Interrelationships of the Critical Success Factors of BOT Projects in Iran: A Grey–DEMATEL Approach

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Abstract:

The purpose of this study is to analysis interrelationship of critical success factors (CSFs) for implementing Build-Operate-Transfer (BOT) projects in Iran, using a Grey-based DEMATEL method. For this goal, primary CSFs extracted from the literature and sent to experts and practitioners through a questionnaire to select the most essential and relevant CSFs for BOT projects in Iran, which finally 39 factors were identified that grouped into seven main factors, supporting the existing literature. Then, to analyse and prioritize the interrelationship of these factors, an online questionnaire shared among Iranian instructors and professionals in this field, and finally, 40 completed questionnaires collected. To analyse interactions of factors in each group, first, experts’ opinion (under uncertainty) stated in the system of Grey numbers and unified into a single opinion afterward. Subsequently, interrelationships of factors analysed with DEMATEL approach. The results show effectiveness, influence, and interrelationship of the critical success factors for BOT projects in Iran.

Keywords: BOT Projects; Critical Success Factors (CSFs); Grey DEMATEL; Interrelationships.

1. Introduction

The build-operate-transfer (BOT) project has been extensively supported with the increasing demand for public infrastructure in the past decade (Wang et al., 2019). Population increase and impressive economic growth lead to significant demand for public infrastructure, which is the basis of a sustainable and fruitful society (Shen et al., 2011). BOT has been increasingly crucial in presenting public infrastructure as an innovative method to mobilize private sector's funding, efficient management, and technology (Xu et al., 2012). BOT defined as an arrangement of contract in which the private sector finances a public infrastructure's design, construction, operation, and maintenance for a particular concession period, and at the end of it transfers the ownership to the government (Sarvari et al., 2019). Several types of research demonstrate that government-sponsored BOT projects motivate the private sector to take part in public infrastructure schemes (Dias and Ioannou, 1995; Liddle, 1997). However, the route to a successful BOT contract is not quite facile. The entire project development process is a lengthy, expensive, and complicated business. The competition is intense, financial risk is high, negotiations are expansive, and opportunity costs are high (Huang and Dzeng, 2019). Thus, BOT contracts must comprise calculated risks, attitude flexibility, and adaptable proposals to uncertain circumstances. Both government and bidders must consider these concerns in accepting/proposing BOT proposals. It is also essential that they recognize the
critical success factors (CSFs) to be successful in BOT contracts (Tiong et al., 1992). In the ground of BOT projects, CSFs are those features of the bid that when correctly sustained and managed have a considerable effect on a successful BOT contract. In other words, CSFs are those criteria that must be given specific and successive attention because they can increase the project sponsors' chances of preserving the contract proficiently (Tiong et al., 1992). The concept of CSF could put in an application for three main objectives comprising the project itself; the consortium that sponsors the project; and the economic, political, and social environments of the project location. Strengths at any of these domains can affect the chances of a successful outcome (Tiong et al., 1992).

Therefore, it is so important to identify critical success factors and develop theories for efficient and effective implementation of BOT projects in developing countries such as Iran. Surprisingly, few studies have been identified the critical success factors towards implementing the BOT system in Iran considering their interrelationships. Thus, to fill this research gap, this paper identifies and evaluates the critical success factors related to BOT projects in Iran. To this end, we recommend to apply the Grey-DEMATEL approach, which not only helps to define the interactional relationship between each factor, but assists to define the importance of each factor concerning the other ones.

2. Build-Operate-Transfer (BOT)

Build-operate-transfer (BOT) project commonly refers to as public-private partnerships (PPPs) or private participation (PP)—which are collective terms for BOT—, build-operate-own (BOO), build-operate-own-transfer (BOOT), build-transfer-operate (BTO), build-transfer (BT), reconstruction-operate-transfer (ROT), operate-transfer (OT), etc. are contingent on concession agreement (Kumaraswamy and Morris, 2002). Generally, various types of PPPs have been applied in infrastructure development to reach optimum results (Gupta et al., 2013). BOT is long-term cooperation of public and private sectors to gain mutual advantages in which the cooperating sectors concur to share benefits, costs, and risks mutually in the products or services development (Muhammad and Johar, 2019). BOT projects which adopted in wealthy industrialized countries endeavor to finance new infrastructure projects through the participation of the private sector (Senturk et al. 2004). Various studies represent that BOT projects which sponsored by the government, encourage the private firms to take part in such public infrastructure projects (Dias and Ioannou, 1995; Liddle, 1997). In the application of BOT procurement system, a private investor, or a group of investors creating a consortium, which provides funds for the construction and operation of infrastructure in the specified period from the government. This private sector mostly refers to as the investor franchise, by which the investor is to "build" and "operate" the project within a pre-set concession period which at the end of that "transfer" the project to the host government without any charge. Since half of the 1980s, this arrangement type of contract has been extensively utilized to infrastructure projects whole the world. The advantage of this contractual arrangement is generally assumed to be the use of private money for public infrastructure facilities development such as railways, highways, tunnels, ports, airports, hydraulic structures, power plants, and water conservation facilities (Shen et al. 1996). This unique approach provides a step forward in supplying the world's demand for further infrastructure development, particularly in the swiftly developing countries. Meantime, the BOT concept which along with reduced government involvement and
an excellent opportunity to obtain profits, opens up chances for market penetration of foreign and also local contractors and developers in the context of infrastructure project construction and operation (Tiong et al., 1992). The private funding in BOT scheme not only diminishes the risks, responsibilities, and financial pressures on the government but also facilitates further innovations by utilizing the technologies, skills, and operational efficiency of the private sector (Gupta et al., 2013). Although the BOT model for the financing of the infrastructure has a rapidly growing for the developing countries and construction industry lacking funds, several difficulties have been faced in global infrastructure development via BOT (for example the slow progress in the BOT implementation). There are other crucial problems such as political, legal, environmental, and social, which have even resulted in BOT projects failures (Gupta et al., 2013).

