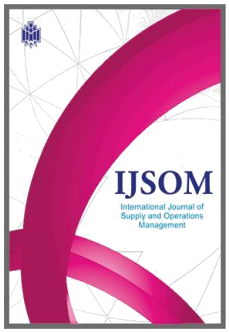
International Journal of Supply and Operations Management

IJSOM

February 2021, Volume 8, Issue 1, pp. 81-95
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



A Method for Project Performance Evaluation by Combining the Project Golden Triangle, BSC, AHP, and TOPSIS

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Abstract

There are several critical measures in the project performance evaluation such as time, cost, and quality. In this paper, a new method for project performance evaluation is presented by combining the project Golden Triangle and the methods in decision science. At first, strategies and measures are introduced for the perspectives of the Balanced Scorecard (BSC) method according to their effect on time, cost, and quality. Next, the Analytic Hierarchy Process (AHP) method is used to weigh the measures by the judgments of experts after integrating AHP and BSC. Then, the weights of the five project phases — from the initiation to the closure — are calculated by the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Our proposed TOPSIS is not only able to involve the judgments of experts, but also, in combination with AHP, can provide a comprehensive performance evaluation method for a project. Finally, using the judgments of experts of a real project-based organization, computational results show that financial measures are more important than other measures and the planning phase is the most important phase of the project. By the proposed method, a project-based organization can evaluate its performance and determine its competitiveness.

Keywords: Project Performance Evaluation; Project Golden Triangle; Bsc; Ahp; Topsis.

1. Introduction

The project is a set of non-repetitive activities that begin and end at specific times (this is our definition in this paper). Every project should be given enough attention because the existence of defects and flaws anywhere in the system will lead to a lot of damage and cost. Today, the rapid development of industries and the growing competition between companies have made organizational activities a project. In today's highly competitive world, countries with strong economies can produce their products at a lower cost and high quality in an acceptable time. There are several critical factors in the project performance evaluation i.e., time, cost, and quality. In this regard, the production of products with lower prices, higher quality, and acceptable makespan, will not only satisfy domestic customers but will also lead to a boom in exports.

Also, project performance evaluation within a project-oriented organization is always a major concern for managers and decision-makers of these organizations. From the past to the present, many methods have been introduced to evaluate the project performance from the traditional methods such as expert opinions and holding meetings, which have generally been "qualitative evaluations", to new methods based on hybrid qualitative and quantitative approaches. Moreover, creating a performance evaluation system is important since managers need to observe the project performance to understand the reasons for the failure and success of the project.

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DOI: 10.22034/IJSOM.2021.1.7

In this paper, we aim to introduce a comprehensive project performance evaluation method, both theoretically and practically. Our method is based on the combination of project Golden Triangle, BSC, AHP, and TOPSIS. We have first integrated Golden Triangle with BSC and AHP. Then, by modifying the TOPSIS method, we have integrated the AHP with TOPSIS, which makes our approach a comprehensive project performance evaluation tool. Finally, we have validated our methodology by implementing it for a real case study and based on the judgments of experts in a project-oriented organization.

In the next section, the literature review is presented. In the third section, the methodology of the paper is discussed. In the fourth section, the computational results of the implementation of the proposed model for a real case study are shown. Finally, in the fifth section, the concluding remarks and suggestions for future studies are presented.

2. Literature Review: Golden Triangle, BSC, AHP, and TOPSIS

2.1. Golden Triangle

It can be argued that project management is the management of project measures, including time, cost, and quality. It can be said that all organizations and even project-oriented companies seek to observe these three measures, where project managers are always trying to provide the product or service in the acceptable time and with the most appropriate cost and the best quality. The last three measures make the project Golden Triangle so that the goal of any project is to reach and satisfy all three measures at the same time. By quality, we mean "the degree to which a set of inherent characteristics fulfill requirements"; a definition from PMBOK[1].

2.2. Balanced scorecard (BSC)

In the past decades, most managers have used analytical tools only to evaluate the financial aspects of the company, so that other aspects of the organization have been generally ignored. Since these tools were not capable of considering more aspects of an organization, they lost their effectiveness in evaluating the overall performance of the organization. In the 1980s, Kaplan and Norton presented a four-dimensional model for performance management known as BSC.

In the first perspective of BSC, the stakeholders' and customers' views towards the organization's performance and satisfaction or dissatisfaction of customers with the company's services are examined. In the second perspective, the internal business processes of the organization are considered to determine in which areas the organization has excelled and its performance in dealing with the internal processes of the organization. In the third perspective, it examines the organization's approach to value creation and innovation, and whether the organization has done innovative activities in creating new services or ideas. In the fourth and last perspective, the organization is examined from the perspective of financial performance. These four perspectives are known in the literature as a customer, internal business processes, growth and learning, and financial, respectively (Kaplan and Norton 1996).

BSC is performance management that helps organizations move toward action and implementation through the organization's goals, vision, and strategies. In other words, BSC is an executive and practical procedure that not only helps the organization in recognizing and analyzing weak points and strengths but also provides practical measures according to organizational goals and strategies and ultimately provides practical solutions to the organization (Kaplan and Norton 2001).

2.3. Analytic Hierarchy Process (AHP)

AHP method was first introduced by Thomas L. Saaty in the 1980s. This method is one of the most popular methods designed for multi-criteria decision making (MCDM). This method enables the formulation and structuring of the problem hierarchically and considers both quantitative and qualitative criteria in the problem. Also, the compatibility and incompatibility metric of the decision is applied by this method. AHP is based on the pairwise comparison matrices, which are filled by the judgments of experts. The general steps of the AHP method are described briefly in (Saaty 2008).

