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PRIORITIZATION AND SELECTION OF CONSTRUCTION PROJECT PORTFOLIO IN CONTRACTOR COMPANIES USING PROJECT PORTFOLIO MANAGEMENT APPROACH (CASE STUDY: CASPIAN CONTRACTOR COMPANY)

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RESUMEN: La supervivencia de los negocios orientados a proyectos depende de su capacidad para construir y modificar su cartera de proyectos en línea con sus objetivos organizacionales para lograr la mayor creación de valor. Este estudio introduce un modelo basado en principios de gestión de cartera de proyectos para la creación y priorización de portafolios de proyectos en contratistas iraníes y empresas de construcción. En este modelo, los criterios cuantitativos y cualitativos de evaluación de proyectos se derivarán de la literatura, los proyectos actuales y futuros candidatos serán priorizados por el método AHP, y las carteras se construirán mediante un método de toma de decisiones multicriterio con la debida atención a las limitaciones de la organización. A continuación, se identificarán los criterios de priorización de la cartera y las carteras se ajustarán y se equilibrarán según sus méritos y riesgos. Este modelo permite a los gerentes evaluar y comparar sus carteras bajo diferentes condiciones y escenarios. Este modelo fue implementado en una empresa contratista que opera en Teherán para ayudar a la administración de la empresa en la evaluación y selección de proyectos futuros basados en dos criterios de riesgo y valor acumulado.

Palabras clave: Gestión de Cartera de Proyectos, Construcción de Cartera, Empresa Contratista, Priorización, AHP

ABSTRACT: Survival of project-oriented businesses depends on their ability to construct and modify their project portfolio in line with their organizational goals so as to achieve the highest value creation. This study introduces a model based on project portfolio management principles for creation and prioritization of project portfolios in Iranian contractor and construction companies. In this model, quantitative and qualitative project evaluation criteria will be derived from literature, current and candidate future projects will be prioritized by AHP method, and portfolios will be constructed by a multi-criteria decision-making method with due attention to organization's limitations. Then, portfolio prioritization criteria will be identified, and portfolios will be adjusted and balanced according to their merits and risks. This model allows managers to evaluate and compare their portfolios under different conditions and scenarios. This model was implemented in a contractor company operating in Tehran to aid the company management in evaluation and selection of future projects based on two criteria of risk and earned value.

Keywords: Project Portfolio Management, Portfolio Construction, Contractor Company, Prioritization, AHP

1. INTRODUCTION

Project portfolio selection and review are believed to be among the most critical managerial challenges of project-oriented organizations. Project portfolio management is an essential part of managerial activities in almost every organization, but it is particularly critical for project-oriented businesses such as construction companies. Project portfolio management (PPM) is an approach derived from project management knowledge, whose purpose is to select those design, implementation or construction projects that can help a business reach its strategic objectives. Theoretically, this process involves selecting a set of most profitable projects with due consideration given to allocation of limited resources, guidelines of strategic statement, and the state of coordination and synergy in the resulting portfolio [1].

The contractor companies are project-oriented in nature and earn the bulk of their revenues from their projects, thus smart

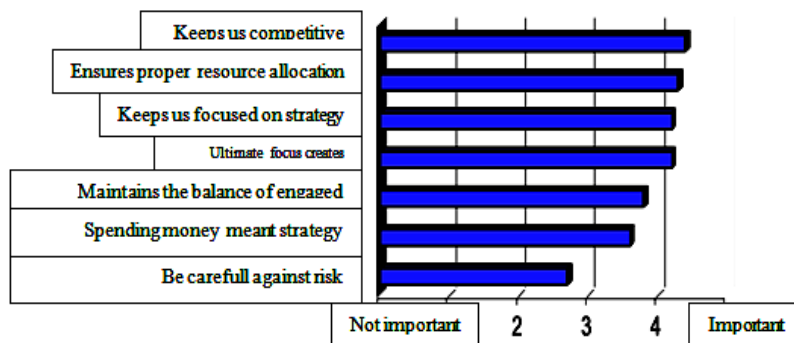


Fig. 1. The effect of portfolio management as viewed by Iranian senior managers

The critical importance of project portfolio selection for project-oriented businesses such as construction companies is therefore undeniable.

