Prototype Model for Build-Operate-Transfer Risk Assessment

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Abstract: The build-operate-transfer (BOT) approach for project delivery, where the private sector has to finance, design, build, operate, and maintain the facility and then transfer it to the government after a specified concession period, is now gaining widespread popularity in developing countries. Compared with conventional project delivery methods, BOT sponsors expose themselves to a high risk, so that special attention must be paid to analyzing and managing risks. The identification, analysis, and allocation of various types of risks are an important aspect for the validation of privately promoted infrastructure projects. The BOT risk model presented in this paper is a prototype evaluation model that provides a logical, reliable, and consistent procedure for assessing the BOT project risk. The proposed model introduced the BOT risk index (F), which relied on the actual performance of eight main BOT risk areas. Two different modeling approaches were used in constructing this index: a new developed and an adapted Dias and Ioannou model. Not only can this index be used for BOT projects' risk evaluation, but also for ranking them to select the lowest risk project as well.

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Introduction

The shortage of public funds to finance the construction of new infrastructure projects and the rehabilitation of existing facilities, coupled with increased demands for capital from traditional alternative sources (for example, national and international development banks and agencies), has contributed to the creation or resurgence of alternative forms of project delivery. Well-publicized examples are BOT (build-operate-transfer) and BOO (build-operate-own) projects where private sectors become responsible for project promotion. Due to the increasing demand for public facilities and the shortage of public funds, privately financed projects have been considered a desirable solution to provide better service for the public. This paper focuses on the fundamental questions of whether a potential infrastructure project has the necessary characteristics for successful promotion by a private-sector company, and whether a company has the capability to undertake the promotion of such a project (Dias and Ioannou 1996).

The BOT approach to infrastructure delivery, where the private sector has to finance, design, build, operate, and maintain the facility and then transfer it to the government after a specified concession period, is now gaining widespread popularity, especially in developing countries (Chee and Yeo 1995). The opportunity for profit and reward, however, does not come easily. The responsibilities are heavy and the stakes are high (Tiong 1995). An essential part of the agreement between the government and the private contractor is the allocation of risk between the parties: that is, when an event occurs that influences the cost or quality of the contracted service, which party must pay to rectify the situation or, alternatively, which party should gain the resulting benefits (Arndt 1999).

Compared with conventional delivery methods, there is a higher risk exposure for the BOT sponsors because of the following:

- High front-end development costs,
- Extensive and lengthy negotiations with the host government,
- Multiparty involvement,
- Long-term commitment, and
- Equity contribution from the sponsors.

The high-risk exposure associated with BOT projects means that special attention must be paid to analyzing and managing risks (Chee and Yeo 1995). Risk in a construction project, however, cannot be eliminated, but it can be minimized or transferred from one party to another (Kangari 1995). BOT infrastructure projects carry higher-than-traditional levels of risk as they typically involve high capital outlays, long lead times, and long-lived assets with little value in alternative use. The identification, analysis, and allocation of various types of risks are an important aspect for the validation of privately promoted infrastructure projects (Dias and Ioannou 1995). On the other hand, determining the relative importance of these types of risks is very essential for BOT management decision makers. The decision makers of construction companies should evaluate and rank BOT projects with respect to their risk. Therefore, there is an essential need for a tool that uses a risk index (F) to evaluate the pending BOT projects. This paper presents the results of a study that aims at developing a prototype model for evaluating BOT risk. This model provides the risk evaluation and risk index (F) determination. This procedure was accomplished through the following case studies of BOT projects: Plymouth County, Wyatt Detention Facility, State Route 91, Dulles Green way, Wijker Tunnel, Indian Power Plant,

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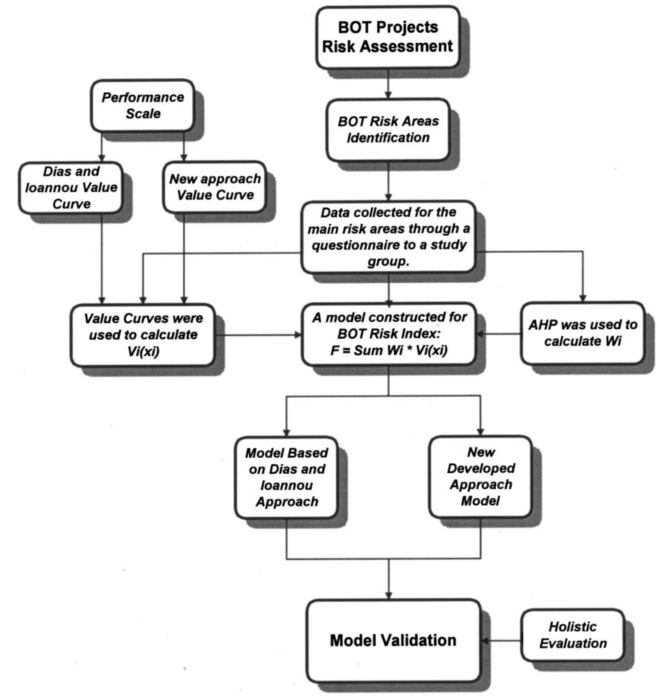


