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A project portfolio selection framework for transforming Iranian universities into entrepreneurial institutions

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Abstract

Purpose – This research proposes a framework by which universities can define and implement projects that transform them into entrepreneurial universities. The framework helps decision-makers identify suitable goals and strategies, gather a list of projects to fulfill the goals and strategies and prioritize the projects and form a portfolio.
Design/methodology/approach – In the proposed framework, importance–performance matrix, hierarchical strategic planning, Delphi technique, DEMATEL-based ANP and a multi-objective model are used. The mathematical model consists of four objective functions including efficiency, quality and balance maximization and also cost and risk minimization. The proposed framework is applied to Amirkabir University of Technology, Tehran, Iran, and the results are brought in this paper.
Findings – The output of the proposed framework is a portfolio of projects that aims to transform a traditional university into a third-generation one. Although the final portfolio must be customized for different universities, the proposed steps of the framework can be helpful for almost all cases.
Originality/value – The suggested framework is unique and uses both qualitative and quantitative techniques for project portfolio selection.

Keywords Entrepreneurial university, Strategic management, Project portfolio selection, DEMATEL-based ANP, Linear programming

Paper type Research paper

1. Introduction

Iran's economy has relatively low productivity. The annual budget of the country is mostly dependent on the sale of raw materials. Also, transfer of capital and technology from the developed countries to Iran is associated with many difficulties (World Bank, 2017). There is a large number of university graduates looking for a job in Iran, and the market is incapable of creating enough new job opportunities for them. Also, the education system does not teach entrepreneurial and self-employment skills to the students (Almonitor, 2015). Most of the economists believe that the technology-based entrepreneurship and adding knowledge and creativity to businesses and products are the best solutions for improving the economic situation of Iran (Karimi *et al.*, 2010). In the near future, those countries which have proper infrastructure for creating knowledge-based added value will be the main players in the global economy (Vrateovska *et al.*, 2014). Due to the increasing demand for self-employment training, the need for establishing entrepreneurial universities is more than ever before (Alexander and Evgeniy, 2012). The most important and influential producers of knowledge are universities. Commercializing the knowledge of universities has several benefits for the economy. It increases the rate of job creation, improves the competitiveness of the country in

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the world, stops the brain drain phenomenon in the developing countries' domestic production, prevents the sale of natural resources in raw form and decreases the outflow of capital for importing technologies (Kalar and Antoncic, 2015). An entrepreneurial University is the place for training expert human resource. These experts should be systematically able to transfer their ideas and thoughts to the society. The society should also be able to use these new ideas. Many of the country's issues and challenges, including security, employment, healthcare, cultural development and social welfare require new and technological ideas urgently. Also, the authorities need scientific and professional solutions for social, economic and environmental problems of the country. University is the best source for obtaining these solutions (Sooreh *et al.*, 2011).

But, developing an entrepreneurial university is a very complex and time-consuming program. In such a situation, failure will be inevitable without a strategic plan and a portfolio selection framework. This study aims to develop a comprehensive framework to help traditional universities move toward third-generation universities. The proposed framework answers two important questions including the following: 1. How to set the strategic goals and priorities? 2. How to define a portfolio of projects and programs to reach strategic goal?

2. Literature review and theoretical framework

Entrepreneurial universities are one of the most important constituents of knowledge-based economies. After the second academic revolution, the third mission was added to teaching and research which were the traditional missions of the university. This new mission is entrepreneurship and the universities that have developed the needed infrastructures for this mission are called entrepreneurial universities. Etzkowitz described the third-generation university as an institution that has many research contracts and strategic partnerships with other organizations and is financially independent (Etzkowitz, 1984). Clark insisted on the concept of innovation as a key feature of the third-generation universities (Clark, 1998). Chrisman added the idea of founding spin-offs by academics, graduates and students to the main concept of the entrepreneurial university (Chrisman, 1995). Dill focused on the commercialization of university researches and suggested university technology transfer (UTT) (Dill, 1995). According to Ropke, an entrepreneurial university should have three features: It should be an entrepreneurial institution, provide its members with knowledge and skills needed for being an entrepreneur and set its relationships with other entities based on the policy of entrepreneurship (Röpke, 1998). Sporn paid attention to the interaction of entrepreneur universities with their environment and determines how they should adapt to the dynamic environmental situation (Sporn, 2001). Poole listed the failure and success factors of the international strategy of an entrepreneurial university (Poole, 2001). Audretsch *et al.* conducted a comprehensive research about entrepreneurial finance and technology transfer. The study is focused on the role of governmental venture funds, subsidy programs and patent-friendly regulatory. They also discussed the impact of technology transfer offices on university entrepreneurship and regional competitiveness (Audretsch *et al.*, 2016). Zhoa *et al.* introduced four characteristics that can be seen in all of the entrepreneurial universities (Zhoa, 2004):

(1) Revenue generation through the transfer of knowledge and technology and the sale of patents.

(2) Considerable influence on regional industries and economy.

(3) Adoption of the entrepreneurship ideology among the academics.

(4) Strong and systematic relationship with the industry and government.

O'Shea *et al.* explored the reasons for the success of some universities in developing and running spin-offs (O'Shea *et al.*, 2007). D'Este *et al.* researched about the incentives and motivations that can stimulate academics to follow the mission of entrepreneurship. They concluded that the managers should not exclusively focus on the monetary incentives and it is better to consider a wider range of incentives to improve the level of interaction between academia and industry (D'Este and Perkmann, 2011). Jacob *et al.* claimed that the success of the transformation toward entrepreneurship depends on the national climate and the internal policies of the universities. They mentioned the infrastructural and cultural changes needed for this gradual transformation process. They also pointed out that the universities face a kind of role uncertainty when they start to carry out the third mission. Flexibility and diversity in both macro and micro levels are necessary for solving this issue (Jacob *et al.*, 2003). Kirby listed seven critical barriers to entrepreneurship in universities as follows: (Kirby, 2006)

(1) Relationships are typically impersonal.

(2) Structure of the universities is hierarchical and bureaucratic.

(3) Rules and procedures are constraining and anti-creative.

(4) Organizational culture resists innovation and diversity.