3. Research background

In the past few decades, the responsibilities and roles of the owner, architect or engineer, and contractor have been determined clearly. The owner (or client) employs the architect for preparing project design and construction documents. Then, in a tender, the contractor with a reasonable suggested price is selected for construction of a project. The contract for the mentioned project will be signed between the owner and the contractor. Advisory and monitoring roles in the contract will also be signed between the architect or engineer and the owner. Moreover, the right selection of implementation system for projects in the construction industry is critical to achieve success. (Kahvandi et al., 2019). In practical literature, the role of BOT implementation is taken in varied places (for example: Marriott and Brown, 1991; Chu, 1999; Qiao et al., 2001; Askar and Gab-Allah, 2002; Lu et al., 2003; Shams and Awamleh, 2004; Subprasom and Chen, 2005; Algarni et al., 2007; LLanto, 2008; Chan et al., 2010; Shrestha, 2011; Markom and Ali, 2012; Yong and Mustaffa, 2012; Cheung et al., 2012; Olusola Babatunde et al., 2012; Ismail, 2013; Gupta et al., 2013; Yusof and Salami, 2013; Toulabi, 2013; Emmanuel, 2014). Markom and Ali (2012) found that there are extensive fundamental factors involving to the success of BOT projects comprising: strong government support, firm policy, and regulatory framework, project transparency in formulation and documentation, dependable sponsors and impartial deals for all sections. They concluded that measures to eliminate the problems are clarified to increase the productiveness and efficacy of both BOT proper technique and privatization as a whole. Yong and Mustaffa (2012) indicated that considerable stability in conception between respondents in verifying the importance of human-related factors comprising devotion, capability, collaboration, and communication for a successful construction project. Cheung et al. (2012) analysed CSFs of PPPs implementation in Hong Kong and China. They found that both Hong Kong and China have been intense to provide further infrastructure service projects via PPP mode, and furthermore unlike Hong Kong, China perceived multi-benefit objectives significantly and was more interested in an impartial mechanism of risk sharing. Ismail (2013) explored the importance of the success factors in Malaysia and identified the “good governance”, “favourable legal framework”, “commitment of the public and private sectors”, “availability of finance market” and “sound economic policy” as the top five success factors in implementing PPP in Malaysia. Yusof and Salami (2013) investigated the CSFs of BOT power plant projects in Iran, in which identified the appropriate project identification, stable political situation, favourable legislation regulation, and well-organized and committed public agency as the most important factors in
BOT power plant projects in Iran. Toulabi (2013) investigated the potential of BOT implementation in the Iranian environment, in which discovered that there is a need to identify CSFs for BOT projects. Emmanuel (2014) represented that CSFs for prospering PPP implementation is explicit and forcible regulatory framework, universal feasibility study and appropriate risk allocation amongst others, and furthermore some CSFs for instance dedication and responsibility of public and private sectors, stable private society and admissible cost/benefit evaluation amongst others are essential for implementation of PPP.

Despite several previous studies which have investigated the CSFs of BOT projects, studies on CSFs for implementing BOT projects in Iran remain scarce, in which there is no research to identify the critical success factors considering their interrelationships (cause and effect relationships) in an environment of uncertainty and vagueness. Therefore, to cover this research gap, this study identifies and evaluates the critical success factors relevant to Iranian's BOT projects, using a Grey-DEMATEL approach which not only helps to define the interactional relationship between each factor but assists to define the importance of each factor concerning the other ones.

The methods that researchers used in the past to analyse and prioritize CSFs are shown in Table 1 with an overview of applied methods and their limitations against the adopted method in this research. As mentioned in Table 2, the most important advantages of using Grey-DEMATEL approach are considering interrelationships and uncertainty to prioritize CSFs.