2.4. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

Among the various methods available in the literature for MCDM, we prefer a set of multi-attribute decision making (MADM) methods over a set of multi-objective decision making (MODM) methods because, in this study, comparisons between different alternatives are made based on the various criteria. Among MADM methods, we choose TOPSIS since

1. Project Management Body of Knowledge

"compensatory methods such as TOPSIS allow trade-offs between criteria, where a poor result in one criterion can be negated by a good result in another criterion" (Greene, Devillers et al. 2011). This property makes TOPSIS more realistic than other MADM methods.

TOPSIS was first introduced by Ching-Lai Hwang and Yoon in 1918 and is one of the most widely used MCDM methods. The concept of TOPSIS is based on the assumption that the best alternative should have the least distance with the positive ideal solution and the greatest distance with the negative ideal solution (Hwang, Lai et al. 1993). The general steps of TOPSIS are described briefly in (Hwang and Yoon 1981).

2.4.1. Combination with BSC and AHP

Due to its high capability in combination with other decision-making methods, TOPSIS and its combination with other methods have been studied by many researchers to the present. Table 1 lists recent articles that combine the TOPSIS with BSC and AHP.

Table 1. Recent articles on a combination of TOPSIS with BSC and AHP

Ref.	Year	Case	Methodology		
			BSC	AHP	TOPSIS
(Ertuğrul and Karakaşoğlu 2008)	2008	Facility location selection	×	✓	✓
(Seçme, Bayrakdaroğlu et al. 2009)	2009	Performance evaluation in the Turkish banking sector	×	✓	✓
(Ertuğrul and Karakaşoğlu 2009)	2009	Performance evaluation of Turkish cement firms	×	✓	✓
(Gumus 2009)	2009	Evaluation of hazardous waste transportation firms	×	✓	✓
(Azar, Olfat et al. 2011)	2011	Supplier selection strategy	✓	×	✓
(Shojaee and Fallah 2012)	2012	Strategic planning	✓	×	✓
(Bhutia and Phipon 2012)	2012	Supplier selection problem	×	✓	✓
(Önder, Taş et al. 2013)	2013	Performance evaluation of Turkish banks	×	✓	✓
(Vinodh, Prasanna et al. 2014)	2014	Selecting the best plastic recycling method	×	✓	✓
(Aly, Attia et al. 2014)	2014	Prioritizing faculty of engineering education performance	✓	✓	✓
(Graham, Freeman et al. 2015)	2015	Green supplier selection	×	✓	✓
(Sehhat, Taheri et al. 2015)	2015	Ranking of insurance companies in Iran	×	✓	✓
(Yudatama and Sarno 2016)	2016	Priority determination for higher education strategic planning	✓	✓	✓
(Pramanik, Haldar et al. 2017)	2017	Resilient supplier selection	×	✓	✓
(Hájek, Stříteská et al. 2018)	2018	Innovation performance evaluation	✓	×	✓
(Yılmaz and Nuri İne 2018)	2018	Assessment of sustainability performances of banks	✓	×	✓
(Chou, Yen et al. 2019)	2019	Assessing the human resource in science and technology for Asian countries	×	✓	✓
(Chatterjee and Stević 2019)	2019	Supplier evaluation in the manufacturing environment	×	✓	✓
(Guru and Mahalik 2019)	2019	Performance measurement of Indian public sector banks	×	✓	✓
(Ban, Ban et al. 2020)	2020	Performance evaluation model of Romanian manufacturing listed companies	×	✓	✓
(Yucesan and Gul 2020)	2020	Hospital service quality evaluation	×	✓	✓
Present work	2020	Performance evaluation of a project-based growth and entrepreneurship organization in Iran	✓	✓	✓

2.5. Project Performance Evaluation

After introducing BSC as a tool for evaluating the performance of various aspects of an organization, the use of this method in evaluating and analyzing the performance of project-oriented companies was quickly applied. In (Keyes 2010), project management is examined using a BSC approach known as "project management balanced scorecard". By this book, the project has been evaluated from different aspects such as scheduling, scope, risk, estimation, procurement, and termination by using BSC. In (Remer and Nieto 1995) and (Remer and Nieto 1995), 25 various techniques and methods for evaluating the project performance have been introduced. These methods are generally classified into 5 categories, including net present value methods, rate of return methods, ratio methods, payback methods, and accounting methods. Also, using the data from different projects, these methods are compared with each other, and the strengths and weaknesses of each have been revealed. In (Milis and Mercken 2004), information and communication technology (ICT) projects have been evaluated by the BSC method. They have also adjusted the traditional evaluation methods and have

introduced new evaluation techniques for ICTs. In the end, the authors conclude that the BSC method is highly effective in evaluating the performance of various projects, especially ICT projects.

(Devine, Kloppenborg et al. 2010) studies the measurement of project success with the BSC approach. In their method, from the customer perspective, criteria such as scope, quality, and stakeholder satisfaction are included. Integration, risk, communications, and procurement are also considered from the perspective of internal project processes. From a financial perspective, scheduling, cost, profit, and market share are included. Finally, in the perspective of growth and learning, the two criteria of participant development and knowledge management are considered. In (Bing and Hao 2008), projects of the construction industry are examined by the BSC method. According to this paper, project performance evaluation is not sufficient in terms of cost, time, and quality, but in addition to these three aspects, also known as the Golden Triangle, other performance evaluation methods and decision-making techniques should be used to improve performance evaluation system.