Fig. 1. Study methodology flowchart

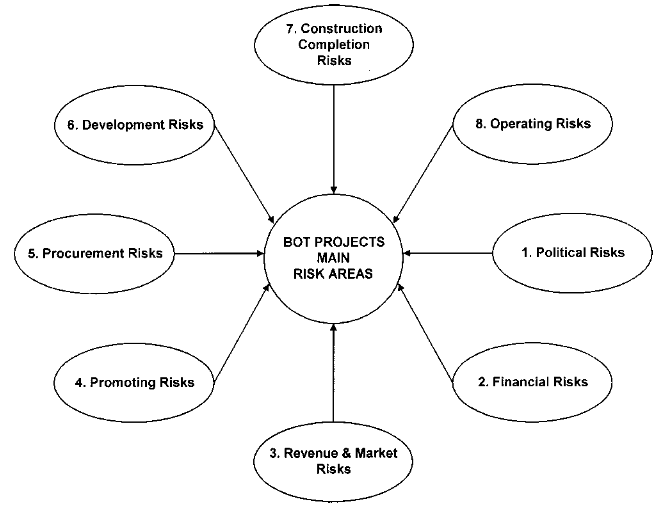


Fig. 2. Build-operate-transfer (BOT) projects main risk areas

and Confederation Bridge. For more information about these projects, the reader is referred to Menheere and Pollalis (1996).

Study Objective

The objective of this study is to provide the BOT decision maker with a method for evaluating and ranking BOT projects based on risk prospective. This method is a risk index (F) to assess BOT project risk that is basically constructed to interpret the subjectivity of risk areas as quantitatively measured values using the analytical hierarchy process (AHP) (Saaty 1980).

Study Methodology

This study passed through different methodology phases to determine the risk index (F) and highlight BOT risk areas. Fig. 1 shows these phases and their interrelationship. They are described in detail throughout the entire paper and can be briefly listed as follows:

1. The BOT main risk areas have been identified and analyzed. Fig. 2 shows the BOT main risk areas that can be encountered in construction projects. Each main area consists of several attributes that build the identity of this area. Both BOT risk areas and attributes have been categorized and defined in this study phase.
2. A questionnaire was designed to collect information on BOT risk areas and attributes from a study group. This information includes risk areas' identification, evaluation on a designed performance scale, and pairwise comparison.
3. A model was constructed to determine the risk index (F). This model consists of two parts: risk areas' weights and their worth score. Risk areas' weights were determined using the AHP, while the worth score was assessed using a new developed approach and the Dias and Ioannou (1996) approach. Therefore, two models had been constructed based on the above worth score approaches.
4. The validation process was performed to check both models by comparing their results with the holistic evaluation.

Risk Definitions

There are many risk definitions in construction. Jaafari (1990) defined risk as the presence of potential or actual constraints that could stand in the way of project performance, causing partial or complete failure either during construction and commissioning or at time of use. Risk is the exposure to the chance of occurrences of events adversely or favorably affecting project objectives as a consequence of uncertainty (Al-Bahar 1990). Then, risk$=f$ (uncertainty of event, potential loss/gain from event). Dias and Ioannou (1995) concluded that there are two types of risk: *Pure risk*: exists when there is the possibility of financial loss but no possibility of financial gain (for example, physical damages); and *Speculative risk*: involves the possibility of both gains and losses (that is, financial and production risk).

Identification of BOT Project Risk Areas

Dias and Ioannou (1995) emphasized that project financing requires identification and analysis of risk areas during different phases of the project using different parameters. Several writers have proposed classification and definition of risk in project financing, concluding that the allocation of risks to the parties to the BOT projects is the key ingredient for successful project-financing undertakings. They classified risks according to the following BOT project phases:

- Development phase (technology, credit, and bid risks);
- Construction phase (completion, cost overrun, performance, and political risks);
- Operating phase (performance, cost overrun, liability, equity resale, and off-take risks); and
- Ongoing risks (interest rate and currency risks).