<table>
<thead>
<tr>
<th>Researchers</th>
<th>Subject</th>
<th>Methods</th>
<th>Shortcomings Interrelations</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li and Wang (2019)</td>
<td>Risk assessment of PPP: A China perspective</td>
<td>fuzzy analytic network process (ANP) and ISM PLS- Structural Equation Model (SEM)</td>
<td>Partially supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Ahmadabadi and Hera (2019)</td>
<td>The effect of CSFs on project success in PPP projects: A case study of highway projects in Iran</td>
<td>Case study approach</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>Muhammad and Johar (2019)</td>
<td>CSFs of PPP projects: a comparative analysis of the housing sector between Malaysia and Nigeria</td>
<td>Mean score ranking technique</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>Sarvari et al. (2019)</td>
<td>Approaches to risk identification in PPP projects: Malaysian private partners’ overview</td>
<td>Descriptive statistics, mean score, Kruskal–Wallis test, risk significance index</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>Babatunde et al. (2019)</td>
<td>Identification of critical risk factors in PPP project phases in developing countries: A case of Nigeria</td>
<td>Regression model</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>Wang et al. (2019)</td>
<td>The role of governance setting on the association between risk allocation and private investment in PPP markets: developing countries</td>
<td>Qualitative (interview), content analysis. Analytical Hierarchy Process (AHP) Mean, Factor Analysis, Correlation, Regression and ANOVA</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>Kavishe and Chileshe (2018)</td>
<td>CSFs in PPPs on affordable housing schemes delivery in Tanzania</td>
<td>fuzzy analytic hierarchy process (FAHP) Correlation coefficients analysis</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Kuwaiti et al. (2018)</td>
<td>Determining success factors in Abu Dhabi health care construction projects</td>
<td>Correlation and ANOVA</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Vijayabanu and Vignesh (2018)</td>
<td>Critical factors determining the success of PPP in construction projects: an Indian Context</td>
<td>Mean, Factor Analysis, Correlation, and ANOVA</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Yu et al. (2018)</td>
<td>Assessment and grade of risk factors in transnational PPPs projects</td>
<td>Correlation coefficients analysis</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Ghanbaripour et al. (2018)</td>
<td>CSFs for subway construction projects – main contractors’ perspectives</td>
<td>Correlation coefficients analysis</td>
<td>Partially supported</td>
<td>Not supported</td>
</tr>
</tbody>
</table>
4. Identifying the CSFS for BOT Projects

The exploration of critical success factors (CSFs) is indispensable to the favourable outcome of business process management (Trkman, 2010). Rockart (1982) defined CSFs as “the key scopes of activity necessary to be focused on making certain competitive performance towards an organization’s strategic objectives.” Kwak et al. (2009) described the CSFs as the core aspects where “things must go well for the business to develop.” Boynton and Zmud (1984) defined CSFs as a methodology to focus on identifying the key areas essential to successful management. This methodology has been used extensively in industries such as construction, manufacturing, information systems, and financial services (Rockart, 1982; Boynton and Zmud, 1984; Mohr and Spekman, 1994). CSFs also defined as the essential factors of the project participants for project objectives achievement. (Tiong, 1992; Sanvido et al., 1992; Cooke-Davies, 2002). Furthermore, Rockart (1982) emphasized that CSFs relate to the particular features or circumstances of an industry. It will surely be different in each country, depending on their operating environment, policies, and legal restriction. Also, mostly the CSFs will change with the changes in the industry’s environment, the company’s position within an industry change or a specific problem or opportunity happen for that industry. Therefore, CSFs are not a standard set of key measurements, which can be utilized in all industry. However, CSFs are the specific areas of main significance to a specific industry, at a specific period (Rockart and Bullen, 1981).

Studies and discussions about CSFs for BOT projects have been previously done. Zhang (2005) identified 47 CSFs of public-private partnership projects such as BOT, which have been categorized into five main dimensions of CSFs namely “economic viability”, “sound financial package”, “appropriate risk allocation via reliable contractual arrangements”, “reliable concessionaire consortium with strong technical strength”, and “favourable investment environment”. Jacobson and Choi (2008) applied qualitative analysis to examine essential factors that taking part in success of PPP projects, in which identified 10 CSFs comprising: “commitment”, “specific plan/vision”, “willingness to compromise/collaborate”, “open communication and trust”, “community outreach”, “respect”, “political support”, “risk awareness”, “expert advice and review”, and “clear roles and responsibilities”. Chan et al. (2010) indicated that CSFs for success of project can be classified into five sub-factors comprising: “shared responsibility between public and private sectors”, “stable macroeconomic environment”, “transparent and efficient procurement process”, “judicious government control”, and “stable political and social environment”. Ismail and Ajija (2011) identified top five CSFs for implementing PPP in Malaysia including: “favourable legal framework”, “good governance”, “availability of finance market”, “sound economic policy”, and “commitment of the public and private sectors”.