The review of local literature in the field of project prioritization and portfolio selection shows the absence of such work in regard to Iranian construction and contractor companies. Therefore, this study is an attempt to identify the main criteria of project prioritization and portfolio selection of Iranian construction and contractor companies, and to utilize the project portfolio management (PPM) principles to provide a suitable model for project prioritization and portfolio selection in a construction company operating in Tehran.

2. THEORETICAL PRINCIPLES

project selection is particularly important for their financial wellbeing and ultimate survival. There are many techniques for evaluation of individual projects, but in today's highly competitive world, a contractor company has to choose project according to its organizational goals and limitations in a way that the multitude of projects engaged at a given time would collectively yield the greatest total profit. Failure in proper selection of project portfolio however may expose the company to problems such as lack of sufficient access to resources needed to continue and finish the projects, long delays and decline in economic feasibility of the projects, and ultimately bankruptcy and loss of human and financial capital. Figure 1 shows the results of a study on the effects of successful portfolio management on organizations in the view of Iranian senior managers (on a scale of 0 to 5) [2].

2.1 Definition of project portfolio

Project portfolio refers to an economic unit's ongoing projects that share strategic objectives and resources [3].

2.2 Definition of project portfolio management (PPM)

Project portfolio management refers to centralized management of one or several project portfolios in an organization through identification, prioritization, licensing, management, and control of project, plans and other related work in line with business-specific strategic objectives [4].

Portfolio management has numerous advantages over separate management of individual projects, as it serves as a bridge between organizational strategies and

projects and as a means to optimize resource allocation. Figure 2 is an illustration of PPM functions in an

organization [4].



Fig.2. project portfolio management functions in a typical organization

2.3 Objectives of project portfolio management

- Maximizing the portfolio value by careful examination of candidate projects and plans and elimination of projects that are in conflict with organization’s strategic objectives.
- Balancing the project portfolio by capital adjustment aimed at optimal resource utilization, through the following activities:
- Linking portfolio to business strategy
- Aiming for the right balance and mix of projects
- Maximizing the portfolio value

The ultimate goal of linking portfolio management to organizational strategy is to create balanced and executable plans to achieve organizational goals [5].

2.4 Portfolio management processes

Portfolio management processes can be classified in two categories:

- Aligning process group, which involves how components will be categorized, evaluated, selected and managed.
- Monitoring and controlling process group, which involves periodic review of performance indicators to ensure alignment with strategic objectives and validity of profits of portfolio components for the organization [4].

Portfolio management processes		
Monitoring and controlling process group	Aligning process group	Knowledge Area
Portfolio performance review and reporting	Identification of components	Portfolio management
Monitoring business strategy changes	Categorization of components	
Communicating portfolio adjustments	Evaluation of components	
	Selection of components	
	Prioritization of components	
	Portfolio balancing	
	Authorization of components	
Portfolio risk monitoring and	Portfolio risk identification	Portfolio risk

control		management
	Portfolio risk analysis	
	Development of portfolio risk responses	

Fig.3. Portfolio management processes

2.5 Project selection models

The principles of project selection were first introduced in a study by Buffer and Pound (1964) on the art and science of evaluating and selecting R&D projects. The use of structured and numerical procedures for project evaluation and selection is a relatively recent phenomenon, which has generally emerged after World War II. Initially, parameters such as return period and average annual rate of return were the dominant criteria of evaluation in this field, and of course these criteria are still in use in many applications where uncertainty may undermine the quality of selection. During 1950s and 1960s, the use of structured models gradually grew. During this time, the majority of models were focused exclusively on profit and profitability, and tended to shorten the time horizon of investment decisions [6]. With emerging awareness about the shortcomings of this approach, 1970s saw a growing interest in the use of models that facilitate selection and evaluation based on several criteria. This trend then led to emergence of interactive decision systems. 1990s witnessed a significant progress in the field of preference evaluation based on the use of input information for ranking. These models were then evolved for use in applications such as allocation modeling and goal programming. Later, with the emergence of resource constraints, multi-objective designs, and diverse considerations and preferences in project selection field, attentions were shifted toward the models that allow the best combination of several projects to be chosen. At first, projects used to be ranked by the existing ranking models. But eventually, comprehensive mathematical models that operate by maximizing an objective function with respect to selection criteria, constraints and preferences (e.g. multi-criteria decision-making models and goal programming, etc.) were adapted for project portfolio selection and resource allocation. Currently, there seems to be an interest in adapting decision support systems and expert systems for this field [6].