(5) The need for immediate results contradicts the time-consuming nature of becoming entrepreneurial.

(6) Lack of talented human resource.

(7) Lack of a suitable strategic plan and road map.

He also proposed some strategies to overcome the mentioned barriers. These strategies are summarized in Table I:

Guerrero *et al.* categorized the factors affecting the development of entrepreneurial universities into formal and informal factors. They also proposed a set of indicators and measures to ease monitoring and assessing the transformation process toward entrepreneurship. Table II shows the overall form of the assessment method (Guerreo *et al.*, 2006). According to Nelles & Vorley, five critical elements form the fundamentals of an entrepreneurial university. These elements are shown in Figure 1

Salamzadeh *et al.* claimed that for transforming to entrepreneurship, universities should revise and improve their processes. The most important processes which must be considered are teaching, research, managerial, logistical, commercialization, selection (for students, university professors and staff), funding and financial, networking and multilateral interaction processes (between students, university professors, staff, industrial

Action	Activity
Endorsement	Top managers and high-ranking staff should act as role models
Incorporation	Faculty, department and personal plans
Implementation	Setting targets and monitoring them
Communication	Consulting on the strategies and disseminating them
Encouragement and support	Hard support: laboratories, pre-incubators, incubators, science parks, meeting rooms, computing support, office support services and seed corn funding Soft support: training, mentoring and advice, signposting to sources of external support and ongoing technical and management support once the venture is launched
Recognition and reward	Fairness, job promotion, etc.
Organization	Cross-disciplinary research and teaching groups, educational partnerships, a multidisciplinary Entrepreneurship Centre
Promotion	Business plan competitions, entrepreneurship "halls of fame", Cases, role models

Table I.
Strategic actions to overcome the barriers to entrepreneurship

Environmental factors		Indicator	Measure
Formal factors	University organization and government structure	Mission	(1) Clear orientation to 3rd educational revolution (2) Transmission of staff members
		Organizational structure	(1) Hierarchical levels (2) Organizational units
		Governance structure	(1) Autonomy from state (2) Systems and procedures
		Manager	(1) Personal profile (2) Professional profile
	Support measures	Existence	(1) Types of support measure (2) Expenditure invested on them
		Diffusion	(1) Communication channels (2) Expenditure invested on them
	University entrepreneurship education	Programs Courses	(1) Types (2) Expenditure (3) Demand
Informal factors	University's attitude toward entrepreneurship	Students Faculty Academics	(1) Intentions (2) Desirability (3) Feasibility
	How-teaching methodology	Methodology	(1) Theory and practice (2) Teaching resources (3) Training professorate
	Role models and academic reward systems	Role models	(1) Entrepreneurs, prominent doctoral
		Reward system	(1) Orientation (2) Type

Table II. Assessment model of Guerrero *et al.*

researchers, entrepreneurial centres, industries, policy makers and society) (Salamzadeh *et al.*, 2011). Rhoades expanded Clark's theories about entrepreneurial university by relating the considerations of systems analysis and organizational studies (Rhoades, 2017). According to Etzkowitz, becoming an entrepreneurial university takes place in three stages:

University entrepreneur one: The university must determine its strategic direction, start acquiring the needed abilities, develop a facilitative legal framework and set its own priorities.

University entrepreneur two: The research activities of the members must actively get commercialized. Facilitating the technology transfer, enhancing the research corporations, preserving the intellectual properties and supporting the start-ups are also the important tasks of this stage.

University entrepreneur three: The university takes a leading role in innovation, has a tight relationship with the regional industries and government and makes a significant contribution to both regional and national economy (Etzkowitz, 2016). In this research, initial list of projects is created based on the Etzkowitz model.

3. Methodology

This study aims to propose a project portfolio selection framework that facilitates the transition toward university entrepreneurship. This framework consists of five stages including the following:

Stage 1: Evaluating the status of the academic entrepreneurship indicators.

Stage 2: Determining the strategies and goals.

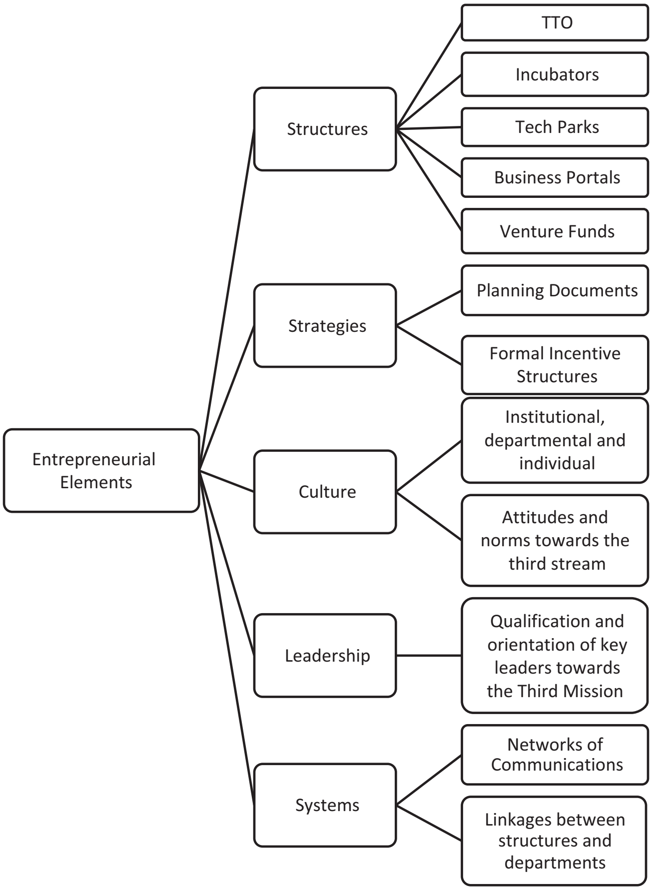

Figure 1.
Elements of entrepreneurial architecture proposed by Nelles

Stage 3: Identifying the relationships between the final-level goals and rankings the goals.

Stage 4: Creating a list of candidate projects and programs to meet the objectives.

Stage 5: Creating a portfolio of projects by a multi-objective mathematical model.

3.1 Evaluating the status of the academic entrepreneurship indicators

The two main questions raised at this point are as follows: What indicators should be evaluated? and how should this evaluation be done?