<table>
<thead>
<tr>
<th>Author et al. (Year)</th>
<th>CSFs of public-private-community partnership in Bali tourism infrastructure development</th>
<th>Exploratory factor analysis</th>
<th>Supported</th>
<th>Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharaffudin and Al-Mutairi (2015)</td>
<td>Success factors for the implementation of BOT projects in Kuwait</td>
<td>Mean score ranking technique</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>Wang et al. (2015)</td>
<td>Factors influencing the financial efficiency of PPP projects and their relations</td>
<td>DEMATEL</td>
<td>Supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>Gupta et al. (2013)</td>
<td>Identifying and ranking of CSFs for BOT projects in India</td>
<td>Analytical Hierarchy Process (AHP)</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
</tbody>
</table>
In the current study, the primary CSFs were collected according to a literature review and sent to 40 Iranian professors and practitioner through a questionnaire to select the most important and relevant CSFs for BOT projects. Finally, 39 factors are identified that grouped into seven main factors according to the literature and previous research. For instance, TC1 (Technical innovation/complexity) regarding other research works mostly related to “Technical Considerations” so as we. The final CSFs and their sub-factors demonstrated in Table 2.

Table 2. Critical success factors of BOT projects

<table>
<thead>
<tr>
<th>CSFs</th>
<th>Success sub-factors</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Considerations (FC)</td>
<td>FC1: Financing budgeted stable</td>
<td>Adnyana et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>FC2: The investment scheduling payments</td>
<td>Adnyana et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>FC4: Appropriate toll/tariff level(s) and suitable adjustment formula</td>
<td>Tiong et al. (1992), Qiao et al. (2001), Zhang (2005), Ng et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>FC5: Long-term availability of suppliers needed for the normal operation of the project</td>
<td>Gupta et al. (2013), Zhang (2005)</td>
</tr>
<tr>
<td>Risk Allocation (RA)</td>
<td>RA1: Design and construction contract</td>
<td>Gupta et al. (2013), Hwang et al. (2013), Zhang (2005)</td>
</tr>
<tr>
<td></td>
<td>RA2: Concession agreement</td>
<td>Adnyana et al. (2015), Qiao et al. (2001), Tiong (1992)</td>
</tr>
<tr>
<td></td>
<td>RA3: Shareholder agreement</td>
<td>Adnyana et al. (2015), Zhang (2005)</td>
</tr>
<tr>
<td></td>
<td>RA4: The insurance agreement</td>
<td>Adnyana et al. (2015), Zhang (2005)</td>
</tr>
<tr>
<td></td>
<td>RA5: Loan agreement</td>
<td>Adnyana et al. (2015), Gupta et al. (2013), Zhang (2005)</td>
</tr>
<tr>
<td></td>
<td>RA6: Operating expenses agreement</td>
<td>Adnyana et al. (2015), Zhang (2005)</td>
</tr>
<tr>
<td></td>
<td>RA7: Predicable risk scenarios</td>
<td>Adnyana et al. (2015), Zhang (2005)</td>
</tr>
<tr>
<td></td>
<td>CC2: Strong and capable project team</td>
<td>Gupta et al. (2013), Ng et al. (2012), Zhang (2005), Dixon et al. (2005)</td>
</tr>
<tr>
<td></td>
<td>CC4: Leading role by a key enterprise or entrepreneur</td>
<td>Adnyana et al. (2015), Gupta et al. (2013), Zhang (2005), Tiong (1992)</td>
</tr>
<tr>
<td></td>
<td>CC5: Rich experience in international BOT project management</td>
<td>Sharaffudin and Al-Mutairi (2015), Zhang (2005), Qiao et al. (2001)</td>
</tr>
<tr>
<td></td>
<td>TC2: Project technical feasibility</td>
<td>Li et al. (2005)</td>
</tr>
<tr>
<td></td>
<td>TC3: Advanced and appropriate technology</td>
<td>Adnyana et al. (2015), Gupta et al. (2013), Sharaffudin and Al-Mutairi (2015), Jefferies et al. (2002), Qiao et al. (2001)</td>
</tr>
<tr>
<td></td>
<td>TC4: Technology transfer</td>
<td>Adnyana et al. (2015), Gupta et al. (2013), Zhang (2005), Tiong (1992)</td>
</tr>
<tr>
<td></td>
<td>TC5: Availability of providers at the time of long-term operational</td>
<td>Adnyana et al. (2015), Gupta et al. (2013), Zhang (2005), Tiong (1992)</td>
</tr>
<tr>
<td></td>
<td>TC6: Cost effective</td>
<td>Adnyana et al. (2015), Gupta et al. (2013), Zhang (2005), Tiong (1992)</td>
</tr>
<tr>
<td></td>
<td>GS2: Special guarantees by the government</td>
<td>Liu and Wilkinson (2013), Ng et al. (2012), Olusola Babatunde et al. (2012), Li et al. (2005), Qiao et al. (2001)</td>
</tr>
</tbody>
</table>
**Prevailing Environment (PE)**

| GS: Good cooperation of government with the private sector and communities in terms of authority | Adnyana et al. (2015) |
| PE: Public/community awareness and support | Gupta et al. (2013), Zhang (2005) |
| PE: Stable government | Gupta et al. (2013) |