2.6 Suitable selection criteria

After extensive research on a large number of companies and organizations, Souder (1973) proposed five criteria for project selection. The following are the Souder's criteria plus a newer criterion proposed by Meredith (2000).

- Realism
- Capability
- Flexibility
- Ease of use
- Cost-effectiveness
- Ease of computerization

2.7 Project portfolio management frameworks and models

Models and frameworks describe the process of decision-making and project portfolio selection. There are more than one hundred techniques and tools of project portfolio selection, and this multitude of techniques may confuse the decision-maker [8], so development of a suitable and logical approach that could evaluate different available projects and construct a portfolio aligned with organizational strategies is crucial [9].

2.8 Common principles of portfolio management frameworks and models

frameworks and models classify the candidate projects into interrelated subsets [9].

These Any project subset could be a group of projects that align with a particular organizational strategy or a group of projects with the same characteristics [10].

This classification allows the organization to evaluate the projects of each subset by the same criteria and techniques [11].

2.9 Research questions

- 1- What is a desirable portfolio of construction projects in the view of a contractor company?
- 2- What are the criteria for prioritization of such projects?
- 3- What is the suitable model for ranking project portfolios?
- 4- What is the result of portfolios prioritization? and how should it be analyzed?

3. RESEARCH METHODOLOGY

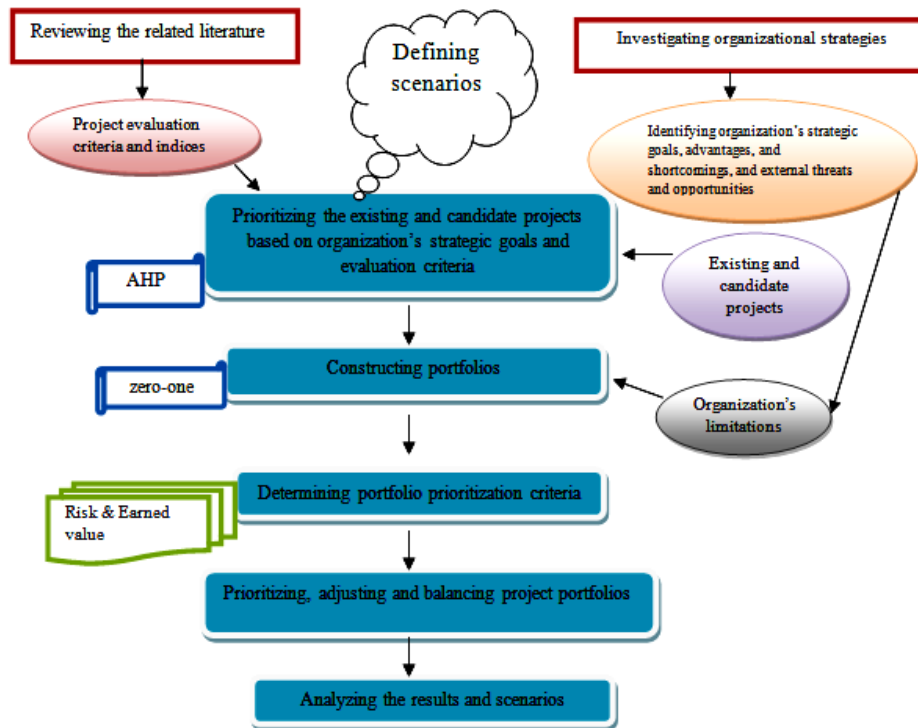


Fig.4. An overview of research procedure

3.1 Phases of the proposed model

This study introduces a model of project portfolio management. This model is the result of systematic review of scientific and practical considerations in regard to application of concepts present in the existing

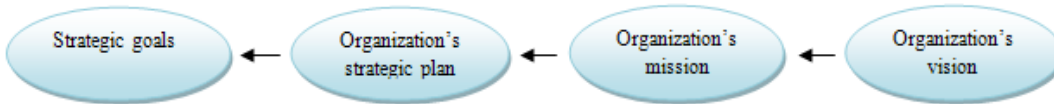
project portfolio selection literature with the aim of improving project

Table 1 shows the summarized descriptions of model phases, involved parties, and the tools and techniques to be utilized in each process.