In (Moe, Gehbauer et al. 2007), natural disaster projects are evaluated by the BSC. To implement the BSC method in the natural disaster project management, the performance measures of the four perspectives of the BSC are determined and then the desired measures are defined. In (Van Grembergen and Amelinckx 2002), e-business projects have been evaluated by the BSC method. This article shows how to manage and measure the e-business projects by BSC. In these articles, the project performance is evaluated only from the point of view of the BSC method, while considering today's complex and competitive world; it is helpful to use other decision-making methods along with BSC. In (Eilat, Golany et al. 2008), project evaluation was performed using an integrated BSC approach and data envelopment analysis (DEA). In this paper, in particular, R&D projects are considered. (Asosheh, Nalchigar et al. 2010) is methodologically like the previous article and, like it, has used BSC and DEA to evaluate the performance of information technology (IT) projects.

In (Varmazyar, Dehghanbaghi et al. 2016), a novel hybrid MCDM approach based on BSC is proposed to evaluate the research centers of the Research and Technology Organization (RTO) in Iran. To rank the alternatives they have used four MCDM methods including Additive Ratio Assessment (ARAS), Complex Proportional Assessment (COPRAS), Multi-Objective Optimization by Ratio Analysis (MOORA), and TOPSIS. (Cho and Hong 2017) evaluates the performance of the Marine Forest Creation project by using BSC, AHP, and IPA. They first determine the critical success factors (CSF) and key performance indicators (KPI) to evaluate the performance of the project from the four perspectives of BSC. They use AHP to weigh the CSFs and KPIs and use IPA to conduct the improvement of the project.

As a result, in the recent articles, the project performance evaluation is considered by combining the BSC and decision-making methods to measure the performance of the project-based (project-oriented) organizations and monitor their failure or success. As shown in the review of the articles, the project performance evaluation has not been studied by combining the project Golden Triangle, BSC, AHP, and TOPSIS for a project-based Growth and Entrepreneurship Center. So the contributions of this paper in the literature can be written as follows:

- Proposing a project performance evaluation method for a project-based Growth and Entrepreneurship Center in Iran based on the project Golden Triangle, BSC, AHP and TOPSIS
- Defining the strategies and measures using the combination of the project Golden Triangle and four perspectives of BSC for a project-based Growth and Entrepreneurship Center
- Calculate the weights of BSC measures and project phases based on the judgments of experts of a project-based Growth and Entrepreneurship Center

3. Research Methodology

The steps used in this paper for research methodology are as follows:

- Introducing strategies (sub-criteria) for each perspective (criteria) of the BSC based on the goals of the organizations so that these strategies are placed within the project Golden Triangle i.e., time, cost, and quality (based on PMBOK and the judgments of experts and literature).
- Introducing measures (alternatives) for each strategy of the BSC perspectives (based on the literature and experts' opinions)
- Calculating the weights of the measures and perspectives of BSC by AHP (based on the scores given by experts on a questionnaire)
- Calculating the weights of the five project phases (initiation, planning, execution, monitoring and control, closure) by the TOPSIS (based on the scores given by experts on a questionnaire)

3.1. Data collection tools

As mentioned in the first step of methodology, the contents of the PMBOK and available references will be used. In addition to these resources, the questionnaire will be used to gather the judgments of experts of a project-based Growth and Entrepreneurship Center. This center is located at Sharif University of Technology and the experts' profiles are given in the Acknowledgment section.

3.2. Strategies for the perspectives of BSC

At first, the strategies (sub-criteria) for the four perspectives (criteria) of BSC should be identified. These strategies should well reflect the goals of the organization and on the other hand, cover all aspects and scope of the organization. For this purpose, in this section, the strategies for four perspectives of BSC have been extracted by the experts' opinions and available references. These strategies are shown in Tables 2-5 for the growth and learning, internal business process, customer, and financial perspectives, respectively. Also, for each strategy, we have determined its field of action in the project Golden Triangle. In other words, these strategies are defined not only based on the perspectives of BSC but also under the edges of the Golden Triangle i.e., time, cost, and quality.

Table 2. Strategies for the growth and learning perspective

Perspective	Strategy	Field of action
Growth and learning	1. Increase the learning ability and skills of the workforce	Time (increase the skills of the workforce will lead to doing works faster)
		Cost (learning courses will need money and cost)
		Quality (increase the skills of the workforce will lead to doing works efficiently)
	2. Increase the motivation of the workforce	Time (increase the motivation of the workforce will decrease the slowness in doing works)
		Quality (increase the motivation of the workforce will lead to doing works efficiently)
	3. Increase the power of information and data	Cost (Increase the power of information and data will need money and cost)
		Quality (Increase the power of information and data will lead to doing works efficiently)
	4. Development of organizational culture and civilization	Cost (learning organizational culture will need money and cost)
	5. Increase the convergence of individual goals and the overall goal of the organization	Time (Increase the convergence of individual goals and the overall goal of the organization will lead to a commitment to doing works on time)
		Quality (Increase the convergence of individual goals and the overall goal of the organization will lead to providing services with high quality)
	6. Increase the experience and organizational knowledge	Time (Increase the experience and organizational knowledge will lead to doing works on time and without delay)
		Quality (Increase the experience and organizational knowledge will lead to doing works with high-quality next time)

