Investigating the Concept of Effectiveness in Technology Development Projects in a Research and Technology Organizations; Evaluating Eight Technology Development Projects in the Research Institute of Petroleum Industry (RIPI)

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ARTICLE INFO

Keywords:

Research and Technology Organization, technology development projects, effectiveness

Received: 18 August 2020
Revised: 09 September 2020
Accepted: 14 September 2020

ABSTRACT

One of the governmental research organizations is Research and Technology Organization (RTO), whose primary is to harness science and technology in the service of innovation or public bodies and industry, to improve the quality of life and build economic competitiveness. Despite the importance and role of research and technology organizations in the innovation system, previous studies have not addressed the concept of technology development projects' effectiveness implemented in RTOs. This study attempts to investigate this concept from two aspects: "the concept of effectiveness in research projects" and "the concept of effectiveness in RTOs" to define this concept in a research and technology organization (RIPI). To evaluate and implement the proposed framework, eight technology development projects are studied at the Research Institute of Petroleum Industry. Based on the developed indicators and their weights, the effectiveness of eight technology development projects has been evaluated using ARAS, COPRAS, MOORA, and TOPSIS multi-criteria decision-making methods.

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1. Introduction

In innovation policy research, the role of universities and other policy organizations has been studied at length (Loikkanen, et al. 2011). In the national innovation system, the role and function of research institutes are different from universities and industry. (De Fuentes & Dutrénit, 2012; Zhang et al., 2016) The research institute determines that if it can be in science and technology, it can try to create the latest basic needs of existing national science and technology. (Bai, 2016)

There are different forms of public research organizations, one of which is research and technology organizations (RTOs). The European Association for RTOs (EARTO) defines RTOs as "regional and national actors whose core mission is to harness science and technology in the service of innovation or public bodies and industry, to improve the quality of life and build economic competitiveness in Europe". (Charles, & Ciampi Stancova, 2015)

If we place different actors in an innovation system (institutions, organizations, companies, individuals) in a range from basic research to the market, the position of RTOs will be as follows. Based on the pattern of technology readiness levels, this range includes levels 3 to 7.

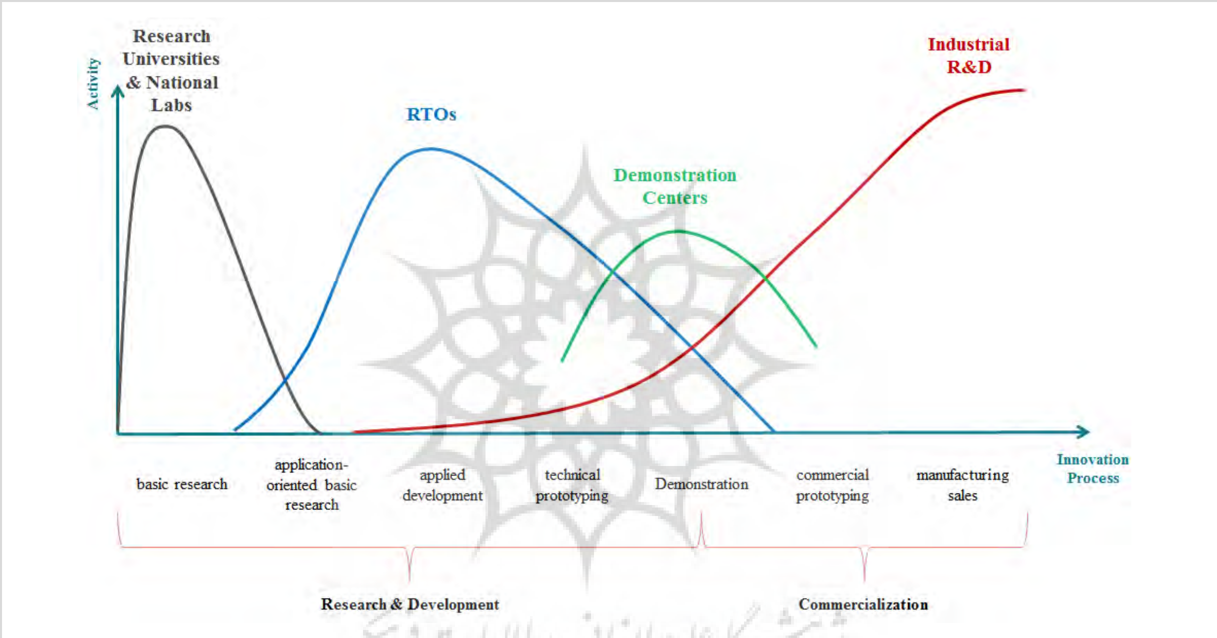

Figure 1. RTOs builds a bridge between basic research and commercial and industrial application. Uygun (2015).

Despite the importance and role of RTOs in the innovation system, previous studies have not addressed the concept of effectiveness of technology development projects implemented in RTOs. As Zhang mentioned in 2016, in these studies, public research institutes were included as subsidiary bodies included in the category of university or government sectors. (Orozco et al., 2010; Welsh et al., 2008; Scandura, 2016).

Therefore, this study, intends to examine this concept from two aspects: "concept of effectiveness in research projects" and "concept of effectiveness in RTO" to define this concept in a research and technology organization (RIPI). In order to evaluate and implement the developed framework, eight technology development projects in the Petroleum Industry Research Institute have been studied, and their effectiveness has been evaluated.

2. Theoretical Foundations and Literature Review of Research

2.1. Effectiveness

Despite the importance of organizational effectiveness in Organizational Management Studies and the presentation of different approaches and models to evaluate effectiveness, there is no universal approach and model for evaluating it in all organizations. According to Balduck and Buelens (2008), effectiveness in organizations revolves around four main approaches: the system resource approach, the goal attainment approach, the multiple constituencies approach, and the internal processes approach. In Ms. Ashraf Ganjavi's Ph.D. dissertation (2012), organizational effectiveness models are divided into two sections: traditional models and modern models. Traditional models include the goal attainment model, the system resource model, and the internal processes model, and the modern model includes the integrated model, the stakeholder model (multiple constituencies model), the competitive values-based model, and the ineffectiveness-based model. The following table summarizes these models.