In this research, we evaluate the indicators of Table II which are suggested by Guerrero *et al.* (Guerreo *et al.*, 2006), by the importance–performance analysis (IPA) which was firstly introduced by Martilla & James (Martilla and James, 1977). IPA is a gap analysis method. Data collection in this technique is very similar to the SERVQUAL technique. IPA is an effective tool for evaluating the competitive position of an organization, identifying development opportunities, designing marketing strategies and providing targeted services. For the first time, this method was used to identify and prioritize the product or service characteristics that the organization should focus on to maximize its customer satisfaction. Through the formation of a two-dimensional matrix its vertical axis is performance (quality) of each feature and its horizontal axis is the importance of that feature in customers' decision-making. Then, a two-dimensional network is created which consists of four areas. Figure 2 shows the importance–performance matrix and corresponded strategies.

The measurement method is as follows: The questionnaires are designed according to the indicators of Table II to evaluate the performance of the university based on each indicator. Validity and reliability of the questionnaires are checked by the experts and Alpha Cronbach test respectively. Also, the importance of the indicators can be determined by one of the multi-criteria decision-making (MCDM) methods. After quantifying the performance and importance of the indicators, critical levels must be determined for performance and importance. If the importance degree of an indicator is larger than the critical level, it should be considered a high importance indicator. Otherwise, it will be considered a low importance indicator. The same process should be carried out for the performance dimension. In the next stage, we focus on the indicators which are located in quarter four of the importance–performance matrix. Of course, this does not mean that other indicators should be ignored. These indicators should also be developed based on their own strategies in the importance–performance matrix.

3.2 Determining the strategies and goals

Indicators that are located in the fourth quarter are the best choices for improvement and investment. The universities should set strategies and goals to improve the selected indicators effectively. In this study, the hierarchical strategic programming with zigzag motions is used (Shirazi, 2005). In the literature of strategic management, the goals and strategies are usually presented in a hierarchical structure. However, these structures are usually not completely relevant to one another and their dependency is not clear. Although major studies classify the objectives into long-term, mid-term and short-term, in this study, organizational goals are divided into two main levels as follows: 1. Major goals 2. Operational goals.

Major goals: This includes the goals that the university wants to achieve in the long term. In other words, there is idealism in expressing these goals. For example, the goal is to increase profits, quality, credibility and so on, which are important for the university. In order to

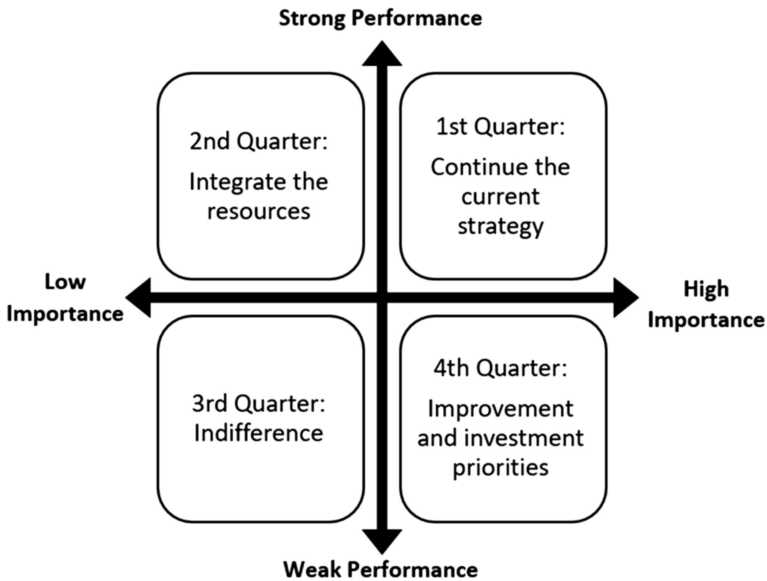

Figure 2.
The importance–performance matrix and the corresponded strategies

achieve the major goals, the university must determine the major strategies eg. the development strategy, diversity strategy and so on.

Operational goals: These goals are usually expressed at different levels of long term, mid term and short term. These goals reflect the expected results of the strategies of the previous level. Operational goals should be quantitative, measurable, realistic, understandable, challenging, hierarchical, achievable, and consistent with other organizational goals. The hierarchical strategic planning with zigzag motion is based on the axiomatic design method and aims to create harmony between the two spaces of strategies and goals at all levels. In the hierarchical strategic planning, the mission and vision of the organization must be determined at first. Then, major organizational goals must be outlined. Then, at least one major strategy must be set for each major goal. At the next level, for the successful implementation of each strategy, at least one goal must be set. These goals should be in line with the higher-level goals. In fact, we move between the goals space and the strategies space with zigzag motions until the goals are specific enough to be met with one or two projects or activities. Figure 3 shows the overall form of the hierarchical strategic planning with zigzag motions.

3.3 Identifying the relationships between the goals and rankings them

The suggested projects and programs for creating and developing an entrepreneurial university are in line with the final-level goals. Therefore, the importance of these projects and programs is a function of the importance of their corresponded goals. Therefore, before listing the proposed projects, the existing relationships between the goals must be detected and the importance of each goal must be determined. In this study, the DEMATEL-based ANP (DANP) method is used to do this.