Table 1. phases of the developed project portfolio selection model and the involved organizational parties

Phase	Activities to be performed	Parties to be involved	Tools and techniques to be utilized
Phase1	Investigating organization's strategic considerations	characterization by board of directors; investigation by research team	interview with senior managers
Phase2	Identifying quantitative and qualitative project evaluation criteria	identification by middle managers and research team; confirmation by senior managers	Review of related literature and identification of indicators
Phase3	Defining scenarios	senior managers and research team	
Phase4	Collecting and categorizing ideas and suggestions about the current projects and prioritizing the candidate projects	middle managers	AHP
Phase5	constructing portfolios	middle managers and research team	Multi-criteria decision-making method (zero-one)
Phase6	Determining portfolio prioritization criteria	senior managers and investors	interview with experts
Phase7	Prioritizing, adjusting and balancing portfolios	senior and middle managers, research team with inputs from investors	risk analysis (NPV variance)
Phase8	analyzing the scenario and its results	senior managers	
Phase9	reviewing the project portfolio performance and reporting	senior and middle managers	

3.1.1 Phase 1: Characterizing, organizing, and investigating strategic considerations



The first step is to organize and investigate organization’s vision and goals to identify capabilities, limitations, threats, opportunities, and what organization seeks to achieve. One of the efficient strategic tools available for evaluation of relation of organization’s internal strengths and weaknesses with external threats and opportunities is the SWOT matrix. The experts’ inputs must also be utilized to develop a more realistic strategic plan based on internal and external realities. In this study, these inputs are gathered from closed interviews of managers, shareholders, experts of the

studied company and then organized into the SWOT matrix.

3.1.2 Phase 2: Identifying quantitative and qualitative project evaluation criteria

In this step, the literature is reviewed to identify project selection criteria in the related industry (*here, construction industry*); the identified criteria are then rated by experts and senior managers of organization.

Table 2. criteria and sub-criteria

criteria and sub-criteria					
Risk	Organizational evaluation	economic criteria	Business-political criteria	financial criteria	Technical criteria
Project risk	Management	inflation	Demand	Project cost	Resource availability
Industry risk	Capabilities of human resources	Currency exchange rate	Government policies and regulations	capital availability	Human capital availability
Company risk	Project approval in different organization levels	Project’s environmental effects	Sensitivity to politics	profitability	Technology availability
Economic risk	Past experience in similar projects	Competitiveness	Business environment	Net present value	Project time horizon
				Return period	Equipment and machinery
					Project executability
					Project location

3.1.3 Phase 3: Defining scenarios

To define scenarios, decision makers (senior managers and investors) review the organization’s condition and specific features of current projects, identify the project, factor, or criteria whose uncertainty has the greatest impact on the success of organization, and decompose that uncertainty into multiple scenarios [10].

This allows the decision to account for uncertainties and their effect on key factors of performance and thereby on project portfolios. For

example, the company investigated in this study may face two scenarios:

A) Strong demand for mass construction with pre-tensioning system (company’s specialty and business advantage) more than 30,000 square meters.

B) Weak demand for mass construction with pre-tensioning system less than 30,000 square meters.

3.1.4 Phase 4: Collecting and categorizing ideas and suggestions about the current projects and prioritizing the candidate projects

The inputs of this step include a list of evaluation and selection criteria and a categorized list of the current projects. Project prioritization is performed by multi-criteria rating tools such as AHP [12] based on experts' inputs.

3.1.5 Phase 5: Constructing portfolios

In this step, portfolios need to be constructed according to organization's limitations in -for example- the existing and available capacity of human resources, finances, capabilities, etc. This task can be accomplished by one of many available MCDM methods [13]. In this study, the zero-one linear programming model [14] is used for this purpose. The aim of this model is to find the best combination of alternatives with highest profit in feasible space. In this model, variables can only take zero and one values, and this perfectly matches the aim of work, i.e. determining whether or not a project should be included in a portfolio.

$$X_i = \begin{cases} 1 \\ 0 \end{cases} \quad (1)$$

$X_i=1$ if project i is included in the portfolio.
 $X_i=0$ if project i is not included in the portfolio.