Table 1. A summary of approaches to the concept of effectiveness in both traditional and modern sections (Ganjavi, 2012).

sections	approach	Conceptualizing in the organization	Focus
Traditional models	goal attainment approach	Organization as a rational set of arrangements that tends to achieve goals	Achieving and realizing the result (goals)
	system resource approach	Organization as an open system (input, change, output)	Input, acquisition of resources, and use of internal resources (tools and methods)
	internal processes approach	Effectiveness means that the organization is efficient and the processes and procedures within the organization are well defined.	The focus of the organization is on the process of integration in the organization. Effectiveness means the level of health and efficiency of the organization.
Modern models	multiple constituencies approach	The organization as an internal and external factor that negotiates with a complex set of constraints and goals.	Responding to the expectations of the main stakeholders of the organization.
	competitive values-based approach	Organization as a competitive value that creates multiple conflicting goals.	Three dimensions of competitive values: • Internal focus versus external focus • Control versus flexibility • Goals versus tools or practices (Provides a model of a combination of the previous four models)
	ineffectiveness-based approach	Organization as a set of problems and failures	Factors that prevent the successful operation of the organization.

2.2. Explain the Appropriate Effectiveness Approaches for RTOs

RTOs, in terms of ownership, are often public organizations or non-profit organizations that depend on public bodies. (Arnold et al., 2010). In the field of effectiveness literature, Kolar Bryan (2018) has identified three broad approaches to assessing organizational effectiveness with a focus on nonprofit effectiveness: the goal attainment, the system resource, and the multiple constituencies models.

On the other hand, the main mission of RTOs is to apply science and technology in the field of innovation services to improve the quality of life and create economic competitiveness. (Reza Bandarian, 2016). In the literature on the "internal processes" approach, this approach is to fulfill the objectives by providing timely and sufficient information to the students and the academicians. (Kleijnen et al.; 2009)

Therefore, due to the non-profit and knowledge base nature of RTOs, four approaches were selected to evaluate the effectiveness of the project Research projects in these organizations: "achievement of goals", "system resources", "multiple stakeholders" and "internal processes" Since there are criticisms of each of these approaches, in this study, all four approaches were considered to examine the concept of effectiveness. The following table lists the critiques in the literature on each of the approaches:

Table 2. Criticisms of the "achievement of goals", "system resources", "multiple stakeholders" and "internal processes" approaches to effectiveness in the literature.

approaches	goal attainment	system resources	multiple stakeholders (multiple constituencies)	internal processes
Definition	organizations are effective to the extent they are able to accomplish specified goals and objectives (Kolar Bryan, 2018)	effective organizations as “resource-getting systems. (Yuchtman and Seashore,1967)	the multiple constituencies model views effectiveness as a socially constructed concept in which multiple stakeholders will assess an organization’s effectiveness differently (T. Connolly, Conlon, & Deutsch, 1980; Mitchell, 2015; Zammuto, 1984)	By effectiveness, it is meant that the organization is internally healthy and efficient and the internal processes and procedures in that place are quite well-oiled. In an effective organization, there is no trace of stress and strain. The members are completely part of the system, and the system itself works smoothly. The relationship between the members is based on trust, honesty, and goodwill. Finally, the flow of information is on a horizontal and vertical basis (Cameron, 1981).
Criticisms	goals are multiple, conflicting, ill defined, and ambiguous, making it difficult to measure (Herman & Renz, 1999; Yuchtman & Seashore, 1967).	this perspective does not measure organizational effectiveness as much as it measures the acquisition of resources necessary for organizations to accomplish mission (Boyne, 2003a), and that the mission of non-profit organizations is social, not financial in nature (Moore, 2003).	it is difficult to accurately weigh differing stakeholder assessments of effectiveness (Friedlander & Pickle, 1968), and that it focuses on who defines effectiveness and not the substance of the organization’s mission (Boyne, 2003a)	The trend of this approach in higher educational institutions (Ashraf et al,2012)
Concept of index	measuring performance through	1- The ability to respond to	organizational legitimacy and	The collection of information and

approaches	goal attainment	system resources	multiple stakeholders (multiple constituencies)	internal processes
	organizational outputs and outcomes (Andrews & Boyne, 2010; Boyne, 2003a, 2003b; Lee & Nowell, 2015).	potential problems is, in this model, a comparison between the total array of problems which could occur under different circumstances and the number of resources which are available to handle each problem. 2- The organization's ability to use its resources in producing outputs and in maintaining and restoring the system 3- the organization maximizes its bargaining position and optimizes its resource procurement. (Barton Cunningham-1978)	reputation as the most important measure of effectiveness (Mitchell, 2015; Willems, Jegers, & Faulk, 2016)	communication management. (Kleijnen, Dolmans, Muijtjens, Willems, & Van Hout, 2009)

2.3. Research Background on Evaluating the Effectiveness of Technology Development Projects in RTOs

By studying the literature related to the effectiveness of technology development projects in RTOs, as shown in Table 3, these studies can be classified into the following three scopes:

- Studies that have dealt with the issue of effectiveness in a type of research organization (such as national laboratories). (As mentioned in the introduction, research and technology organizations, despite the similarities, differ from other government research organizations in terms of technology development and their place in the innovation system)
- Studies that have examined an RTO but do not focus on its performance or effectiveness.
- Studies that focus only on the performance and effectiveness of a technology development project.

- Accordingly, as mentioned in the introduction, one of the innovations of this research is to eliminate the existing literary gap in this field and provide a definition of the effectiveness of technology development projects in RTOs.