The DANP method is one of the multi-criteria decision-making (MCDM) methods. It computes the ANP super matrix using the DEMATEL communication matrix and calculates the weights of criteria and sub-criteria. In fact, the DANP method is the hybrid form of DEMATEL and ANP. This method has nine steps (Chiu *et al.*, 2013):

Step 1: calculate the direct influence matrix by scores

The relationships between the goals (influence of a goal on other goals) are expressed based on the experts' opinions using a five-point scale (0–4). 0 = no influence, 1 = low influence, 2 = medium influence, 3 = high influence and 4 = very high influence . Thus, the direct influence matrix (D) can be calculated. (Eqn 1)

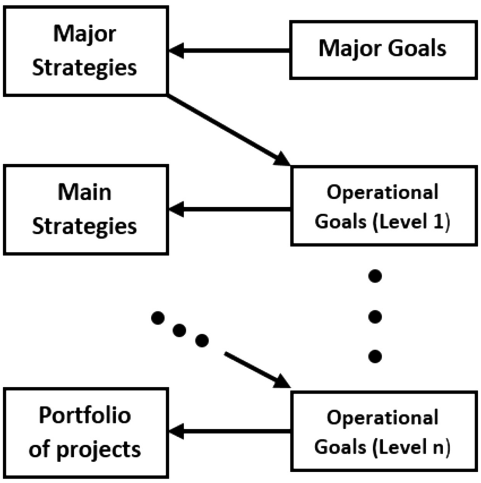

Figure 3.
Hierarchical strategic planning

$$D = \begin{bmatrix} d_c^{11} & \dots & d_c^{1j} & \dots & d_c^{1n} \\ \dots & & \dots & & \dots \\ d_c^{i1} & \dots & d_c^{ij} & \dots & d_c^{in} \\ \dots & & \dots & & \dots \\ d_c^{n1} & \dots & d_c^{nj} & \dots & d_c^{nn} \end{bmatrix} \quad (1)$$

Step 2: normalizing the direct influence matrix

The normalized direct influence matrix can be obtained using Eqn 2:

$$N = DV; V = \min\left\{ \frac{1}{\max\limits_i \sum_{j=1}^{n} d_{ij}}, \frac{1}{\max\limits_i \sum_{i=1}^{n} d_{ij}} \right\} \quad (2)$$

Step 3: calculating the total influential matrix (TC)

The total influential matrix is obtained by Eqns 3 and 4. Note that "I" represents the unit matrix.

$$T_C = N + N^2 + \dots + N^h = N(I - N)^{-1}, \text{When } h \to \infty \quad (3)$$

$$T_c = \begin{bmatrix} T_C^{11} & \dots & T_C^{1j} & \dots & T_C^{1n} \\ \dots & & \dots & & \dots \\ T_C^{i1} & \dots & T_C^{ij} & \dots & T_C^{in} \\ \dots & & \dots & & \dots \\ T_C^{n1} & \dots & T_C^{nj} & \dots & T_C^{nn} \end{bmatrix} \quad (4)$$

Step 4: analyze the results

In this step, the summations of each row and column should be calculated separately according to Eqns 5 to 6.

$$r = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij} \right]_{n\times 1} \quad (5)$$

$$c = [c_j]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij} \right]_{1\times n} \quad (6)$$

$$T = [t_{ij}], \quad i,j \in \{1, 2, \dots, n\} \quad (7)$$

The index (r_i) represents the sum of the rows (i) and the index (c_j) represents the sum of the column (j). The index $(r_i + c_j)$ is obtained from the sum of the row (i) and the column (i) and shows the importance of the criteria (i). Similarly, the index $(r_i - c_j)$ shows how much the criterion(i) affects the other criteria and gets influenced by them. If $(r_i - c_j)$ is positive, the criterion (i) affects some of the other criteria, otherwise it gets influenced by some of the other criteria. Now we can use DANP for finding the influential weights in each criterion:

Step 5: find the normalized total influential matrix

The normalized form of the matrix TD is obtained from the mean $T_c[ij]$. Thus, the sum of each row is computed, and each element is divided by the sum of the elements of its corresponded row. (Eqns 8 and 9)

$$T_D = \begin{bmatrix} t_{11}^{D_{11}} & \dots & t_{1j}^{D_{11}} & \dots & t_{1m}^{D_{1m}} \\ \dots & & \dots & & \dots \\ t_{i1}^{D_{i1}} & \dots & t_{ij}^{D_{ij}} & \dots & t_{im}^{D_{im}} \\ \dots & & \dots & & \dots \\ t_{m1}^{D_{m1}} & \dots & t_{mj}^{D_{mj}} & \dots & t_{mm}^{D_{mm}} \end{bmatrix} \begin{matrix} \rightarrow & d_1 = \sum_{j=1}^{m} t_{1j}^{D_{1j}} \\ \rightarrow & d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}} \\ \rightarrow & d_m = \sum_{j=1}^{m} t_{mj}^{D_{mj}} \end{matrix} \quad , \quad i = 1, 2, \dots m \tag{8}$$

$$T_D^{\alpha} = \begin{bmatrix} t_{11}^{D_{11}}/d_1 & \dots & t_{1j}^{D_{1j}}/d_1 & \dots & t_{1m}^{D_{1m}}/d_1 \\ \dots & & \dots & & \dots \\ t_{i1}^{D_{i1}}/d_i & \dots & t_{ij}^{D_{ij}}/d_i & \dots & t_{im}^{D_{im}}/d_i \\ \dots & & \dots & & \dots \\ t_{m1}^{D_{m1}}/d_m & & t_{mj}^{D_{mj}}/d_m & & t_{mm}^{D_{mm}}/d_m \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \dots & t_D^{\alpha 1j} & \dots & t_D^{\alpha 1n} \\ \dots & & \dots & & \dots \\ t_D^{\alpha i1} & \dots & t_D^{\alpha ij} & \dots & t_D^{\alpha in} \\ \dots & & \dots & & \dots \\ t_D^{\alpha n1} & \dots & t_D^{\alpha nj} & \dots & t_D^{\alpha nn} \end{bmatrix} \tag{9}$$

Step 6: find the normalized form of (T_C) by dimensions and clusters

In this step, matrix T_C is normalized with the total degrees of effect and influence of the dimensions and clusters. Eqns 10 and 11 are examples of how to calculate $T_C^{\alpha 11}$. Other $T_C^{\alpha nm}$ are calculated similarly.