Objective function:

$$\text{Max: } Z = \sum_{i=1}^n a_i X_i \quad (2)$$

where a_i is a factor obtained for project i in the prioritization step (from AHP).

Constraints:

A realistic model should be able to reflect the constraints of the organization. Some of these constraints are briefly reviewed in the following [10].

1- Resource constraint

$$\sum_{i=1}^n a_{ij} X_i \leq C_j \quad (3)$$

Where C_j is the available amount of resource j , and a_{ij} is the amount of resource j needed in project i .

2- Constraint of mandatory projects

$$X_i = 1 \text{ for } i \in S_m \quad (4)$$

where S_m is the set of mandatory projects.

3. CONSTRAINT OF PROJECT INTERRELATIONSHIP

3.1 Mutual exclusiveness (one but not both):

$$\sum_{i \in S_n} X_i \leq 1 \quad (5)$$

where S_n is a set of mutually exclusive projects.

3.2 Constraint of contingent projects

This constraint states that project X_k can be selected only if project X_j is also selected.

$$X_j \geq X_k \quad (6)$$

4. CONSTRAINT OF THE NUMBER OF PROJECTS

This constraint ensures that the number of projects to be selected from m possible candidates will remain below n .

$$\sum_{j=1}^m X_j \leq n \quad (7)$$

3.1.6 Phase 6: Determining portfolio prioritization criteria

The final decision regarding the portfolio will be made by senior managers and investors, in other words, portfolios must fulfill the goals and expectations of these stakeholders, thus, the main portfolio prioritization criteria is determined based on the inputs of senior experts, managers, investors and other major parties within the organization. In all businesses, portfolios are expected to yield the highest earned value for the investors, but considering the fluid condition of today's business environments, portfolio risk should also be duly considered in prioritization. In the case of this study, two factors are selected as portfolio prioritization criteria: (1) the value earned by portfolio and (2) the risk of portfolio.

3.1.7 Phase 7: Prioritizing, adjusting and balancing portfolios

In this study, portfolios are prioritized based on two criteria: portfolio's earned value, and portfolio risk. Here, the latter criterion is evaluated by NPV variance.

The aim of this adjustment and balancing process is to develop combinations of portfolio components with the best potential in working collectively toward fulfillment of organization's strategic goals. This task

can be accomplished by a variety of methods, e.g. transferring or swapping projects between selected and active portfolios, postponing the projects with insufficient resources, selling stocks, etc. In this study, portfolios are balanced by scenario and portfolio risk analyses.

3.1.7.1 Risk analysis

Risk analysis is one of the key and yet most challenging tasks of project selection and portfolio management.

3.1.7.1.1 project risk analysis

In this study, risk of the projects is considered as a factor in project prioritization.

3.1.7.1.2 portfolio risk analysis

The importance of portfolio risk analysis stems from the organization's absolute need to make sure that portfolios are not riskier than what is deemed acceptable by its standards. Otherwise, management will need to balance the portfolio to hedge the risk. In this study, portfolio risk is evaluated by NPV variance obtained from the following equation.

$$\sigma_p^2 = \sum_{i=1}^{i=n} K_i^2 \sigma_i^2 + \sum_{i \neq j} K_i K_j \rho_{ij} \sigma_i \sigma_j$$

(8)

Where σ_p^2 is the portfolio variance, σ_p is the standard deviation (portfolio risk), and k_i and k_j are the ratio of budgets of projects i and j to the total budget of all projects in the portfolio.

ρ_{ij} is a correlation coefficient that determines the impact of projects on another.

$$\rho_{ij} = \frac{NPV(i) \times NPV(j) - \sqrt{NPV^2(i) \times NPV^2(j)}}{\sqrt{NPV^2(i) - NPV^2(j)}} \quad (9)$$

The majority of projects in the case of this study are new, so correlation coefficient is considered to be zero.

σ_i and σ_j are the standard deviations of NPV of projects i and j respectively.

In the case of construction projects however, calculating this standard deviation faces two problems:

- 1- In essence, each construction project has unique characteristics that make it hardly comparable to others.
- 2- Contrary to the case of stocks, where each year has its own data and stock variance can be obtained by collecting and analyzed the data pertaining to different years, construction projects often take a few years to finish, but finally give only one standard deviation.