However, in previous studies, the concept of effectiveness in research organizations (including government research organizations and national laboratories) has been addressed. As described below, the results of these studies are used as input to the panel of experts (A panel). A summary of the studies conducted in the evaluation of research and development organizations is given in the table below.

Table 3. A review of studies on evaluation of effectiveness in research organizations

scope of study	Subject of study	the writer	Year of publication	Focus and structure of the evaluation model
Technology Development Project Evaluation	Describing the process of designing such a system for a high-tech, product-development organization, and also provides a reduced list of ten R&D productivity indicators for ongoing monitoring purposes.	Warren B. Brown and David Gobeli	1992	The ten most important indicators in research and development evaluation are identified in seven categories.
Evaluation in a research organization differs from RTO	Measuring R&D Productivity in research and development laboratories	Brown, M. G., & Svenson	1998	In this research, the research and development laboratory are examined as a system and the body of the research production system, including five sections: "inputs", " processing system", "outputs", " receiving system" and "outcomes".
Evaluation in a research organization differs from RTO	performance evaluation of public research institute	Krishna, D., Mohan, S. R., Murthy, B. S. N., & Rao, A. R	2002	Public research organizations are considered as a system and has evaluated the performance of eight Indian research organizations based on eight indicators in two dimensions of "input" and "output".
Evaluation in a research organization differs from RTO	Evaluation of public research institutes	MARIO COCCIA	2004	The performance of research in government research organizations was measured on the basis of five indicators: "self-financing", "Training", "teaching", "national publications" and "international publications".
Evaluation in a research organization differs from RTO		MARIO COCCIA	2005	assessment of scientific research performance within 108 public research institutes belonging to the Italian National Research Council Based on: INPUTS 1. Public funds. 2. Payroll personnel. 3. Cost of labor OUTPUTS. 4. Self-financing (€) deriving from activities of technological transfer from the institute to outside users. 5. Training such as degree students, Ph.D. students, etc... 6. Teaching is the number of courses held by researchers at universities and other institutions. 7. International publications are those that appear in journals listed

scope of study	Subject of study	the writer	Year of publication	Focus and structure of the evaluation model
				in the Social Science Citation Index. 8. Domestic publications. 9. International proceedings. 10. Proceedings concerning conferences with domestic diffusion
Evaluation in a research organization differs from RTO		MARIO COCCIA	2006	Provide a new taxonomy based on the research performance of public research institutes
Technology Development Project Evaluation	Measuring research and development (R&D) effectiveness in industry	Teresa Garcı´a Valderrama and Eva Mulero-Mendigorri	2005	Development of 24 indicators in four dimensions: "input", "process", "output" and "performance".
Evaluation in a research organization differs from RTO	Performance Evaluation of Laboratories	S.Vijayalakshmi and Nagesh R.Iyer	2011	The laboratory performance evaluation model is presented as eight indicators in four dimensions of knowledge production, knowledge transfer, knowledge recognition and knowledge management.
Technology Development Project Evaluation	R&D performance measurement	Valentina Lazzarotti, Raffaella Manzini, Luca Mari	2011	Presenting a model for evaluating the performance of research and development projects based on 15 indicators under the five dimensions of "financial perspective", "customer perspective", " innovation and learning perspective", "internal business perspective" and " alliances and networks perspective ".
Evaluation in a research organization differs from RTO	performance management in industrial research	Tatjana Samsonowa	2012	Identified 11 performance clusters for R&D organizations and developed key performance indicators in each of these clusters. (Total 37 KPIs)
Evaluation in a research organization differs from RTO	Developing a performance measurement system for public research centres	Agostino & Arena & Azzone & Molin & Masella	2012	a comprehensive framework for measuring the performance of public research institutes in the form of five dimensions of "Effectiveness", "Outcome ", " Efficiency ", "Risk" and "Network" and the development of 23 indicators.
Evaluation in a research organization differs from RTO	CONCEPTUAL STRUCTURE OF R&D PRODUCTIVITY ASSESSMENT IN PUBLIC RESEARCH ORGANIZATIONS	Laliene & Sakalas	2014	Conceptualizing productivity, efficiency and effectiveness in research and development activities that led to the presentation of a conceptual model.
Evaluate a specific topic in RTO	study knowledge transfer from Research	Thurner & Zaichenko	2014	62 Russian RTOsin three sectors of "agriculture,

scope of study	Subject of study	the writer	Year of publication	Focus and structure of the evaluation model
	and Technology Organizations (RTOs) into primary sector producers			hunting and forestry", "fishing" and "mining and quarrying" were surveyed, and finally, 20 indicators were presented.
Technology Development Project Evaluation	Technology assessment model for sustainable development of LNG terminals	Yoon & shin& lee	2017	In this study, functional areas were extracted based on the three dimensions of "Source", "Make" and "Deliver" at the individual, organizational and technological levels (nine areas in total) and then the evaluation indicators of each area were compiled. (36 indicators)

3. Research Method

This research is applied in terms of purpose and result and is descriptive in nature and method. In conducting this research from the perspective of quantification, a combination of quantitative and qualitative methods is needed.

3.1. The Concept of Evaluating the Effectiveness of Technology Development Projects in RIPI

In this study, to investigate the concept of effectiveness in RIPI, this issue was examined from two aspects. The first aspect deals with the concept of effectiveness in a technology development project from the sight of project managers and research staff, regardless of its implementation in a research and technology organization. Another aspect examines the concept of effectiveness in the activities of a research and technology organization and, consequently, the unique concept of the effectiveness of projects in such organizations. The conceptual model of the research method is presented in the figure below.