Table 3. Strategies for the internal business processes perspective

Perspective	Strategy	Field of action
Internal business processes	7. Product improvement	Cost (product improvement will lead to producing economically)
		Quality (product improvement will lead to producing with high quality)
	8. Establish coordination among all parts of the organization	Time (coordination among all parts of the organization will lead to reducing extra activities)
		Cost (coordination among all parts of the organization will lead to reducing redundant costs)
	9. Reduce failures and wastes of the production	Quality (reduce failures and wastes of the production will lead to producing with high quality)
	10. Timely delivery and fast service	Time (timely delivery and fast service will lead to decreasing the time delivery)

Table 4. Strategies for the customer perspective

Perspective	Strategy	Field of action
Customer	11. Increase customer satisfaction	Quality (customer satisfaction needs products with high quality)
	12. Increase the number of current customers	Cost (Increase the number of current customers will need cost and expenses on advertisement and Marketing)
	13. Reasonable pricing	Cost (Reasonable pricing will lead to producing at a reasonable cost)

Table 5. Strategies for the financial perspective

Perspective	Strategy	Field of action
Financial	14. Increase in profit	Cost
	15. Improving the debt recovery process	Cost
	16. Increase revenue	Cost
	17. Improving the cost structure	Cost

3.3. Measures for the strategies and perspectives of BSC

In this section, we extract appropriate measures for each strategy, and the definition of each measure that needs further explanation is given in the footnote. These measures and their related strategy are given in Tables 6-9. Like the strategies, these measures have been extracted by the experts' opinions and available references.

Table 6. Measures for the growth and learning perspective

Strategy	Measure
1. Increase the learning ability and skills of the workforce	1. The ratio of the total learning costs to the overall sales during the project[1]
	2. The ratio of the number of trained workers to the total number of workers during the project[2]
	3. The ratio of the total number of trained workers to the total number of training hours during the project
	4. The ratio of the number of specialized training hours to the total number of training hours during the project[3]
	5. The ratio of the total training hours to the total working hours during the project
2. Increase the motivation of the workforce	6. The ratio of the retained workers to the total workers during the project
	7. The number of times workers are rewarded during the project
3. Increase the power of information and data	8. The ratio of the total number of workers who read the internal journal to the total number of workers during the project[4]
	9. The ratio of total expenses on R&D to the total revenue during the project
	10. The ratio of the number of successful projects to the total number of projects
	11. The ratio of the public relations costs to the overall sales during the project
	12. The ratio of the number of pages related to the benchmarking reports to the total number of the projects
4. Development of organizational culture and civilization	13. The ratio of the number of hours of seminars for strengthening collective communication to the total number of training hours during the project
5. Increase the convergence of individual goals and the overall goal of the organization	14. The ratio of the number of meetings held with the presence of all members of the organization to the total number of meetings held during the project
6. Increase the experience and organizational knowledge	15. The ratio of the number of the previous projects reviewed at the start of the new project to the total number of the previous projects

1. Learning costs include expenses of classes and online courses for workers
2. The number of trained workers is determined by checking attendance in courses and classes
3. Specialized training hours means the hours of training related to the advanced and specialized classes
4. This measure is obtained by dividing the total number of internal journals sold by the total number of the printed internal journals.

Table 7. Measures for the internal business processes perspective

Strategy	Measure
7. Product improvement	16. Monthly production increase rate
	17. The ratio of the number of new technologies[1] used in the current project to the total number of technologies used in the previous project
8. Establish coordination among all parts of the organization	18. The ratio of the number of new workers to the total number of workers during the project
	19. Manpower productivity index[2]
9. Reduce failures and wastes of the production	20. Percentage of the waste rate (the ratio of the wasted products to the total number of the products during the project)
	21. The ratio of the number of returned products to the total number of the products during the project
	22. The ratio of the reworked products to the total number of the products during the project
10. Timely delivery and fast service	23. The ratio of the total idle times to the total working hours during the project
	24. The ratio of the number of delays in the current project to the previous project
	25. The ratio of the planned completion time to the actual project completion time

Table 8. Measures for the customer perspective

Strategy	Measure
11. Increase customer satisfaction	26. The ratio of the number of customer complaints in the current project to the previous project
	27. The ratio of the number of survey forms completed by customers in the current project to the previous project
	28. The ratio of the number of complaints related to the product quality to the total complaints during the project
12. Increase the number of current customers	29. The ratio of the number of the customers attracted in the current project to the previous project
	30. The ratio of the total advertising costs to the total costs during the project
	31. The ratio of the number of customers introduced to the company by the current customers to the total customers during the project[3]
13. Reasonable pricing	32. The ratio of the price offered by the company to the price offered by the competitor
	33. The ratio of the number of renewed contracts in the current project to the previous project

Table 9. Measurings for the financial perspective

Strategy	Measure
14. Increase in profit	34. The ratio of the gross profit (profit before tax deduction) to the total sales during the project
	35. The ratio of the accumulated profit to the net profit during the project
15. Improving the debt recovery process	36. The ratio of the total debt to equity (D/E) during the project
	37. The ratio of the total debt to the total assets during the project
16. Increase revenue	38. The ratio of the rate of return on investment in the current project to the previous project
	39. The ratio of the net present value of the current project to the previous project
	40. The ratio of the available capital to the total project costs during the project
	41. The ratio of the net profit (profit after tax deduction) to the total sales
17. Improving cost structure	42. The ratio of the cost reduction by implementing reforms in the current project to the previous project
	43. The ratio of the net profit to the total project costs
	44. The ratio of the earned value index (EVI) in the current report to the previous report during the project

To summarize, in this section, a total of 17 strategies and 44 measures were introduced, which have been tried to be all these measures in the field of action of the three edges of the Golden Triangle i.e., time, cost, and quality. Also, among all 44 measures, 26 are cost measures, 6 are time measures, and 12 are quality measures, indicating the high importance of cost and financial measures in the BSC.