$$d_{ci}^{11} = \sum^{m_1} t_{cij}^{11}, \quad i = 1, 2, \dots, m_1 \tag{10}$$

$$T_C^{\alpha 11} = \begin{bmatrix} t_{c11}^{11}/d_{c1}^{11} & \dots & t_{c1j}^{11}/d_{c1}^{11} & \dots & t_{c1m_1}^{11}/d_{c1}^{11} \\ \dots & & \dots & & \dots \\ t_{ci1}^{11}/d_{ci}^{11} & \dots & t_{cij}^{11}/d_{ci}^{11} & \dots & t_{cim_1}^{11}/d_{ci}^{11} \\ \dots & & \dots & & \dots \\ t_{cm_1 1}^{11}/d_{cm_1}^{11} & \dots & t_{cm_1 j}^{11}/d_{cm_1}^{11} t & \dots & t_{cm_1 m_1}^{11}/d_{cm_1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\alpha 11} & \dots & t_{c1j}^{\alpha 11} & \dots & t_{c1m_1}^{\alpha 11} \\ \dots & & \dots & & \dots \\ t_{ci1}^{\alpha 11} & \dots & t_{cij}^{\alpha 11} & \dots & t_{cim_1}^{\alpha 11} \\ \dots & & \dots & & \dots \\ t_{cm_1 1}^{\alpha 11} & \dots & t_{cm_1 j}^{\alpha 11} & \dots & t_{cm_1 m}^{\alpha 11} \end{bmatrix} \tag{11}$$

Step 7: building an unweighted supermatrix W_C

The transposed form of the matrix T_c^α is called "unweighted supermatrix" and is shown by W, as in Eqn 12.

$$W = \left(T_c^\alpha\right)' = \begin{bmatrix} W^{11} & \dots & W^{i1} & \dots & W^{n1} \\ \dots & & \dots & & \dots \\ W^{1j} & \dots & W^{ij} & \dots & W^{nj} \\ \dots & & \dots & & \dots \\ W^{1n} & \dots & W^{in} & \dots & W^{nn} \end{bmatrix} \tag{12}$$

Step 8: building a weighted supermatrix (W^α)

The weighted supermatrix is obtained by the product of the normalized total influential matrix (T_D^α) and the unweighted supermatrix (W). (Eqn 13)

$$W^\alpha = T_D^\alpha W = \begin{bmatrix} t_D^{\alpha 11}\times W^{11} & \dots & t_D^{\alpha i1}\times W^{i1} & \dots & t_D^{\alpha n1}\times W^{n1} \\ \dots & & & & \\ t_D^{\alpha 1j}\times W^{1j} & \dots & t_D^{\alpha ij}\times W^{ij} & \dots & t_D^{\alpha nj}\times W^{nj} \\ \dots & & \dots & & \dots \\ t_D^{\alpha 1n}\times W^{1n} & \dots & t_D^{\alpha in}\times W^{in} & \dots & t_D^{\alpha nn}\times W^{nn} \end{bmatrix} \tag{13}$$

Step 9: find the influential weights of the DANP

The weighted supermatrix must be raised to a sufficiently large power Z until it converges and reaches stability. The output of this step is the effective DANP weights. (Eqn 14)

$$\lim_{Z\to\infty} (W^\alpha)^Z \tag{14}$$

3.4 Creating a list of candidate projects and programs to meet the objectives

The most important issue in defining a project is scope management. The scopes of the proposed projects should be consistent with at least one of the last-level goals set out in Section 3.2. The high-level scope of the project must be outlined in the project charter (according to BMBOK) or the business case (according to Prince2) (PMBOK, 2017) (Prince2, 2017). By specifying the scope of the project, we can see what the project contains or does not contain. It also shows with what goals the project is consistent, on which goals have negative effects and on which ones has no impact.

In this study, the Delphi technique is used to identify and sort the most important projects and programs for entrepreneurship. Although the Delphi technique is not a MCDM method, it can be used before applying these techniques to reach an agreement on the candidate projects. Figure 4 denotes the main steps of this method and their sequence.

In the first stage, the problem statement is identified, and the characteristics of the experts' panel members are determined based on that. Then, the qualified experts are identified and invited to the panel. Regarding the subject of this research, top managers, high-level university staff, faculty members, entrepreneurship experts, managers of the key industries, government officials, spin-off owners and entrepreneur students can be members of the experts' panel.

The second step of the Delphi method is to generate ideas in the field of research. Expert panel members express their views about the questions the researchers ask. By analyzing and refining these ideas and removing duplicates and identical terms, the researcher extracts the list of issues related to the topic of research. The proposed method of this study is to provide the expert panel members with the last-level goals outlined in Section 3.2 and ask

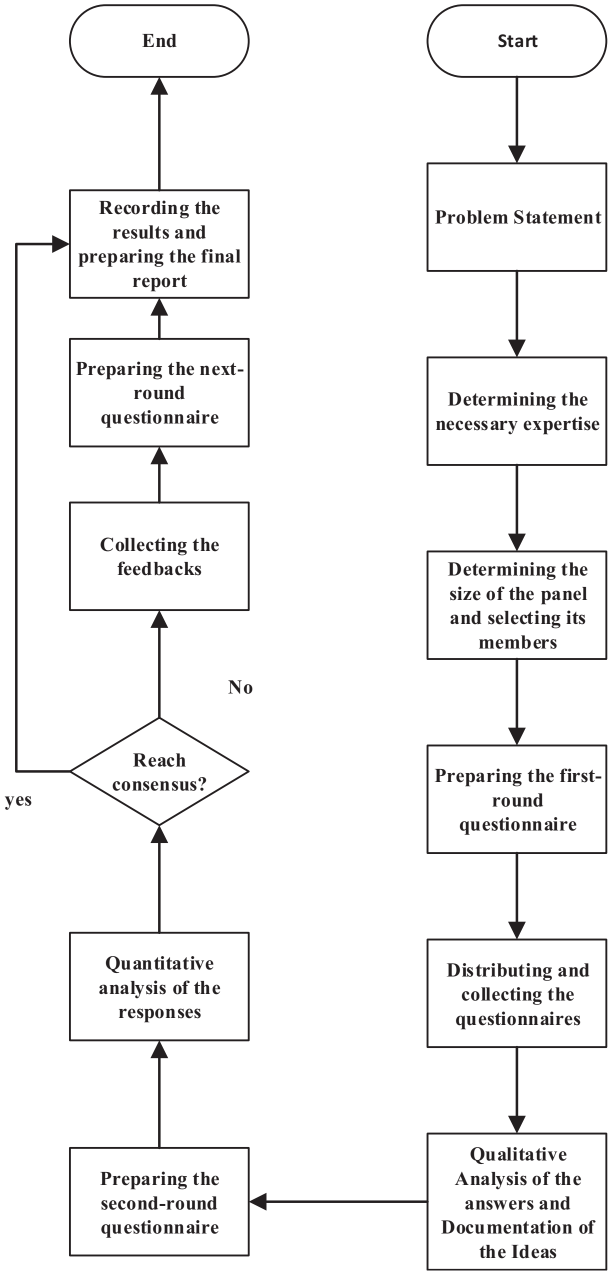

Figure 4.
The Delphi technique

them to suggest programs and projects achieve the goals. By editing the suggestions, the initial list of projects will be formed. In the third step, members are asked to express the importance of the items listed in the initial list by linguistic or numerical variables or select some of the most important ones. Then, using MCDM methods such as AHP, or the Q-Sort method, we exclude the projects or programs that are considered unimportant by the members. This process continues until the members reach a consensus on the list of suggested projects. The output of section 3.4 is a list of projects and programs suggested by the experts, in which the importance of each project is also specified.