**Social and Culture (SC)**

| SC: Activities that do not conflict with religious, social communities and national law | Adnyana et al. (2015) |
| SC: Utilize local company in the project company | Sharaffudin and Al-Mutairi (2015), Tiong et al. (1992) |
| SC: Giving priority to local employment during the construction and operational | Adnyana et al. (2015) |
| SC: Giving priority to local raw materials | Adnyana et al. (2015) |
| SC: Training local staff | Sharaffudin and Al-Mutairi (2015), Qiao et al. (2001) |

A BOT project includes various procedures which are affected by many internal/external factors. The CSFs in this research may not be the precise criteria for every project, but they were derived through the research process of extensive literature review and interviews with local professionals involved in BOT projects. These CSFs were validated using survey research and case studies. The CSFs cover a full range of key aspects of BOT projects and provide a set of factors that assist in proposing a framework for evaluating and analysing CSFs of Iranian’s BOT projects.

### 5. Research method

#### 5.1 Grey system theory

Grey systems theory aims at covering the data and series production for the real patterns modelling that is based on poor (negligible) information (Liu and Lin, 2006). The grey theory introduced by Deng (1982) from a grey set. In grey systems, the word "grey" is applied when the information is partly known and partly unknown. In other words, being "grey" refers to having "incomplete information" (Mierziak et al., 2018). Grey systems theory can handle many of the ambiguities generated from vague human decisions (Fu et al., 2001; Li et al., 2007). Grey theory is useful to solve the multi-criteria decision making (MCDM) problems in an uncertainty and vagueness environment, and further has been applied to various areas such as decision-making, forecasting, system control, computer graphics, etc. (Li et al., 2007). The grey value is the number of uncertain data (Dong et al., 2006).
Let $X$ as a universal set, $G$ as Grey set of universal set $X$, $\mu_G(x)$ and $\mu_G(x)$ defines as the upper and lowest boundary of the $G$ membership function as in equation (1):

$$\mu_G(x) : X \rightarrow [0,1] , \quad \mu_G(x) : X \rightarrow [0,1]$$ (1)

The equation $\mu_G(x) \geq \mu_G(x)$ is completely understandable and changes into a fuzzy set in the form of an equation of the grey set. This shows that the grey theory includes fuzzy and flexible cases when facing fuzzy problems (Nezhad et al., 2009). In this study, the grey number $\otimes X_{ij}^p$ for $P$ decision is considered to assess the effect of $i$ criterion on $j$ (Asad et al., 2016a, 2016b):

$$\otimes X_{ij}^p = [\otimes X_{ij}^p, \otimes X_{ij}^p]$$ (2)

The grey data turns into a crisp number as following three steps:

1: Normalization:

$$\Delta_{\text{Max}} = \text{Max}_j \otimes X_{ij}^p - \text{Min}_j \otimes X_{ij}^p$$ (3)

$$\otimes \bar{Y}_{ij}^p = (\otimes X_{ij}^p - \text{Min}_j \otimes X_{ij}^p) / \Delta_{\text{Max}}$$ (4)

$$\otimes \bar{X}_{ij}^p = (\otimes X_{ij}^p - \text{Min}_j \otimes X_{ij}^p) / \Delta_{\text{Max}}$$ (5)

2: Calculate total normalized crisp number:

$$Y_{ij}^p = \frac{(\otimes X_{ij}^p (1-\otimes X_{ij}^p) + (\otimes X_{ij}^p \times \otimes X_{ij}^p)}{1 - \otimes X_{ij}^p + \otimes X_{ij}^p}$$ (6)

3: Calculate the crisp number:

$$Z_{ij}^p = \text{Min}_j \otimes X_{ij}^p + Y_{ij}^p \Delta_{\text{Max}}$$ (7)

From equation (8) is used to turn opinions into a unit viewpoint:

$$Z_{ij}^p = \frac{1}{p} (Z_{ij}^1 + Z_{ij}^2 + \ldots + Z_{ij}^p)$$ (8)

### 5.2 DEMATEL method

Decision-making trial and evaluation laboratory (DEMATEL) approach in the first place developed by the Battelle Memorial Institute of Geneva. It could structure and handle complicated interrelationship among the criteria using a combination of matrices or graphs, and also intended to resolve the complicated problem by understanding the particular problem, the cluster of intertwined problem, and recognition of practicable solutions through a hierarchical structure (Jeng and Tzeng, 2012; Wu, 2012; Hsu et al., 2013). DEMATEL approach based on assumptions of a system that comprised a variable set and paired comparisons and the relationship amongst these variables is made via mathematical models (Büyüközkan and Çifçi, 2012). Compared with other multi-attribute decision-making approaches such as Analytical Hierarchical Process (AHP), in which criteria are assumed independent; DEMATEL method is
a structural modelling approach that aims at discovering the interdependence amongst the elements of a system by a causal diagram (Tseng, 2009; Wu et al., 2010).

In this approach, firstly, according to the experts' viewpoints and the critical factors, a direct relation matrix organized. The consequential T-matrix is an \( n \times n \) matrix which represents interactions criteria, as \( T_{ij} \) denotes to the degree of effect of \( i \) factor on \( j \) factor, \( T = [T_{ij}]_{n \times n} \) (Asad et al., 2016a, 2016b).