1. Technologies in both production and service sections
2. In this paper, this measure is considered as dividing the total working hours of workers (as output) by the total number of hours of staff training (as input) during the project.
3. With the help of a survey

3.4. Combination of BSC and AHP

To implement the proposed model, a relationship must be established between the perspectives and measures of the BSC with the hierarchical levels in the AHP. In this paper, in the proposed model, the goals, criteria, and alternatives in the AHP are in one-to-one correspondence with the goals of the organization, the perspectives of BSC, and the measures of each perspective, respectively (Figure 1).

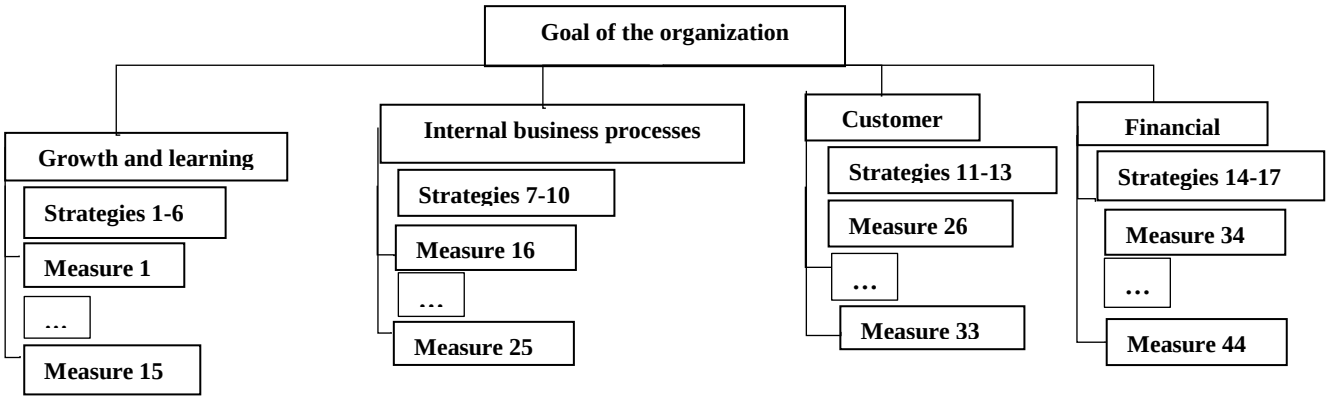

Figure 1. Combination of BSC with AHP in the proposed model

According to Fig. 1, the weights of the measures of the BSC can be calculated based on the judgments of the experts like the AHP calculations. To clarify, in the proposed method, first, the strategies for each perspective are compared in pairs; in other words, we will have four pairwise comparison matrices, which together with the pairwise comparison matrix for the perspectives of BSC, there will be five matrices in total. Finally, the weights of each strategy and each perspective are obtained based on the calculation of the AHP. To calculate the weight of each measure, the weight of each strategy is divided by the number of measures within it to obtain the weight of each measure. The reason for using strategies is that the total number of matrices and calculations is reduced.

3.5. Calculation of the weight of the five project phases with TOPSIS

In this section, we describe how to implement the TOPSIS in the proposed model. As mentioned before, the AHP is based on the pairwise comparison matrix, while the TOPSIS is based on the decision matrix and the comparison between alternatives according to the different criteria. In our model, in the decision matrix, we use project phases instead of alternatives and measures instead of criteria (Table 10). Thus, the weights of the project phases can be calculated based on the judgments of the experts with the help of the calculations described below:

1. Consider matrix $R_{(n,m)}$ as the decision matrix in TOPSIS.
2. $R_{(n,m)}$ is normalized by Eq. (1).

$$n_{ij} = {r_{ij}}\Big/{\sum_{i=1}^{n} r_{ij}} \quad ; \forall i,j \tag{1}$$

3. The weighted normalized decision matrix is calculated by Eq. (2), where $W_{n\times n}$ is the diagonal matrix with the weights of the measures in its main diagonal (these weights are determined by AHP) and $N_{n\times m}$ is the normalized matrix.

$$V_{n\times m} = W_{n\times n} * N_{n\times m} \tag{2}$$

4. The distance of each alternative from positive ideal solution (PIS) and negative ideal solution (NIS) are calculated by Eq. (3) and Eq. (4), respectively (v_j^+ and v_j^- are the maximum value of the j-th column and the minimum value of the j-th column of the matrix $V_{n\times m}$, respectively).

