically, choosing between them causes complexity and disagreement between managers. The presented hybrid model can be a conceptual and technical guide for tech industry managers to determine their technology portfolio. The design of this new model helps managers to identify technologies first at certain times. Then, step by step, it allows the analyst to finally assign the necessary points to each technology based on the opinion of the managers and in an uncertain environment and choose the best set of technologies for the organization.

According to the literature, advanced industries, while having the ability to use new technologies, see their future as dependent on handling fast changes in technology [27].

6. CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

Nowadays, technology plays a critical role in promoting organizational competitiveness; hence, it should be considered an essential organizational resource from a strategic perspective. In fact, appropriate TSF helps organizations reach a technological advantage. Regarding the research novelty, the present study, for the first time, addressed a complicated issue, i.e., determining some attractiveness-competitiveness evaluation indices and their weights in technology-oriented industries, including MCI. We consider the methodology of the present study to be unique and as such, it makes a significant contribution to the literature on national innovation systems.

The present study sought to combine the models existing in the technology management literature to develop a novel model more compatible with the telecom industry's uncertain environment. In this regard, a TSF model underpinned by ACM was proposed. Given the inherent uncertainty in this industry, the fuzzy TOPSIS method was used to evaluate the company's attractiveness and competitiveness. After analysing the position of each technology in ACM, an appropriate strategy was introduced for each technology. If the proposed model is to be used in technology-oriented industries, ETs and existing technologies are recommended to be detected in detail, and their positioning, including their position in the hype cycle, should be specified.

When ACM was used to evaluate technologies, many technologies in this matrix were in District 3, indicating their high attractiveness and low competitive strength. Accordingly, since the detailed fuzzy TOPSIS method was used to evaluate the attractiveness of the technologies, the scores of these technologies can be considered to prioritize them and select the best technologies in the concerned district for making strategic decisions. Future researchers can propose a new approach to solve this problem.

The main problem with ACM specifying the general strategies of the matrix districts is to detect strategies placed within the boundaries of the matrix cells. It seems challenging to determine a crisp boundary for different districts to have different strategies on each side of the boundary. Accordingly, future studies can address the definition of fuzzy and probable boundaries.

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APPENDIX A

TABLE A1. Attractiveness and capability competitive scores for some technologies in district 4 (priority 1)

Code	Technology	STU	Attractiveness score	Competitiveness score	District
T99	LTE-A	Infrastructure	1.0000	0.9132	4
T161	IMS/ vIMS	Infrastructure	0.7080	0.8810	4
T63	vEPC	Infrastructure	0.9279	0.8259	4
T125	IPv6	Infrastructure	0.5419	0.8235	4
T102	Network Firewalls	Infrastructure/ security	0.7696	0.7861	4

TABLE A2. Attractiveness and competitiveness scores for some technologies in district 3 (priority 2)

Code	Technology	STU	Attractiveness score	Competitiveness score	District
T57	eSIM	Device	0.5858	0.4721	3
T93	LTE for Mission-Critical and Public Safety Networks	Infrastructure	0.5089	0.4709	3
T190	5GC	Infrastructure	0.7784	0.4686	3
T44	Cloud-Native CSP Infrastructure	Infrastructure	0.7204	0.4307	3
T91	Edge Computing for CSPs	Infrastructure	0.5202	0.4296	3

Persian Abstract

چکیده

جهانی شدن و افزایش ارتباطات مجازی، چالش های متعددی را برای شرکت‌های مخابراتی ایجاد کرده است. برای رفع چالش‌های جدید و نوظهور نظیر بار ترافیکی، امنیت سیستم‌های ارتباطی و بهینه سازی زیرساخت‌ها، سازمان‌ها و شرکت‌های تلکام به دنبال شناخت فنآوری های برتر این حوزه می باشند. از طرفی، سازمانهای خدمات ارتباطی از محیطهای بسیار پویا و غیرقطعی برخورد هستند و فناوریهای مروبط به آنها با سرعت فزاینده ای در حال تغیر و توسعه می باشند. برای این منظور در مقاله‌ی حاضر، یک مدل کارای تدوین پورتفولیو فنآوری، برای شرکت های تلکام مبتنی بر فضای پویا و غیرقطعی آنها ارائه داده است. مدل پیشنهادی یک مدل هیبریدی از رویکرد ماتریس جذابیت – توانمندی و رویکرد تصمیم گیری چندمعیاره در فضای غیرقطعی و پویا است. در این مدل، عوامل ومعیارهای ارزیابی جذابیت-توانمندی مبتنی بر نیازمندهای محیط پویا و غیرقطعی این شرکتها ارائه شده است تا تصویر دقیقتری از فناوریهای به شدت در حال تغییر در تدوین استراتژی فناوری ارائه دهد. در این مدل، برای کنترل عدم قطعیت ناشی از ارزیابی فناوریهای نوظهور گسترده در چنین سازمانهایی از تکنیک تاپسیس فازی در ارزیابی فناوریها استفاده شده است. مدل پیشنهادی بر اساس ضرورتهای شناسائی شده در MCI اجرا و نتایج آن تحلیل شده است.