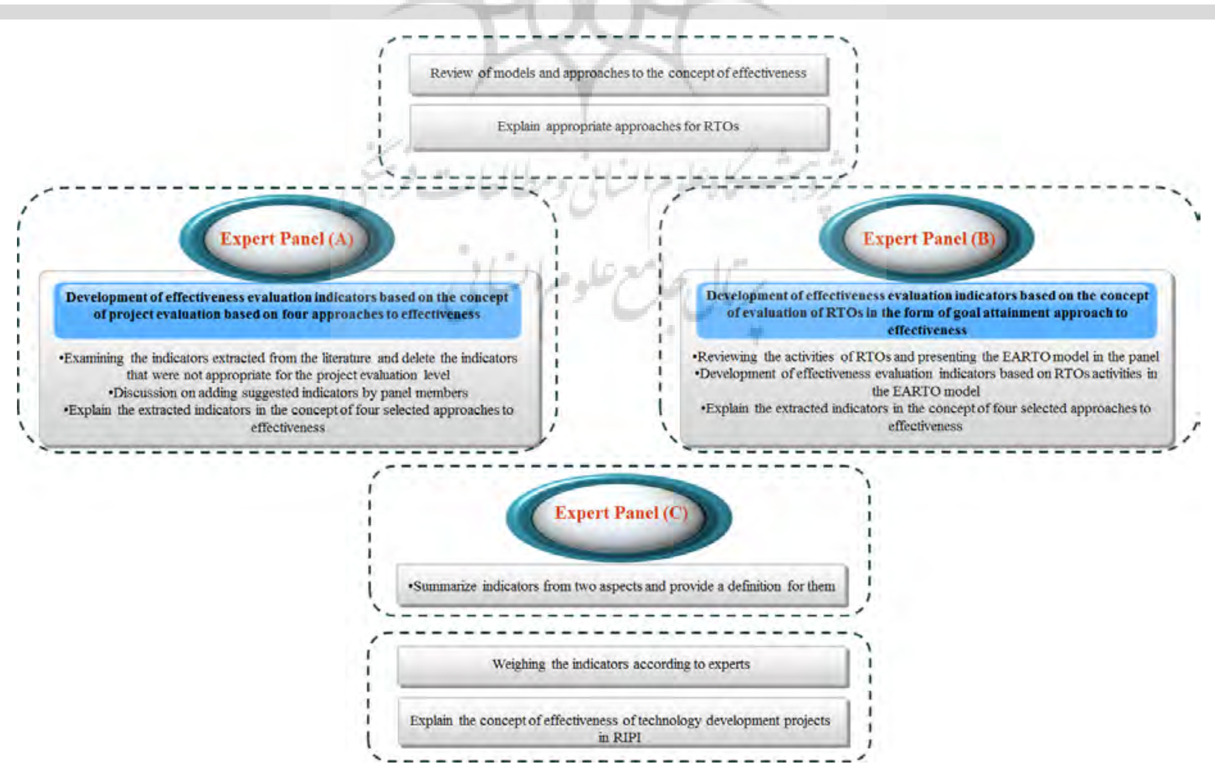

Figure 2. A conceptual model for evaluating the effectiveness of technology development projects in RIPI.

In order to identify the concept of effectiveness in technology development projects and develop indicators to evaluate it, a panel of experts was formed. The members of this panel (hereinafter referred to as Panel A) must be knowledgeable about how to work in a technology development project and the factors influencing the success/failure of the project. Therefore, Panel A consisted of six managers in project management, technology commercialization management, organization strategy management, and systems and standards management. Since the study in this section focuses on the "effectiveness of the research project", the results of research in the field of performance evaluation of research organizations (Table 3) were presented as input to Panel A.

In the second aspect, the activities of RTOs and the concept of effectiveness in these organizations were examined. Accordingly, in order to identify the concept of effectiveness in RTOs and develop indicators to evaluate it, a panel of experts was held. The members of this panel (after this referred to as Group B panel) are aware of how RTOs operate and their role in the innovation system. The experts in this department include five managers of the organization and one expert outside the organization. In order to discuss the concept of effectiveness in RTOs, the EARTO model (2018) was presented as an input to the panel.

In order to summarize the indicators presented from the two aspects, a panel consisting of a selection of panel A and B experts was formed (Panel C).

After explaining the evaluation indicators of the concept of effectiveness in technology development projects in RIPI, in order to determine the impact of each of the developed indicators, a questionnaire was prepared, and 30 experts of the organization, including managers in staff and line were asked to determine the importance of the indicators by assigning the number 1 to 10 (One represents the least important of the indicator and the number ten represents the most important indicator), determine the importance of the indicators. Out of 30 questionnaires that were sent, 26 questionnaires were received (response rate 87%).

Finally, according to the weights of the indicators and also categorizing each indicator in effectiveness approaches, the concept of effectiveness of technology development projects in RIPI was explained.

3.2. Implement the Proposed Framework by Evaluating Eight Technology Development Projects in Research Institute of Petroleum Industry (RIPI)

In implementing the proposed evaluation framework, eight technology development projects were selected from the projects of the Research Institute of Petroleum Industry (RIPI). The effectiveness of the technology development projects evaluates during a long time. But on the other hand, spending a lot of time after the completion of the project has a negative impact on data quality, and especially quality data. Therefore, it was decided that in selecting technology development projects, the condition of one to ten years from the completion of the project be observed.

In order to collect the required data, quantitative data were obtained from the relevant headquarters units. Regarding the collection of data related to quality indicators, these indicators were collected in the form of structured questionnaires and in the presence of experts. Accordingly, experts assign a number between 1 and 10 for each of the quality indicators in the project.