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^+)^2} \quad ; i = 1, \dots, n \tag{3}$$

$$d_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \quad ; i = 1, \dots, n \tag{4}$$

5. Now we can calculate the closeness coefficient of each alternative by Eq. (5).

$$CL_i^* = {d_i^-}\Big/{(d_i^- + d_i^+)} \quad ; i = 1, \dots, n \tag{5}$$

6. Finally, the rank of each alternative can be determined by the values of CL_i^*.

Table 10. Decision matrix in the proposed AHP-TOPSIS model

Decision matrix in the proposed model		**Criteria**			
		Measure 1	Measure 2	…	Measure 44
Alternatives	Project phase1	$r_{1,1}$	$r_{1,2}$	…	$r_{1,44}$
	…	…	…	…	…
	Project phase5	$r_{5,1}$	$r_{5,2}$	…	$r_{5,44}$

4. Results and Discussion

4.1. Case study

To verify our methodology, we used the questionnaire survey to obtain the weights of the measures and project phases. We distributed our questionnaires among the experts and managers of the Growth and Entrepreneurship Center located at Sharif University of Technology in Iran to aggregate their judgments. Our experts are anonymous since we promised that these judgments will be remained confidential. We continued the questionnaire survey until the inconsistency of the output became acceptable. In addition, this center is a project-based organization that tries to support the creation and development of entrepreneurship and the realization of technological innovations by implementing the various projects, so its experts' judgments will be helpful for our model verification.

4.2. Pairwise comparison matrices (AHP inputs)

For the inputs of AHP, the preferences of each of the four perspectives of the BSC and strategies of each perspective were specified by the questionnaire survey (the average of the scores was rounded to the nearest integer number) (Tables 11-15). In these matrices, the inconsistency of each is less than 0.1, so these matrices can be used as inputs for calculating the weights of the measures. Also, by Tables 11-15, the weight of each strategy is calculated.

Table 11. Pairwise comparison matrix for the perspective of the BSC

Perspectives of BSC	Growth and learning	Internal business processes	Customer	Financial
Growth and learning	1.00	0.33	0.50	0.50
Internal business processes	3.00	1.00	2.00	0.50
Customer	2.00	0.50	1.00	0.50
Financial	2.00	2.00	2.00	1.00
Weight * 100	12.55	29.99	19.05	38.39
Inconsistency rate	0.04			

Table 12. Pairwise comparison matrix for the strategies of the growth and learning perspective

Growth and learning	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6
Strategy 1	1.00	0.50	0.33	2.00	0.50	1.00
Strategy 2	2.00	1.00	0.50	1.00	0.33	1.00
Strategy 3	3.00	2.00	1.00	2.00	3.00	2.00
Strategy 4	0.50	1.00	0.50	1.00	0.33	1.00
Strategy 5	2.00	3.00	0.33	3.00	1.00	2.00
Strategy 6	1.00	1.00	0.50	1.00	0.50	1.00
Weight * 100	1.45	1.62	3.85	1.28	2.92	1.45
Inconsistency rate	0.06					

Table 13. Pairwise comparison matrix for the strategies of the internal business processes perspective

Internal Business processes	Strategy 7	Strategy 8	Strategy 9	Strategy 10
Strategy 7	1.00	0.20	0.50	0.50
Strategy 8	5.00	1.00	0.50	2.00
Strategy 9	2.00	2.00	1.00	1.00
Strategy 10	2.00	0.50	1.00	1.00
Weight * 100	3.24	10.36	9.72	6.69
Inconsistency rate	0.09			

Table 14. Pairwise comparison matrix for the strategies of the customer perspective

Customer	Strategy 11	Strategy 12	Strategy 13
Strategy 11	1.00	0.50	3.00
Strategy 12	2.00	1.00	3.00
Strategy 13	0.33	0.33	1.00
Weight * 100	6.36	10.02	2.68
Inconsistency rate	0.02		

Table 15. Pairwise comparison matrix for the strategies of the financial perspective

Financial	Strategy 14	Strategy 15	Strategy 16	Strategy 17
Strategy 14	1.00	0.33	0.33	1.00
Strategy 15	3.00	1.00	1.00	2.00
Strategy 16	3.00	1.00	1.00	4.00
Strategy 17	1.00	0.50	0.25	1.00
Weight *100	4.74	13.12	15.52	5.04
Inconsistency rate	0.01			

4.3. The weights of the measures (AHP output)

Using the AHP calculations, the weights of the measures and perspectives of the BSC are obtained according to Table 16. The weight of each measure is calculated by dividing the weight of each strategy by the number of measures for that strategy. These weights are now the output of the AHP, which can be considered as the inputs of the TOPSIS in the next step.

Table 16. The weights of the measures and perspectives of the BSC

Measure	1	2	3	4	5	6	7	8	9	10	11
Weight * 100	0.29	0.29	0.29	0.29	0.29	0.81	0.81	0.77	0.77	0.77	0.77
Measure	12	13	14	15	16	17	18	19	20	21	22
Weight * 100	0.77	1.28	2.92	1.45	1.62	1.62	5.18	5.18	3.24	3.24	3.24
Measure	23	24	25	26	27	28	29	30	31	32	33
Weight * 100	2.23	2.23	2.23	2.12	2.12	2.12	3.34	3.34	3.34	1.34	1.34
Measure	34	35	36	37	38	39	40	41	42	43	44
Weight * 100	2.37	2.37	6.56	6.56	3.88	3.88	3.88	3.88	1.68	1.68	1.68
Perspective	Growth & learning			internal business processes				Customer		Financial	
Weight * 100	12.55			29.99				19.05		38.39	

4.4. The weights of the project phases (TOPSIS output)

In this section, the decision matrix (with experts' judgments), the normalized matrix, the weighted normalized decision matrix, the distance of each project phase from PIS and NIS, and the closeness coefficient (weight) of each project phase are represented by Tables 17-21, respectively.