3.5 Creating a portfolio of projects and programs by a multi-objective mathematical model

The projects with the highest degree of importance are not necessarily the best choices to carry out. In addition to maximizing benefits, the organization should consider other important factors such as risk, balance and budget constraints. In the following points, we propose a multi-objective programming model that can provide an optimal portfolio of projects and programs for moving toward entrepreneurship considering the mentioned factors. Compared to the similar models, this one is simpler and more comprehensive. As the model is simple and its parameters are definite, it can be solved with the typical software and by people who are not familiar with the operation research.

Parameters:

(1) ϕ_m = Weight of the strategy S_m

(2) $Y_{im} = \begin{cases} 1, & \text{if the project i relates to strategy } m \\ 0, & \text{otheiwise} \end{cases}$

(3) P_{fi} = Probability of occurrence of failure f in project i

(4) S_{fi} = Degree of severity of failure f if happens in project i

(5) q_{il} = Minimum acceptable quality for project i

(6) $\alpha_i, \beta_i, \theta_i$ = Coefficients in the constraints

(7) R_i = Risk of project i

(8) c_{li} = Lowest possible cost for project i

(9) R_T = Maximum tolerable risk for the project portfolio

(10) C_T = Maximum available budget for the project portfolio

(11) ϕ_T = Minimum needed alignment of the selected projects with the strategies

(12) Q_T = Minimum acceptable quality level for the project portfolio

Variables:

(1) $X_i = \begin{cases} 1, & \text{if project i is selected to be implemented} \\ 0, & \text{otherwise} \end{cases}$

(2) γ_m = Productivity of strategy S_m

(3) C_i = Cost of project i

(4) W_i = Coefficients of the objective function

(5) Q_i = Quality level of the project i

Model:

$$\text{Max}\, Z^* = W_1Z_1 + W_2Z_2 + W_3Z_3 - W_4Z_4 - W_5Z_5 \quad (15)$$

$$Z_1 = \sum_i \phi_m Y_{im} X_i \quad (16)$$

$$Z_2 \le \gamma_m \quad \forall m \quad (17)$$

$$\gamma_m = \frac{\sum_i Y_{im} X_i}{\sum_i Y_{im}} \tag{18}$$

$$Z_3 = \sum_i Q_i X_i \tag{19}$$

$$Q_i = \alpha_i C_i + \beta_i R_i + \theta_i C_i R_i \tag{20}$$

$$Q_i \geq q_{il} \tag{21}$$

$$Z_4 = \sum_i C_i X_i \tag{22}$$

$$Z_5 = \sum_i R_i X_i \tag{23}$$

$$R_i = \sum_f P_{fi} S_{fi} \tag{24}$$

$$c_{li} \leq C_i \quad \forall i \tag{25}$$

$$W_j > 0, \forall j \tag{26}$$

Z_1 chooses the projects whose total weights are maximal. Z_2 divides the budget between the projects in a way that the university can grow in a balanced way. To do this, the maximum productivity of each of the sub-portfolio or program is measured, and the objective function maximizes the least relative productivity among the sub-portfolios and programs. Z_3 maximizes the total quality level of the portfolio. Z_4 lessens the total cost of the portfolio. Z_5 minimizes the total risk score of the portfolio.

For more simplicity, we can change Z_1, Z_2 and Z_3 into restrictions. So, the model can be rewritten as follows:

$$\text{Max} \;\; Z \tag{27}$$

$$Z \leq \frac{\sum_i Y_{is} X_i}{\sum_i Y_{is}} \tag{28}$$

$$\sum_i \phi_i X_i \geq \phi_T \tag{29}$$

$$Q_i = \alpha_i C_i + \beta_i R_i + \theta_i C_i R_i \tag{30}$$

$$Q_i \geq q_{il} \tag{31}$$

$$\sum_i Q_i X_i \geq Q_T \tag{32}$$

$$\sum_i C_i X_i \leq C_T \tag{33}$$

$$\sum_i \sum_f P_{fi} S_{fi} X_i \leq R_T \tag{34}$$

$$c_{li} \leq C_i \tag{35}$$

4. Case study (Amirkabir University of Technology, Tehran, Iran)

Amirkabir University of Technology (Tehran Polytechnic) is the first and most experienced school of engineering in Iran. Admission to this university is done through the national entrance exam and is considered very competitive. The university has developed nine strategies in three dimensions as follows: the content, structure and environment for becoming a third-generation university (Table III).

As mentioned earlier, these goals are not independent and can have positive or negative effects on each other. The direct influence matrix for these nine goals is shown in Eqn 36. (Based on the expert judgment).

$$D = \begin{bmatrix} 4 & 3.29 & 2.28 & 2.15 & 2.68 & 3.47 & 3.31 & 2.90 & 1.26 \\ 2.05 & 4 & 3.07 & 2.24 & 3.52 & 2.64 & 0.21 & 0.90 & 3.36 \\ 0.85 & 3.89 & 4 & 1.13 & 1.21 & 2.60 & 0.97 & 1.51 & 3.93 \\ 2.07 & 1.14 & 0.61 & 4 & 1.94 & 2.17 & 2.86 & 2.72 & 0.38 \\ 0.40 & 2.15 & 2.95 & 1.23 & 4 & 2.96 & 2.27 & 1.90 & 2.40 \\ 2.89 & 3.11 & 2.75 & 1.89 & 2.84 & 4 & 0.07 & 3.24 & 1.99 \\ 3.76 & 1.71 & 2.26 & 0.26 & 0.37 & 3.56 & 4 & 1.22 & 3.08 \\ 2.16 & 1.74 & 0.94 & 2.07 & 1.42 & 2.36 & 3.02 & 4 & 0.54 \\ 2.07 & 0.61 & 2.62 & 2.88 & 0.95 & 0.36 & 1.89 & 0.43 & 4 \end{bmatrix} \quad (36)$$

After completing the DANP steps, the weight is obtained for each of the goals. Table IV contains the weights obtained for each of the nine strategies.