Experts in this part of the research were managers and senior researchers in these projects. In each project, the opinions of one project manager and at least two senior researchers were received, and by assigning weight 3 to project managers and 1 to senior researchers, qualitative data related to each project were calculated using the SAW method. (The decision on the weighting ratio between the project manager and the researcher was made in panel C)

a. Multi-criteria decision-making methods (MDCM)

In 2000, Larichev proposed a classification of MCDM methods:

- Methods based on quantitative measurements such as: SAW, MOORA, COPRAS …
- Methods based on qualitative initial measurements such as: fuzzy set theory methods and AHP
- Methods for comparative preference through pairwise comparison of alternatives. such as: TACTIC and ELECTRE
- Methods for uncertain environments includes verbal decision-making analysis

In this study, according to the type of data, several decision-making methods in the first group of the above classification were used. These methods are ARAS, COOPRAS, MOORA, and TOPSIS. All of these decision-making methods are explained in the appendix.

b. Method of calculating the final ranking of several MCDM methods

If all alternatives ranking orders in different MCDM methods are quite the same, the decision-making process will be ended. Otherwise, the ranking results cannot be valid and reliable. If the ranking outcomes from different techniques differ significantly, the validity issue will be crucial. (hobbs et al., 1992). A general finding from these studies is that no single MCDM technique is inherently better. (Hajkowicz and Collins; 2007)

therefore, an accurate combination method is required to determine the final preferences to increase reliability in ranking options. In this study, we used the aggregation method developed by Wang et al. (2005). In this method, a utility interval estimation method is proposed, where ordinal rankings are interpreted as constraints on utilities and each ordinal ranking corresponds to a set of utility interval estimates. Linear programming models are developed to estimate the ranges of utility intervals. A simple additive weighting method is used to aggregate utility intervals. (Wang et al. 2005)

A linear programming (LP) model is first constructed to estimate the interval for each alternative (research centers in this study). This model should be solved for each ranking method, by Eq. (1)-(4).

$$\min/\max \quad u_{i1} \tag{1}$$

$$s.t. \quad u_{ij} - u_{i(j+1)} \geq \varepsilon_{j(j+1)} \qquad j = 1, 2, \ldots, n-1, \tag{2}$$

$$\sum_{j=1}^{n} u_{ij} = 1 \tag{3}$$

$$u_{ij} \geq 0 \qquad j = 1, 2, \ldots, n. \tag{4}$$

Where u_{ij} is the utility of the jth ranked alternative perceived by the ith ranking method. Eq. (1), objective function, calculates the minimum and maximum interval numbers, $[u_{ij}^L, u_{ij}^U]$, for the first ranked alternative by each ranking method. To minimize Eq. (2) shows the preference of alternative j to alternative j+1 in ith ranking method, where ε is a small positive number. The normalized utility vector is presented by Eq. (3).

The aggregated utility (weighted average utility) of each alternative (research centers) can be calculated as follows:

$$u_j^L = \sum_{i=1}^{m} w_i u_{ij}^L, \qquad j = 1, \ldots, n. \tag{5}$$

$$u_j^U = \sum_{i=1}^{m} w_i u_{ij}^U, \qquad j = 1, \ldots, n. \tag{6}$$

Where, wi (i=1…, m) is the relative weight of the ith ranking method

4. Data Analysis and Findings

4.1. The Concept of Effectiveness in Technology Development Projects

In order to explain the concept of effectiveness in technology development projects, in two sitting of Panel A, two agendas were performed: first, it was determined what are the indicators for evaluating the effectiveness of a technology development project, and second, what is the approach of each of the indicators? Based on this, the indicators of effectiveness evaluation in technology development projects in the four approaches to effectiveness were compiled as follows:

Table 4. Indicators for evaluating the effectiveness of the research project in four selected approaches, extracted from panel A

approach	indicator	authors
goal attainment	The amount of use of technology developed in the industry	Brown & Svenson (1998), Brown & Gobeli (1992), Krishna et al. (2002), Vijayalakshmi & Iyer (2011),
	The quality of the results in relation to the technical characteristics mentioned in the proposal and the intended objectives of the project	Brown & Gobeli (1992), García & Mulero (2005)
	Number of national and international patents resulting from the project	Brown & Gobeli (1992), Krishna et al. (2002), Vijayalakshmi & Iyer (2011), Thurner & Zaichenko (2014), Samsonowa (2011), Agostino et al (2012), García & Mulero (2005), Coccia, M. (2006).
	Revenue from patents or licenses resulting from the project	Agostino et al. (2012), Thurner & Zaichenko (2014), Samsonowa (2011),
	The amount of product and process innovation in the project	Brown & Svenson (1998), García & Mulero (2005)
	Participation in political decisions, international projects, collaborations, development of new standards, etc. in the project	Vijayalakshmi & Iyer (2011),
	Competitiveness of technology developed in the industry	Experts of Panel A
	Science and technology contributions through manuals, handbooks, R&D reports, etc	Brown & Svenson (1998), Vijayalakshmi & Iyer (2011),
	Key skill areas learned by R&D personnel in the project	Brown & Gobeli (1992),
	The amount of training and increase the capacity of employees in the project	Brown & Svenson (1998), García & Mulero (2005)
system resources	Lack of environmental knowledge in order to gain resources for technology development in the project	Samsonowa (2011),
	Insufficient competence of employees of the project	García & Mulero (2005), Samsonowa (2011), Brown & Svenson (1998), Krishna et al (2002), Agostino et al (2012), Thurner & Zaichenko (2014)
	Lack of equipment and infrastructure to carry out the project	Brown & Svenson (1998), García & Mulero (2005), Agostino et al (2012),
internal processes	-	-
multiple stakeholders (multiple constituencies)	The extent of effective communication between key stakeholders in the project	García & Mulero (2005),
	The extent and quality of cooperation with universities and educational centers in the project	Samsonowa (2011),
	The extent and quality of cooperation with partners	Samsonowa (2011),
	The extent and quality of cooperation with customers (industry)	Samsonowa (2011),
	The extent and quality of international cooperation in the project	Experts of Panel A

approach	indicator	authors
	The positive reputation of the project from the sight of stakeholders	Mitchell (2015), Willems et al. (2016), Agostino et al. (2012),
	The satisfaction of employees involved in the project	Brown & Gobeli (1992),
	Total number of complaints about the project (customer satisfaction)	Brown & Gobeli (1992),

4.2. The Concept of Effectiveness in RTOs

As mentioned earlier in order to discuss the concept of effectiveness in RTOs, the EARTO model (2018) was presented as an input to panel B. According to the framework presented in the EARTO study, the expected activities of a research and technology organization can be classified into ten areas: "capacity building, human capital development", "sharing facilities", "services, contract research", " training, events, conferences","Cooperation", "Business innovation", "Patenting", "New business start-ups, Spin-offs", "regional specialization, clustering, ecosystem" and "Direct, indirect, induced spending impacts".