In the next step, we create the normalized matrix of direct relation (S), \( S = [S_{ij}]_{n \times n} \), where \( 0 \leq S \leq 1 \). Instructions of making the matrix S are according to equations (9) and (10) as follows (Asad et al., 2016a, 2016b):

\[
K = \frac{1}{\text{MAX}_{i \in 1..n} \sum_{j=1}^{n} a_{ij}} \quad (9)
\]

\[
S = K \times T \quad (10)
\]

Then, the total relation matrix (T) made by equation (11), where \( I \) represent an \( n \times n \) identity matrix:

\[
M = S(I - S)^{-1} \quad (11)
\]

R and D indicate to the sum of rows and columns calculated form the equations (12), (13) and (14) as follows:

\[
M = m_{ij} \text{, } (i,j=1,2...,n) \quad (12)
\]

\[
R = [\sum_{j=1}^{n} m_{ij}]_{n \times 1} \quad (13)
\]

\[
D = [\sum_{i=1}^{n} m_{ij}]_{1 \times n} \quad (14)
\]

Finally, to determine the interrelationships (cause and effect), (R) reflects effectiveness of a criterion on other criteria which means effectiveness of variables; (D) for each criterion indicates the impact of other criteria on it which means influence of variables; the “Influence” horizontal axis vector (R+D) represents the degree of importance, and the “Relation” vertical axis (R-D) classified criteria into a cause group and an effect group. (R-D) positive value indicates that the criterion puts in the cause group, and negative value shows that the criterion belongs to the effect group (Hung, 2011).

5.3 Reliability and Consistency

The validity of the instrument used in this research is in some way, a kind of rational validity or content that is related to the applied method. In the paired comparison method, all factors are measured together, which eliminates all the probabilities associated with not considering a criterion or a question. The structure and criteria used in this study were also decided upon by the team members. Moreover, the ability of the tool to maintain its reliability over time, despite the controllable condition of the test and the status of the respondents, suggests its stability and least variability. However, according to the type of questionnaire, it should be noted that in this type of questionnaire, all criteria and factors are measured in a two-way manner. In other words, the maximum possible questions are asked with the desired structure of the respondent, so there is no need to measure reliability since all the criteria are considered and the designer is not capable of specific orientation in the design of the questions.
Contrasting AHP technique using the consistency ratio (CR) to test for the consistency of the decision makers’ judgment, the DEMATEL approach has not the CR assessment to confirm if the comparisons presented by decision makers are consistent (Lee et al., 2018). Shieh and Wu (2016) suggested a combined method of using corrected item-total correlation and split-half approaches to assess the consistency of the study data. Nevertheless, their research result is to find those experts who have different views than others. Those experts with different views might have unparalleled views to be considered, or their unreliable views should be eliminated. There is no transparent process to decide if each decision maker's view is valid hitherto for the DEMATEL approach. For example, the available research papers of Professor G.H Tzeng, a specialist in DEMATEL approach development and utilization, suppose the decision makers' views are valid with no more checking the reliability of the research results (Liou et al., 2008; Lu et al., 2013; Chang et al., 2015).

6. Research Findings and Discussion

In this present study, according to the literature and research background the critical success factors of Iranian's BOT projects collected, then the opinion of local experts and practitioners asked through a questionnaire, and finally, 39 factors were identified that grouped into seven main factors. Next, to evaluate the interrelationships of factors an online questionnaire was designed with one-by-one questions, in which asked from local experts and practitioners to how each factor affect to the other ones using linguistic variables (no effect, very low affect, low affect, high effect, very high effect). Finally, 40 completed questionnaires collected to analyse interrelationships among the CSFs, using Grey-DEMATEL approach. Also, the demographic statistics of respondents are shown in Table 3.

Table 3. Demographic statistics of respondents

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (year)</th>
<th>Education</th>
<th>Experience (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Under 30</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Number of BOT project executed</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Organization category</td>
<td>17</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

According to Table 3 statistics, the respondents have adequate experience and knowledge in BOT projects in Iran. Therefore, the information provided on BOT projects by these respondents’ organizations is declared to be reliable.

Next, after gathering all the completed questionnaires, the responses from linguistic variable turned into grey value ranges (Table 4), then according to equations (3) to (7), grey numbers are transformed to crisp numbers, and all views are unified into a single opinion by equation (8).

Table 4. Linguistic scales of importance weight of factors and their Grey values

<table>
<thead>
<tr>
<th>Linguistic variable</th>
<th>Grey values</th>
</tr>
</thead>
<tbody>
<tr>
<td>No affect</td>
<td>[0.0]</td>
</tr>
<tr>
<td>Very low affect</td>
<td>[0.0, 0.25]</td>
</tr>
</tbody>
</table>
In the next step, the crisp numbers normalized in DEMATEL using the equations (9) and (10), and total matrix of each of the main factors and their sub-factors are calculated using equation (11). In the end, the values of R, D, R+D, and R-D are calculated in, which the results are shown in Table 5.