Entrepreneurial university portfolio	Structure	Developing non-physical infrastructures of entrepreneurship (S1)
		Developing the infrastructures of education, research, technology (S2)
	Content	Promoting resource efficiency (S3)
		Encouraging academics to produce knowledge (S4)
		Becoming the scientific hub of the country in some academic fields (S5)
		Promoting the level of training courses (S6)
	Environment	Open communication with industries (S7)
		International cooperation (S8)
		Communication with the alumni (S9)

Table III. Main strategies of AUT for becoming a third-generation university

Strategy	Normalized weight
S1	0.134691
S2	0.220503
S3	0.132062
S4	0.109508
S5	0.111642
S6	0.097575
S7	0.079098
S8	0.050287
S9	0.064631

Table IV. Normalized weights of the strategies by DANP method

Developing non-physical infrastructures of entrepreneurship (G1)	Cultural infrastructures (G1-1)	Network of entrepreneurs (P1) Startup events (P2) Information posters about entrepreneurship (P3)
	Organizational structures (G1-2)	Reducing bureaucracy (P4) Increasing organizational flexibility (P5)
	Methods of leadership (G1-3)	Training the managers (P6) Entrepreneurship strategic plan (P7)
Developing the infrastructures of education, research, technology (G2)		Incubators (P8) Research cores (P9) Conference halls (P10) Venture capital funds (P11) Science and technology park (P12) Industrial consulting centers (P13) Laboratories (P14) Innovation institutes (P15) Intellectual property offices (P16) Technology transfer offices (P17)
Promoting resource efficiency (G3)	Management (G3-1)	Proficiency (P18) Relationship with employees (P19)
	Human resource (G3-2)	Number (P20) Wage and benefits (P21) Recreational facilities (P22) Training (P23)
	Facilities and equipment (G3-3)	Equipment (P24) Buildings (P25) Self service (P26) Sports facilities (P27)
	Technology (G3-4)	Educational (P28) Technical knowledge (P29)
Encouraging academics to produce knowledge (G4)	Students (G4-1)	Scholarships and rewards (P30) Admission without entrance test for brilliant students (P31) Paying for researches, conferences and scientific trips (P32)
	Staff (G4-2)	Financial incentives (P33) Job promotion (P34)
	Instructors (G4-3)	Degree promotion (P35) Financial incentives (P36)
Becoming the scientific hub of the country in some academic fields (G5)		Holding international conferences and competitions (P37) Courses for self-employment Pursuing the programs and strategies of the top universities (P38) Increasing the ratio of teachers to students (P39) Inviting international scholars to speak at the university (P40)

(*continued*)

Table V.
The proposed project portfolio before prioritization

Open communication with industries and the government (G6)	Using technical experience of industry (P41)
	Communication with spin-offs of the university (P42)
	Joint meetings (P43)
	Assessing the needs of industry (P44)
	Incentives for hiring university graduates (P45)
	Marketing for the services that the university can offer to the industry (P46)
	Short-term courses for workers and industry executives (P47)
	Assisting the officials in solving the issues and presenting and implementing plans (P48)
Promoting the level of training courses (G7)	World-class contents (P49)
	Presenting internationally-recognized certificates (P50)
	Virtual education in different languages (P51)
	Multimedia education (P52)
	Teaching skills needed for self-employment (P53)
International cooperation (G8)	Joint programs with top universities in the world (P54)
	International research contracts and agreements (P55)
	Attending international scientific events (P56)
	Scholarships and scientific missions for students and instructors (P57)
	Language courses for business and academic purposes (P58)
Communication with the alumni (G9)	Special facilities for alumni to establish spin-offs (P59)
	Communication of students and graduates (P60)
	Hiring brilliant alumni as instructors (P61)

Table V.

Also, to implement each of these nine strategies, there are a number of proposed solutions that can be seen in Table V.

By collecting information about the project costs and the associated risks of them as well as the total budget of the organization and its maximum tolerable risk, it is possible to prioritize the projects and form the project portfolio. The costs and risks of projects can be expressed in deterministic, fuzzy, grey numbers or probabilistic form. Depending on the conditions and type of projects, other constraints can be added to the proposed model of this research. If a part of the projects can be done and another part can be postponed to subsequent periods, continuous variables can be used instead of binary variables. Table VI shows the parameters which are gathered for this case study.

The parameters are replaced in the model and the obtained results are shown in Table VII.