In Panel B, the experts identified the effectiveness evaluation indicators in RTOsbased on the expected activities of RTOs and categorized the indicators into four approaches to effectiveness. The table below shows the output of panel B.

Table 5. Effectiveness evaluation indicators based on expected activities of RTOs in the EARTO model.

expected activities of RTOs	indicators	approach
capacity building, human capital development	The amount of training and increase the capacity of employees in the project	goal attainment
	Key skill areas learned by R&D personnel in the project	goal attainment
	Compliance with the requirements of project knowledge integration	goal attainment
sharing facilities	Science and technology contributions through manuals, handbooks, R&D reports, etc	multiple stakeholders
	The amount of sharing laboratory materials and devices provided in the project to other educational and research centers	multiple stakeholders
services, contract research	The amount of use of technology developed in the industry	goal attainment
	The positive reputation of the project from the sight of stakeholders	multiple stakeholders
	The amount of technology spillover of carrying out the project	goal attainment
Cooperation	The extent and quality of cooperation with partners	multiple stakeholders
	The extent and quality of cooperation with customers (industry)	multiple stakeholders
	The extent and quality of cooperation with universities and educational centers in the project	multiple stakeholders
	The extent and quality of international cooperation in the project	multiple stakeholders
Business innovation	The amount of product and process innovation in the project	goal attainment
Patenting	Number of national and international patents resulting from the project	goal attainment
	Revenue from patents resulting from the project	goal attainment
New business start-ups, Spin-offs	Number of spin-off companies' establishment resulting from the technology development in the project	goal attainment
regional specialization, clustering, ecosystem	Contribute to the formation or development of ecosystem actors as a result of project implementation	multiple stakeholders
	Contribute to the formation or promotion of industrial clusters as a result of project implementation	multiple stakeholders

4.3. Summary of Indicators for Evaluating the Effectiveness of Technology Development Projects in RIPI

Finally, in order to define the concept of effectiveness of technology development projects in RIPI, a panel consisting of selected panel A and B experts was formed. In this panel (panel c), the indicators gained from both panels were investigated and approved by experts. As shown in the table, ten indicators of the total indicators are common to the two panels. It is worth noting that in the "internal processes" approach, the experts in neither panel provided an indicator to evaluate the effectiveness of a technology development project.

In order to determine the weights of the finalized indicators in Panel C, the opinions of experts were obtained in the form of a questionnaire and the results of 26 questionnaires received were calculated using the SAW method.

The results of panel C and the weights of the indicators are given in the table below.

Table 6. Indicators for evaluating the effectiveness of research projects of RIPI and their weights.

approach	indicator	Panel A/B	weigh	positive/ negative
goal attainment	The amount of product and process innovation in the project	A&B	0.036	positive
	The amount of technology spillover of carrying out the project	B	0.042	positive
	Compliance with the requirements of project knowledge integration (based on the definition of knowledge management unit)	B	0.033	positive
	Number of spin-off companies' establishment resulting from the technology development in the project	B	0.023	positive
	Number of national and international patents resulting from the project	A&B	0.023	positive
	The amount of training and increase the capacity of employees in the project	A&B	0.041	positive
	Key skill areas learned by R&D personnel in the project	A&B	0.038	positive
	Revenue from patents resulting from the project	A&B	0.034	positive
	The amount of use of technology developed in the industry	A&B	0.046	positive
	The quality of the results in relation to the technical characteristics mentioned in the proposal and the intended objectives of the project	A	0.045	positive
	Participation in political decisions, international projects, collaborations, development of new standards etc. in the project	A	0.034	positive
	Competitiveness of technology developed in the industry	A	0.045	positive
multiple stakeholders	The positive reputation of the project from the sight of stakeholders	A	0.045	positive
	The extent of effective communication between key stakeholders in the project	A	0.044	positive
	The satisfaction of employees involved in the project	A	0.041	positive
	Total number of complaints about the project (customer satisfaction)	A	0.041	negative
	The extent and quality of cooperation with partners	A&B	0.040	positive
	The extent and quality of cooperation with customers (industry)	A&B	0.043	positive
	The extent and quality of cooperation with universities and educational centers in the project	A&B	0.029	positive
	The extent and quality of international cooperation in the project	A&B	0.037	positive
	Science and technology contributions through manuals, handbooks, R&D reports, etc	A&B	0.035	positive
	The amount of sharing laboratory materials and devices provided in the project to other educational and research centers	B	0.027	positive
	Contribute to the formation or development of ecosystem actors as a result of project implementation	B	0.033	positive

	Contribute to the formation or promotion of industrial clusters as a result of project implementation	B	0.027	positive
system resources	Lack of environmental knowledge in order to gain resources for technology development in the project	A	0.035	negative
	Insufficient competence of employees of the project	A	0.042	negative
	Lack of equipment and infrastructure to carry out the project	A	0.041	negative

According to the calculated weights, an analysis can be provided on the importance of each of the effectiveness approaches from the point of view of the research managers of RIPI. The diagram below shows the weights assigned to each approach.