Table 5. Results of Grey-DEMATEL analysis for CSFs of BOT projects in Iran

<table>
<thead>
<tr>
<th>Factors</th>
<th>R</th>
<th>Rank</th>
<th>D</th>
<th>Rank</th>
<th>R+D</th>
<th>Rank</th>
<th>R-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Considerations (FC)</td>
<td>3.2</td>
<td>6.59</td>
<td>3.6</td>
<td>3.09</td>
<td>6.9</td>
<td>3.02</td>
<td>4.08</td>
</tr>
<tr>
<td>Risk Allocation (RA)</td>
<td>2.8</td>
<td>4.65</td>
<td>3.3</td>
<td>7.31</td>
<td>4.5</td>
<td>5.94</td>
<td>1.02</td>
</tr>
<tr>
<td>Concessionaire Consortium (CC)</td>
<td>3.7</td>
<td>4.08</td>
<td>3.4</td>
<td>6.89</td>
<td>3.1</td>
<td>5.35</td>
<td>1.05</td>
</tr>
<tr>
<td>Technical Considerations (TC)</td>
<td>2.5</td>
<td>2.93</td>
<td>3.0</td>
<td>6.93</td>
<td>1.7</td>
<td>5.33</td>
<td>1.05</td>
</tr>
<tr>
<td>Government Support (GS)</td>
<td>2.2</td>
<td>2.32</td>
<td>3.0</td>
<td>6.93</td>
<td>1.2</td>
<td>5.75</td>
<td>1.05</td>
</tr>
<tr>
<td>Prevailing Environment (PE)</td>
<td>3.1</td>
<td>3.16</td>
<td>3.0</td>
<td>6.93</td>
<td>1.2</td>
<td>5.75</td>
<td>1.05</td>
</tr>
<tr>
<td>Social and Culture (SC)</td>
<td>2.4</td>
<td>2.32</td>
<td>3.0</td>
<td>6.93</td>
<td>1.2</td>
<td>5.75</td>
<td>1.05</td>
</tr>
</tbody>
</table>

In the end, the values of R, D, R+D, and R-D are calculated in, which the results are shown in Table 5.
According to Table 5, the results for the seven main CSFs shows the factor “Concessionaire Consortium (CC)” according to R criterion, has the most considerable influence on other main factors; also, according to D criterion, the factor “Financial Considerations (FC)” most affected from other main factors; it also according to R+D, has the most interaction with the other main factors, which demonstrates great importance of this factor in BOT projects. Furthermore, according to the R-D measure, it was discovered that the main factors “Concessionaire Consortium (CC),” “Prevailing Environment (PE)” and “Social and Culture (SC)” are the causal factors (positive value), and the main factors “Financial Considerations (FC),” “Risk Allocation (RA),” and “Technical Considerations (TC)” are the effect factors (negative value). These findings show that “Financial Considerations” has the most priority and needs more attention from Iranian project managers (PMs). It also discovered that “Concessionaire Consortium” is the most dominant factor among the other ones and should be noticed by PMs.

In sum, the results show that seven main CSFs and their sub-factors prioritized by their interactions (R+D) as below:

1. Financial Considerations (6.93) - Effect
   1. Long-term availability of suppliers needed for the normal operation of the project (4.76) - Cause
   2. The investment scheduling payments (3.91) - Effect
   3. Financing budgeted stable (3.60) - Cause
   4. Appropriate toll/tariff level(s) and suitable adjustment formula (3.37) - Effect
   5. Availability of long-term debt financing (2.94) - Effect

2. Risk Allocation (6.36) - Effect
   1. Predicable risk scenarios (5.58) - Effect
   2. Design and construction contract (4.70) - Cause
   3. Operating expenses agreement (4.62) - Effect
   4. Shareholder agreement (4.13) - Effect
   5. Loan agreement (3.95) - Effect
   6. The insurance agreement (3.65) - Cause
   7. Concession agreement (3.55) - Effect

3. Concessionaire Consortium (6.00) - Cause
   1. Rich experience in international BOT project management (5.69) - Cause
   2. Selection procedure of concessionaire (5.38) - Cause
   3. Strong and capable project team (5.14) - Effect
   4. Leading role by a key enterprise or entrepreneur (4.81) - Effect
   5. Effective and detailed project organization structure (4.30) - Effect

4. Technical Considerations (5.63) - Effect
   1. Cost effective (6.90) - Effect
   2. Advanced and appropriate technology (5.51) - Cause
   3. Project technical feasibility (4.94) - Effect
   4. Technology transfer (4.91) - Cause
   5. Availability of providers at the time of long-term operational (4.70) - Effect
   6. Technical innovation/complexity (4.03) - Effect

5. Government Support (5.54) - Effect
   1. Strong commitment and responsibility from the government (4.27) - Cause
   2. Fiscal concession and investment policy (4.08) - Effect
3. Special guarantees by the government (3.72) - Effect
4. Good cooperation of government with the private sector and communities in terms of authority (3.40) - Effect
5. Government policy support (3.06) - Cause