Project	c_{li}	R_i	α_i	β_i	q_{li}	Project	c_{li}	R_i	α_i	β_i	q_{li}
P1	38.28	135	4.8	0.00294	160	P32	25.49	345	1.78	0.00779	177
P2	33.86	883	2.8	0.00180	9	P33	24.85	131	0.97	0.00972	178
P3	12.01	276	1.7	0.00592	50	P34	71.81	110	1.26	0.00359	29
P4	92.61	515	2.8	0.00494	76	P35	78.48	28	2.22	0.00240	74
P5	66.29	64	2.8	0.00147	10	P36	53.04	829	2.56	0.00317	158
P6	44.37	683	2.2	0.00894	166	P37	36.01	409	3.94	0.00504	175
P7	43.50	489	3.4	0.00848	10	P38	62.87	217	2.32	0.00675	118
P8	73.85	222	3.4	0.00125	91	P39	57.80	336	4.56	0.00224	26
P9	19.32	357	4.8	0.00883	122	P40	1.01	622	0.46	0.00189	18
P10	74.63	283	1.7	0.00541	108	P41	45.40	480	3.86	0.00517	135
P11	68.24	506	0.6	0.00750	12	P42	12.33	855	4.02	0.00586	73
P12	90.10	869	2.6	0.00651	153	P43	31.55	45	2.74	0.00761	189
P13	51.66	149	3.2	0.00797	114	P44	88.49	587	4.52	0.00145	116
P14	15.41	413	1.3	0.00229	196	P45	71.27	665	3.52	0.00224	17
P15	57.98	867	3.9	0.00384	21	P46	95.72	590	3.11	0.00000	24
P16	60.85	252	2.2	0.00393	77	P47	74.97	444	3.48	0.00857	162
P17	60.10	203	2.6	0.00291	70	P48	71.12	412	4.79	0.00548	157
P18	5.31	317	2.5	0.00288	61	P49	37.82	424	2.03	0.00271	76
P19	32.03	494	3.6	0.00259	102	P50	5.98	140	2.35	0.00656	67
P20	22.64	121	3.7	0.00502	75	P51	99.75	389	0.85	0.00928	52
P21	20.74	811	0.3	0.00956	78	P52	62.82	753	0.8	0.00738	172
P22	61.66	809	2.7	0.00804	183	P53	62.23	48	2.41	0.00141	102
P23	57.58	630	3.8	0.00387	107	P54	55.73	268	2.33	0.00893	109
P24	75.76	420	2.8	0.00524	153	P55	22.93	153	1.31	0.00805	35
P25	19.60	105	4.2	0.00258	16	P56	2.88	824	3.49	0.00386	11
P26	63.99	179	4.3	0.00257	135	P57	63.28	395	3.98	0.00929	24
P27	7.77	434	0.9	0.00901	120	P58	33.53	846	0.31	0.00437	48
P28	49.20	316	0.8	0.00397	114	P59	51.78	799	3.4	0.00308	139
P29	91.08	79	4.7	0.00814	156	P60	91.50	603	2.73	0.00719	21
P30	5.27	865	2.6	0.00633	187	P61	43.35	79	4.43	0.00406	91
P31	33.78	555	2.1	0.00445	112						

$\phi_T = 4.023, Q_T = 9395, R_T = 18000, C_T = 4950$

Table VI. Parameters of the proposed model for the case study

Variable	Value	Variable	Value	Variable	Value
X1	1	C1	38.28	Q1	226.25
X2	1	C2	33.86	Q2	257.00
X3	1	C3	18.18	Q3	50.00
X4	0	C4	92.86	Q4	342.64
X5	0	C5	66.54	Q5	350.65
X6	1	C6	52.87	Q6	166.00
X7	0	C7	43.73	Q7	55.54
X8	0	C8	74.10	Q8	138.56
X9	1	C9	40.94	Q9	122.00
X10	0	C10	74.88	Q10	447.76
X11	0	C11	68.45	Q11	420.28
X12	0	C12	90.35	Q12	616.15
X13	1	C13	51.66	Q13	282.58
X14	0	C14	40.25	Q14	196.00
X15	1	C15	15.41	Q15	58.25
X16	1	C16	60.85	Q16	160.04
X17	1	C17	60.10	Q17	311.92
X18	1	C18	13.99	Q18	61.00
X19	1	C19	32.03	Q19	295.96

(continued)

Table VII. Results of the proposed model for the case study

Variable	Value	Variable	Value	Variable	Value
X20	0	C20	22.64	Q20	83.09
X21	1	C21	40.21	Q21	78.00
X22	0	C22	269.35	Q22	183.16
X23	1	C23	57.58	Q23	136.46
X24	0	C24	76.01	Q24	274.38
X25	0	C25	19.60	Q25	121.32
X26	0	C26	100.99	Q26	135.33
X27	1	C27	50.85	Q27	120.00
X28	1	C28	49.20	Q28	177.61
X29	0	C29	91.33	Q29	229.23
X30	1	C30	190.82	Q30	187.00
X31	0	C31	219.85	Q31	112.12
X32	0	C32	218.76	Q32	177.19
X33	0	C33	193.72	Q33	178.22
X34	1	C34	35.80	Q34	29.00
X35	1	C35	98.67	Q35	74.00
X36	1	C36	76.70	Q36	158.00
X37	0	C37	105.03	Q37	175.41
X38	1	C38	80.82	Q38	118.00
X39	1	C39	42.41	Q39	33.50
X40	1	C40	36.41	Q40	34.95
X41	0	C41	217.98	Q41	135.15
X42	1	C42	123.73	Q42	73.00
X43	0	C43	203.47	Q43	189.22
X44	1	C44	59.18	Q44	116.00
X45	1	C45	14.39	Q45	31.51
X46	1	C46	32.41	Q46	117.00
X47	0	C47	39.76	Q47	163.03
X48	0	C48	165.26	Q48	157.00
X49	1	C49	93.83	Q49	76.00
X50	0	C50	94.62	Q50	67.18
X51	1	C51	37.96	Q51	52.00
X52	0	C52	351.27	Q52	172.12
X53	1	C53	112.09	Q53	102.00
X54	0	C54	72.34	Q54	109.23
X55	0	C55	39.48	Q55	35.14
X56	1	C56	36.58	Q56	71.70
X57	1	C57	20.69	Q57	24.00
X58	1	C58	35.74	Q58	76.48
X59	0	C59	86.59	Q59	139.40
X60	1	C60	10.05	Q60	21.00
X61	1	C61	45.73	Q61	91.00

Table VII.

5. Conclusion

Because the entrepreneurial university (third generation) is one of the core requirements of the knowledge-based development, all universities need to have a comprehensive plan to transform them into entrepreneurial universities at the lowest possible cost and risk. The need for such a plan is more vital in developing countries, such as Iran, due to poor industry and poor university connectivity. This paper suggests a framework that help universities make such a plan. This framework consists of five steps including evaluating the status of the academic entrepreneurship indicators, determining the strategies and goals, identifying the relationships between the goals and rankings them, creating a list of candidate projects and programs to meet the objectives and creating a portfolio of projects and programs by a multi-objective mathematical model. The output of this framework is a portfolio of projects that according to the budget and other university conditions have the highest priority in terms of transforming traditional universities into entrepreneurial universities.

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