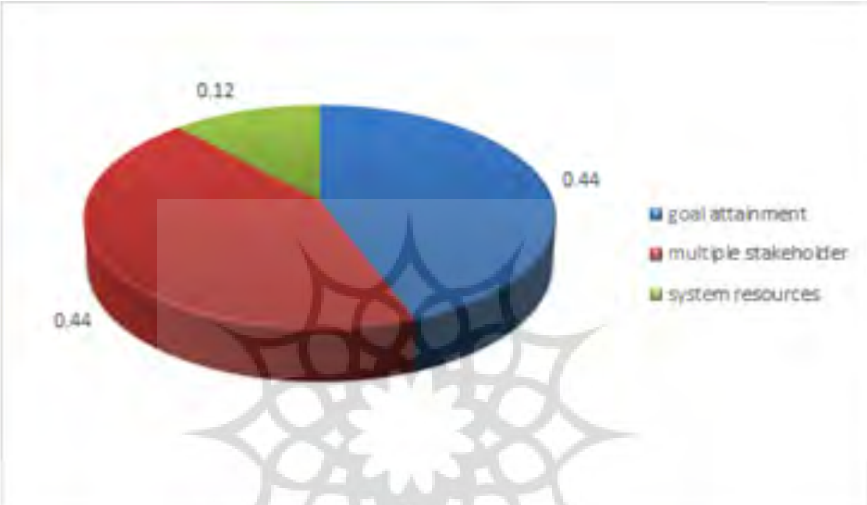

Figure 3. Comparison of the importance of approaches in evaluating technology development projects in RIPI.

According to the calculations, the indicators related to each of the two approaches, "goal attainment" and "multiple stakeholders", account for 44% of the total weight of the indicators. The importance of achieving project goals as well as stakeholder satisfaction in increasing the effectiveness of technology development projects in RTOs has been emphasized both in the discussions in panels A and B and in the literature.

According to experts, the "system resources" approach also has a 12% share. Given that on average, about 70% of the budget of RTOs is funded by the government, this issue has been emphasized as one of the main challenges of RIPI in the literature.

4.4. Evaluating the Effectiveness of Eight Technology Development Projects in the RIPI with a Combination of ARAS, COPRAS, MOORA and TOPSIS Methods

As mentioned in the research method section, in order to implement the proposed framework, eight technology development projects in the RIPI were selected in accordance with the above conditions. In order to maintain the principle of confidentiality, the names of these projects are abbreviated.

It is necessary to mention that regarding the "Customer Satisfaction" indicator, a comprehensive system for measuring this indicator has been launched in the Petroleum Industry Research Institute two years ago; However, since the data on this indicator do not cover the time interval of the last two to ten years, this index was omitted in the evaluation of these eight projects.

The steps for calculating the MOORA method are described in Appendix A1. In this method, the optimization score (Y) is calculated, and finally, the rank of alternatives is obtained. (The weights of indicators and the beneficial and non-beneficial are presented in Table 6). Therefore, according to the MOORA method, the following table was obtained from the ranking of eight technology development projects.

Table 7. Ranking of technology projects by MOORA method.

Technology Development Project	O	SE	DM	C	G	M	SU	DA
The value of "Y"	0.022174	0.024254	0.18821	0.20175	0.16387	0.063764	0.16107	0.24865
Rank in the MOORA method	3	2	5	4	6	8	7	1

The steps for calculating the ARAS method are described in Appendix A2. Based on ARAS method, the value of optimality function (S), the utility degree (K), and the rank of technology projects are indicated in table 8.

Table 8. Ranking of technology projects by ARAS method.

Technology Development Project	O	SE	DM	C	G	M	SU	DA
The value of "S"	0.095228	0.099931	0.082194	0.0851	0.073969	0.041989	0.071864	0.10151
The value of "K"	0.75076	0.78784	0.6473	0.67091	0.58316	0.33103	0.56657	0.80032
Rank in the ARAS method	3	2	5	4	6	8	7	1

The steps for calculating the COPRAS method are described in Appendix A3. Based on COPRAS method, the relative significance value (Q) and the rank of technology projects are indicated in table 9.

Table 9. Ranking of technology projects by COPRAS method.

Technology Development Project	O	SE	DM	C	G	M	SU	DA
The value of "Q"	0.11278	0.11985	0.097268	0.103	0.087268	0.04956	0.085844	0.12287
Rank in the COPRAS method	3	2	5	4	6	8	7	1

The steps for calculating the TOPSIS method are described in Appendix A4. Based on TOPSIS method, the ideal alternatives (RC) and the rank of technology projects are indicated in table 10.

Table 10. Ranking of technology projects by TOPSIS method.

Technology Development Project	O	SE	DM	C	G	M	SU	DA
The value of "RC"	0.71589	0.86008	0.54846	0.65248	0.39222	0.070254	0.41569	0.84293
Rank in the TOPSIS method	3	1	5	4	7	8	6	2

4.5. Combination of ARAS, COPRAS, MOORA, and TOPSIS Methods in Evaluating Eight Technology Development Projects

The ranking results of ARAS, MOORA, COPRAS, and TOPSIS methods for evaluating the effectiveness of eight technology development projects at the RIPI are shown in Table 11.

Table 11. The ranking of eight technology development projects using ARAS, COPRAS, MOORA, and TOPSIS methods.

Technology Development Project	O	SE	DM	C	G	M	SU	DA
Rank in the MOORA method	3	2	5	4	6	8	7	1
Rank in the ARAS method	3	2	5	4	6	8	7	1
Rank in the COPRAS method	3	2	5	4	6	8	7	1
Rank in the TOPSIS method	3	1	5	4	7	8	6	2

Based on the linear programming model proposed by Wang et al. (2005), the aggregated utility (weighted average utility) of each alternative (technology development projects) calculated by developing the correlation matrix between ranking methods. Eq. (1)-(7).

Table 12. Correlation matrix between the results of MOORA, ARAS, COPRAS, and TOPSIS.

methods	MOORA	ARAS	COPRAS	TOPSIS
MOORA	1	1	1	0.952
ARAS	1	1	1	0.952
COPRAS	1	1	1	0.952
TOPSIS	0.952	0.952	0.952	1

The normalized sum of each method's correlation is taken in to account as the weight in Eq. (6) and Eq. (7).