Table 18. Decision matrix (as input of the TOPSIS)

Measures	Project Phases				
	1	2	3	4	5
1	4	2	5	4	7
2	4	6	7	3	1
3	4	6	5	3	2
4	6	7	3	2	2
5	7	7	2	2	1
6	3	5	7	5	5
7	4	7	6	5	3
8	2	5	5	4	2
9	3	2	5	5	6
10	3	5	4	4	7
11	7	4	4	3	3
12	7	8	5	5	3
13	6	8	4	4	2
14	8	9	6	7	2
15	9	8	4	4	1
16	3	7	8	7	2
17	6	9	5	5	2
18	5	8	3	3	1
19	4	8	8	7	3
20	7	5	2	2	5
21	6	5	1	1	5
22	5	5	2	2	5
23	6	6	8	6	4
24	5	8	8	7	4
25	6	8	5	4	5
26	8	6	6	6	2
27	4	5	3	8	6
28	7	7	5	5	3
29	2	6	5	5	7
30	4	2	5	5	7
31	5	7	5	5	6
32	3	1	4	4	4
33	3	3	6	6	6
34	6	8	7	5	6
35	5	6	7	6	6
36	3	2	5	5	5
37	3	3	5	5	6
38	4	8	5	5	7
39	5	7	6	6	5
40	7	9	6	6	4
41	6	7	8	7	5
42	3	4	4	9	4
43	4	8	6	6	6
44	6	8	6	5	7

Table 17. The normalized matrix

N	Project phases				
Measures	1	2	3	4	5
1	0.18	0.09	0.23	0.18	0.32
2	0.19	0.29	0.33	0.14	0.05
3	0.20	0.30	0.25	0.15	0.10
4	0.30	0.35	0.15	0.10	0.10
5	0.37	0.37	0.11	0.11	0.05
6	0.12	0.20	0.28	0.20	0.20
7	0.16	0.28	0.24	0.20	0.12
8	0.11	0.28	0.28	0.22	0.11
9	0.14	0.10	0.24	0.24	0.29
10	0.13	0.22	0.17	0.17	0.30
11	0.33	0.19	0.19	0.14	0.14
12	0.25	0.29	0.18	0.18	0.11
13	0.25	0.33	0.17	0.17	0.08
14	0.25	0.28	0.19	0.22	0.06
15	0.35	0.31	0.15	0.15	0.04
16	0.11	0.26	0.30	0.26	0.07
17	0.22	0.33	0.19	0.19	0.07
18	0.25	0.40	0.15	0.15	0.05
19	0.13	0.27	0.27	0.23	0.10
20	0.33	0.24	0.10	0.10	0.24
21	0.33	0.28	0.06	0.06	0.28
22	0.26	0.26	0.11	0.11	0.26
23	0.20	0.20	0.27	0.20	0.13
24	0.16	0.25	0.25	0.22	0.13
25	0.21	0.29	0.18	0.14	0.18
26	0.29	0.21	0.21	0.21	0.07
27	0.15	0.19	0.12	0.31	0.23
28	0.26	0.26	0.19	0.19	0.11
29	0.08	0.24	0.20	0.20	0.28
30	0.17	0.09	0.22	0.22	0.30
31	0.18	0.25	0.18	0.18	0.21
32	0.19	0.06	0.25	0.25	0.25
33	0.13	0.13	0.25	0.25	0.25
34	0.19	0.25	0.22	0.16	0.19
35	0.17	0.20	0.23	0.20	0.20
36	0.15	0.10	0.25	0.25	0.25
37	0.14	0.14	0.23	0.23	0.27
38	0.14	0.28	0.17	0.17	0.24
39	0.17	0.24	0.21	0.21	0.17
40	0.22	0.28	0.19	0.19	0.13
41	0.18	0.21	0.24	0.21	0.15
42	0.13	0.17	0.17	0.38	0.17
43	0.13	0.27	0.20	0.20	0.20
44	0.19	0.25	0.19	0.16	0.22