6. Prevailing Environment (5.50) - Cause
   1. Stable political system (6.94) - Effect
   2. Stable government (5.80) - Effect
   3. Stable and favourable economic environment (5.60) - Effect
   4. Predictable and reasonable legal framework (3.77) - Cause
   5. Public safety and health considerations (3.02) - Cause
   6. Public/community awareness and support (2.13) - Cause

7. Social and Culture (4.48) - Cause
   1. Training local staff (6.23) - Cause
   2. Giving priority to local raw materials (5.52) - Cause
   3. Activities that do not conflict with religious, social communities and national law (5.49) - Cause
   4. Giving priority to local employment during the construction and operational (5.32) - Effect
   5. Utilize local company in the project company (2.93) - Effect

7. Conclusion

In the current study, the DEMATEL approach applied to analyse interrelationships of the critical success factors for Iranian's BOT projects, in which considering the entrance data as a range of uncertain numbers (Grey numbers), is the special characteristic of merging Grey theory to this method. In other words, the utilization of Grey theory system makes it possible to consider the uncertainty of the decision system structure. Furthermore, the application of decision-making trial and evaluation laboratory (DEMATEL) approach assists the decision maker to recognize causal factor(s) and sub-factor(s) within each other and figure out the relative cause-effect relationships between factors and sub-factors.

Regarding the DEMATEL analysis outputs (R, D, R+D, and R-D), we can say that the revealed results could be divided into four parts namely “effectiveness or dominance”, “influence or impressionability”, “superiority”, and “cause/effect” measures.

According to the measure “effectiveness or dominance”, factors with the most dominant characteristic in each group are: “Long-term availability of suppliers needed for the normal operation of the project” , “Design and construction contract” , “Selection procedure of concessionaire” , “Advanced and appropriate technology” , “Strong commitment and responsibility from the government” , “Stable political system” , and “Training local staff”. These criteria have a leading role in their group and affect other factors significantly, so they need to be well-thought-out by Iranian project managers (PMs) in BOT project management.

Given to the measure “influence or impressionability”, factors with the most impressionability characteristic in each group are: “The investment scheduling payments”, “Predicable risk scenarios”, “Strong and capable project team”, “Cost-effective”, “Fiscal concession and investment policy”, “Stable government”, and “Training local staff”. These factors have a sensitive attribute and are most affected by other criteria in their group; then they require be carefully considering and planning by Iranian PMs in the BOT project management.
Moreover, with respect to the most crucial measure “superiority”, the criteria with the supremacy attribute in each group are: “Long-term availability of suppliers needed for the normal operation of the project”, “Predicable risk scenarios”, “Rich experience in international BOT project management”, “Cost-effective”, “Strong commitment and responsibility from the government”, “Stable political system”, “Stable government”, and “Training local staff”. These factors have a superiority attribute which leads to being the most interactional with other criteria in their group; hence, they necessitate being very well-thought-of within the BOT project management by Iranian PMs.

Finally, according to the classification of factors into “cause” and “effect” groups, the most essential cause factors in each main group are: “Financing budgeted stable”, “Design and construction contract”, “Selection procedure of concessionaire”, “Advanced and appropriate technology”, “Strong commitment and responsibility from the government”, “Public/community awareness and support”, and “Giving priority to local raw materials”. These factors have a causal relationship with the other criteria in their group and could be attained to assist the managers/decision-makers to have an enhanced understanding of the complicated problems. Nevertheless, some causes such as “Public/community awareness and support” and “Public safety and health considerations” are less important than the effect factors including “Stable government” and “Stable political system” that are crucial factors to be considered, they are also required to be paid more attention, since they are the roots of the problems and have a considerable impact on the effect factors.

Also, from the seven main factors point of view, the most dominant factor is “Concessionaire Consortium” which shows that it has a leading role among the main criteria and affects other factors meaningfully; therefore, it needs to be well-thought-out by Iranian project managers and decision-makers in the BOT project management. In addition, the factor with the most impressionability and simultaneously with the most priority is “Financial Considerations” which indicates that while it has sensitivity and most affected from other criteria among the main criteria, has a superiority attribute which leads to be the most interactional with other criteria among the main criteria, thus it needs to be cautiously measured and planned by Iranian PMs and decision-makers in the BOT project management. Moreover, the cause factors in the main group are “Concessionaire Consortium”, “Prevailing Environment”, and “Social and Culture”, while the effect factors are “Financial Considerations”, “Risk Allocation”, “Technical Considerations”, and “Government Support”, which all could be attained to assist the managers/decision-makers to improve their comprehension of the complicated problems.

As the last word, this study provides another point of view to implement BOT projects without assuming factors and sub-factors are mutually independent. Each action taken on net causes (factor/sub-factor) will have direct/indirect effects on the corresponding net receivers (factor/sub-factor). Therefore, the decision maker can give more credit and allocate resources to cause factors and sub-factors to implement BOT projects in Iran effectively.

References