To resolve this problem, Kangari et al. [16] have proposed the use of optimistic and pessimistic estimates of NPV for calculation of standard deviation.

$$\sigma_i = 1/6 \times [NPV_O - NPV_P] \quad (10)$$

In the above formula, NPV_O and NPV_P are the optimistically and pessimistically estimated net present value of project i . While being imprecise, this method seems to be the best solution for rough analysis of construction projects.

3.1.8 Phase 8: Analyzing the scenario and its results

Scenario analysis is an analytical method based on creating a variety of portfolio trends covering different combinations of primary and typical portfolio components. This method allows the decision makers to observe the impacts of key factor of scenario on the portfolios of the organization, and to make deliberate adjustments in the portfolios to limit the adverse effects of extraordinary circumstances and take full advantage of possible opportunities. This approach also allows gives the managers a better insight into not only the value of each portfolio, but also the risk imposed by portfolio on the organization; an insight that enhances their decision making confidence and capability.

3.1.9 Phase 9: Reviewing the project portfolio and reporting

The aim of this process, which will take place after implementation of project portfolio, is to collect, organize, and report performance records, and to review the portfolios to ensure that they remain aligned with the organization's strategy and are properly resourced. As mentioned, this phase of project portfolio management takes place after implementation of project portfolio, so it is beyond the scope of this research.

4. CASE STUDY: PROJECT PORTFOLIO SELECTION AND PRIORITIZATION IN THE CASPIAN COMPANY

The above model was implemented in the Caspian contractor company. As described, first, scenarios were defined based on the company's goals and the inputs given by its managers. The company was then studied to identify the limitations that may involve portfolio selection. The company's current projects and possible future projects were classified in term of their characteristics. For each scenario, these projects were then prioritized by the AHP method based on the criteria and sub-criteria determined as described in the previous section.

Table 3. a_i of projects in scenarios 1 and 2

a _i of projects in scenario 1							
Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8
28	16.8	7.9	6.7	7.2	5	19	9.5
a _i of projects in scenario 2							
Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8
27.5	7.6	14.7	13.4	7.5	11.5	10	7.8

Next, projects portfolios were constructed by zero-one programming and the earned value of every portfolio was calculated.

Table 4. Earned value of portfolios

	Project 8	Project 7	Project 6	Project 5	Project 4	Project 3	Project 2	Project 1	
Scenario 1	1	1	0	1	0	1	1	1	Z=850
Scenario 2	1	1	1	1	0	1	1	0	Z=847

The risk of portfolios was then calculated by variance formula. Naturally, only the projects included in the portfolio were considered in this calculation.

Table 5. portfolio risk

portfolios	Earned Value	Risk
Portfolio 1	850	12
Portfolio 2	847	17.5

5. CONCLUSION

Many Iranian project-oriented construction companies rely on traditional unstructured methods for selection of future projects. But given the rapid growth of investment in Iran's construction industry and evolving economic and political condition which directly influence this industry, these traditional approaches seem to be losing their utility for long term assessments. The use of alternative models and processes can provide construction and contractor companies with the insight necessary for success in this industry. The simple method presented in this paper, which is also implemented in a construction company, allows the project portfolios to be constructed for different scenarios, and thus enables the senior management to easily evaluate the possible portfolios in terms of earned value and risk, under different conditions that could possibly emerge as a result of changes in key factors of

decision making. We also presented a set of general criteria and indicators for evaluation and selection of projects, which ensure that comparisons will be made on a common basis, and allow other industry-specific evaluation criteria to be added depending on competition, environment, and culture of the industry. Using this approach, project portfolio selection can be carried out with due attention to direct affiliation of projects, competitive resource allocation, and constraints and requirements of the business.

The mathematical and operations research models were utilized, as an alternative approach, to enhance the project selection decisions made by senior management of a construction company operating in Tehran. The results of evaluation and analysis carried out by the model for the company show that the use of mathematical methods for strategic project selection is not only possible but also extremely helpful.

The studied company was recommended to consider diversification in its project portfolio, to develop and maintain the capabilities necessary to engage in a wider variety of projects so as to improve its flexibility against extraordinary changes in its current niche, consider further investment in its current strengths, and direct its budget and capital toward more value-creating activities.

Limitations of this study were lack of desirable access to financial information of construction projects, especially those with government funding, and also

unavailability of risk calculation parameters for Iran's construction industry.

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