Table 19. The weighted normalized decision matrix

V	Project phases				
Measures	1	2	3	4	5
1	0.0005	0.0003	0.0006	0.0005	0.0009
2	0.0005	0.0008	0.0010	0.0004	0.0001
3	0.0006	0.0009	0.0007	0.0004	0.0003
4	0.0009	0.0010	0.0004	0.0003	0.0003
5	0.0011	0.0011	0.0003	0.0003	0.0002
6	0.0010	0.0016	0.0023	0.0016	0.0016
7	0.0013	0.0023	0.0019	0.0016	0.0010
8	0.0009	0.0021	0.0021	0.0017	0.0009
9	0.0011	0.0007	0.0018	0.0018	0.0022
10	0.0010	0.0017	0.0013	0.0013	0.0024
11	0.0026	0.0015	0.0015	0.0011	0.0011
12	0.0019	0.0022	0.0014	0.0014	0.0008
13	0.0032	0.0043	0.0021	0.0021	0.0011
14	0.0073	0.0082	0.0055	0.0064	0.0018
15	0.0050	0.0045	0.0022	0.0022	0.0006
16	0.0018	0.0042	0.0048	0.0042	0.0012
17	0.0036	0.0054	0.0030	0.0030	0.0012
18	0.0129	0.0207	0.0078	0.0078	0.0026
19	0.0069	0.0138	0.0138	0.0121	0.0052
20	0.0108	0.0077	0.0031	0.0031	0.0077
21	0.0108	0.0090	0.0018	0.0018	0.0090
22	0.0085	0.0085	0.0034	0.0034	0.0085
23	0.0045	0.0045	0.0059	0.0045	0.0030
24	0.0035	0.0056	0.0056	0.0049	0.0028
25	0.0048	0.0064	0.0040	0.0032	0.0040
26	0.0061	0.0045	0.0045	0.0045	0.0015
27	0.0033	0.0041	0.0024	0.0065	0.0049
28	0.0055	0.0055	0.0039	0.0039	0.0024
29	0.0027	0.0080	0.0067	0.0067	0.0093
30	0.0058	0.0029	0.0073	0.0073	0.0102
31	0.0060	0.0083	0.0060	0.0060	0.0071
32	0.0025	0.0008	0.0034	0.0034	0.0034
33	0.0017	0.0017	0.0034	0.0034	0.0034
34	0.0045	0.0059	0.0052	0.0037	0.0045
35	0.0040	0.0047	0.0055	0.0047	0.0047
36	0.0098	0.0066	0.0164	0.0164	0.0164
37	0.0089	0.0089	0.0149	0.0149	0.0179
38	0.0053	0.0107	0.0067	0.0067	0.0094
39	0.0067	0.0094	0.0080	0.0080	0.0067
40	0.0085	0.0109	0.0073	0.0073	0.0048
41	0.0071	0.0082	0.0094	0.0082	0.0059
42	0.0021	0.0028	0.0028	0.0063	0.0028
43	0.0022	0.0045	0.0034	0.0034	0.0034
44	0.0031	0.0042	0.0031	0.0026	0.0037

Table 20. The distance of each project phase from PIS and NIS

	Project phases				
	1	2	3	4	5
d+	0.0205	0.0168	0.0216	0.0213	0.0256
d-	0.0210	0.0277	0.0193	0.0189	0.0203

Table 21. The closeness coefficient (weight) and rank of each project phase

Project phases	**Rank**	CL_i^*
Initiation	2	0.5059
Planning	1	0.6227
Execution	3	0.4723
Monitoring and control	4	0.4705
Closure	5	0.4425

As a result, the weight of each project phase is calculated according to Table 21. Also, the ranking of the project phases is obtained based on the judgments of experts and managers. The results show that the planning phase is more important than the other phases according to the project Golden Triangle. After that, the initiation and execution phases of the project are also very important. This suggests that the three measures of the Golden Triangle i.e., cost, time, and quality, should be well considered in the initiation and planning phases. Also, as a final point, source data can be provided upon request.

4.5. Discussion on results

Among all measures, the ratio of the total debt to equity (D/E) and the ratio of the total debt to the total assets are among the highest weights since the financial perspective has more weight than the other perspectives of the BSC. In addition to these two measures, the ratio of the number of the new workers to the total number of workers and manpower productivity index was also determined as the important measures indicating the high impact of human resource management in the project Golden Triangle. In other words, the presence of skilled workers reduces project makespan. Also, as the productivity of human resources increases, the costs of the organization will decrease significantly, so the quality of work will increase, and this shows the high importance of the measure of the manpower productivity index over other measures; this is well considered by experts in weighting the measures.

Moreover, the financial and internal business processes perspectives were more important than the customer and growth and learning perspectives. This is because experts and managers have evaluated the first two perspectives according to the project Gold Triangle more important. In other words, the financial perspective itself is directly related to the cost, and also the internal business processes are somehow directly or indirectly related to the time, cost, and quality, so it is expected that they will be considered more important. In addition to the high importance of the planning phase from the experts' judgments, the initiation phase was also more important than other phases, which indicates that if managers want to evaluate project performance, the Planning phase should be well considered from the perspective of the three measures of time, cost and quality. Thus, the results of this paper show that the planning phase and the financial measures are important; this conclusion confirms the results of the previous articles.

5. Conclusion remarks

In this paper, a new method for the project evaluation performance is presented by considering the judgments of experts of a project-based organization. The proposed method is comprehensive in which the BSC method is combined with the project Golden Triangle. Next, the strategies and measures are introduced based on the integrated BSC and project Golden Triangle. These three sides of the Golden Triangle are the most important measures for evaluating the performance of any project. Besides, the 17 strategies and 44 measures are introduced for the BSC perspectives which indicate the comprehensiveness of the introduced measures. In the proposed method, AHP is used to weigh the strategies, measures, and perspectives of the BSC. Then the TOPSIS is used to rank the project phases. In addition to the case study, the results of this paper confirm the results of other articles, so that in most articles the planning phase is always introduced as an important phase and the financial measures as the important factor for evaluating the performance of any organization. By the obtained results, a project-based organization can evaluate its performance and determine its competitiveness.

For future studies, it is suggested that in addition to the measures introduced in the Golden Triangle, other important factors of the project, such as the risk, be involved in evaluating the project performance. In addition, a BSC with new perspectives such as employee satisfaction and the organization's communication with people and society can be used. Also, in addition to definite variables, fuzzy data can be considered.

Acknowledgments

The authors of this article would like to acknowledge the experts and managers of the Growth and Entrepreneurship Center located at Sharif University of Technology and other respectable colleagues from the Simorgh Research Center, the Advanced Technologies of Meghdad, and the Innovative Company of Amn Andish Sharif, which presented their judgments in our discretion.

Disclosure statement

The authors reported no potential conflict of interest.

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