Table 13. Relative weight of MOORA, ARAS, COPRAS and TOPSIS methods.

methods	MOORA	ARAS	COPRAS	TOPSIS
weight	0.25	0.25	0.25	0.25

Finally, the final ranking was presented in a panel consisting of experts and managers of the "Deputy of technology and international affairs" of RIPI who were aware of the development process of the eight technologies discussed in interaction with the industry and the stakeholders' position towards them.

In this panel, considering the complexity of DM technology development and its historical place in the organization's performance as one of the first successful technology development projects (which played a major role in the organization's credibility to its capabilities), The effectiveness of this technology was debated, but in the end, the experts of panel accepted the ranking obtained from the research.

5. Conclusion

5.1. The Concept of Effectiveness of Technology Development Projects in RIPI

In the present study, according to the literature gap regarding the evaluation of the effectiveness of technology development projects in RTOs, in two parts, the concept of effectiveness from the sight of "technology development project" and the concept of effectiveness from the sight of "RTOs", was studied. The results obtained from holding expert panels in these two parts were obtained as evaluation indicators, separating traditional and modern approaches to effectiveness. The weights of the indicators were determined based on the opinions of 26 managers in staff and line, and using the SAW method.

In this study, considering the goals and functions of RTOs, new aspects of evaluating the effectiveness of research projects implemented in such organizations were considered, which did not exist in previous studies. Indicators such as "the amount of technology spillover of carrying out the project", "compliance with the requirements of project knowledge integration (based on the definition of knowledge management unit)" and "number of spin-off companies establishment resulting from the technology development in the project" in goal attainment approach, and "contribute to the formation or development of ecosystem actors as a result of project implementation" and "contribute to the formation or promotion of industrial clusters as a result of project implementation" in multiple stakeholders approach.

Finally, in the defining the concept of effectiveness in technology development projects in RIPI, according to the weights of indicators, it is possible to intersect the concept of effectiveness from two sights of "technology development project" and "RTOs" with three selected effectiveness approach (goal attainment, multiple stakeholders and system resources) draw the following diagram:

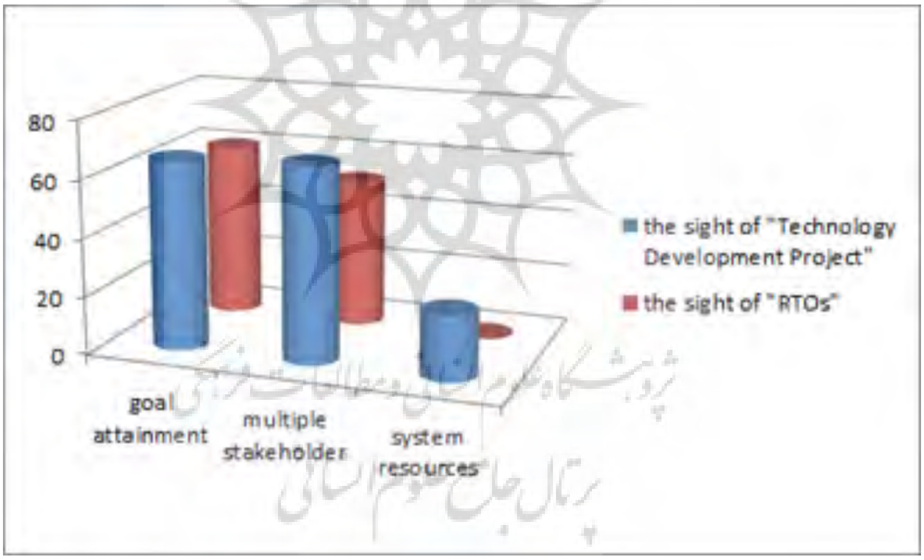

Figure 3. Combining the concepts of effectiveness in the sight of "Technology Development Project" and "RTOs", with three selected approaches to effectiveness.

As shown in Figure 4, in defining the concept of effectiveness in technology development projects in RIPI, the following general framework can be provided:

- Effectiveness in technology development projects in RIPI means achieving the goals of research projects and providing competitive technology. In order to evaluate such a concept, indicators such as "the amount of use of technology developed in industry" and the "competitiveness of technology developed in the industry" are proposed.
- Effectiveness in technology development projects in RIPI means achieving part of the organizational goals in order to make the organization more competitive. In order to evaluate such a concept, indicators such as "compliance with the requirements of project knowledge integration", "the amount of training and increase the capacity of employees in the project" and

"key skill areas learned by R&D personnel in the project" are introduced.

- Effectiveness in technology development projects in RIPI means achieving some goals defined for RTOs. Indicators such as "Number of spin-off companies establishment resulting from the technology development in the project" are discussed.
- Effectiveness in technology development projects in RIPI means the satisfaction of the organization's stakeholders from the results of research projects in the industry. This concept is presented with indicators such as "the positive reputation of the project from the sight of stakeholders" and "the extent and quality of cooperation with partners".
- Effectiveness in technology development projects in RIPI means the satisfaction of the organization's stakeholders from the activities of the RTOs. In other words, some activities in carrying out the project, such as knowledge diffusion and sharing materials and laboratory devices, provide the satisfaction of the stakeholders according to the mission of an RTOs. In this category, other indicators such as "contribute to the formation or development of ecosystem actors as a result of project implementation" and "contribute to the formation or promotion of industrial clusters as a result of project implementation".
- Effectiveness in technology development projects in RIPI means having sufficient resources to carry out the project productively. Accordingly, the need to know the environment, having qualified staff, and the necessary equipment and infrastructure to carry out the project are proposed. It is worth noting that this part of the general framework is less important than other previous parts in defining this concept.

Due to the importance of the effectiveness concept of technology development projects in RTOs, it is suggested that in future studies, this concept be examined in other RTOs and the results of this research be compared with each other.

According to the explanation of this issue in RIPI further research can address the reasons for this concept by identifying the factors affecting them.

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