The identification of possible sources of risk is an essential area in the risk management process because it allows project parties to recognize the existence of uncertainty in the project and hence to analyze its potential impact and to consider an appropriate strategy to mitigate its effect on the project. Dias and Ioannou (1995) have classified sources of risk in the following 10 categories: country (political and regulatory), force majeure, physical, financial, revenue, promoting, procurement, developmental, construction, and operating risks. For more details about these risk areas, the reader is referred to Dias and Ioannou (1995) ⟨www.bakerinfo.com⟩ and ⟨www.airtime.co.uk⟩.

This study focuses on the fundamental questions of whether a potential infrastructure project has the necessary characteristics for successful promotion by a private-sector company based on the risk point of view, and whether the company has the capability of successfully negotiating these kinds of risk. The risk index (F) is a prototype model that addresses the project risk areas based upon the contractor (company)'s risk prospective. It provides a logical, reliable, and consistent method of evaluating potential projects and facilitating a company's decision to engage in the private promotion of an infrastructure project with reasonable knowledge of potential areas of risk.

Risk Index (*F*) Assessment Using Dias and Ioannou Approach

The risk index (F) is a prototype-developed evaluation tool composed of a one-level hierarchical structure that consists of the main eight BOT risk areas. Fig. 2 shows the eight risk areas that this study focuses on: political, financial, revenue, promoting, procurement, developmental, construction, and operating. It evaluates the areas of BOT project risk to provide a quantitative measurement of this risk. Each risk area consists of different attributes or categories of risk, which are not defined and depicted in this paper because of size limits. The current study concentrates only on the main risk areas while their attributes might be studied in a future study. In contrast, the objective of the risk index (F) is to evaluate whether a particular project should be privately promoted based on BOT risk. It assesses the degree of BOT project exposure to risk areas. The risk index (F) can be represented by adding the risk areas' value functions as follows:

$$F=\delta\sum_{i=1}^{n} W_i * V_i(x_i) \tag{1}$$

where F=risk index for BOT project (probability of failure); W_i=weight for each risk area i using eigenvalue method; $V_i(x_i)$=worth score for each risk area (x_i); x_i=different risk areas i; $i=1,2,3,\ldots,n$; n=number of risk areas (8); and δ =constant (explained below).

This functional form was chosen on the basis of the formulation of the Dias and Ioannou (1995, 1996) company and project evaluation model for BOT projects. The procedures of model construction were also selected on the basis of the same reference. Based on the risk areas shown in Fig. 2, the risk index (F) uses n=eight areas of risk x_i. The overall contribution of each risk area is given by its worth score $V_i(x_i)$ multiplied by its composite weight W_i. The term x_i is added to the model to allow any extended future work using the subareas (attributes) of BOT risk areas. The worth score of a risk area $V_i(x_i)$ reflects the 1D value of the performance level of the risk area as it exists for a specific project. The composite weight of a risk area W_i reflects its importance relative to the other areas, irrespective of any particular project.

This model contains the term δ, which was introduced in the model to account for situations where a single dominant attribute's performance level is so low that it is sufficient to render a company incapable of promoting a project, or to make a project unattractive for private promotion. The δ factor is calculated by multiplying the delta of each of n dominant model risk areas δ_i. Consequently, if the intensity of a dominant risk area falls below a certain threshold, P1, set by the decision maker (cutoff point), then its $\delta_i=0$; otherwise, $\delta_i=1$. Thus, $\delta_i=0$ whenever a dominant risk area i has a performance level $x_i \leqslant \text{P1}$ [that is, whenever $V_i(x_i)=0$]. For more details regarding the model and its components, the reader is referred to Dias and Ioannou (1995).

This approach was adapted to BOT project risk through the determination of three main terms: $V_i(x_i)$, W_i, and δ. These three steps are described in detail in the following sections.

One-Dimensional Value Function [$V_i(x_i)$]

To determine the 1D risk area worth score $V_i(x_i)$, it is necessary to evaluate the performance (quality) level x_i of the ith risk area for a given project and then to use a value function $V_i(x_i)$ to transform it into an equivalent worth score. The transformation from the performance (quality) level x_i of the ith risk area into an equivalent worth score requires two steps. Since the eight available risk areas are qualitative in nature, the first step is to assess how well a given project performs with respect to a given risk area i using a meaningful qualitative scale. This is essentially a "risk area measurement" step in which the outcome is project-specific. The second step is to transform this qualitative performance into a 1D worth (or value) score (from 0 to 100). This is a "preference measurement" procedure where the outcome depends on the preference and judgment of the person doing the analysis.

This two-step procedure separates the task of measuring the location of a risk area on the performance scale from the task of determining the worth of the risk area on the worth scale. It also separates qualitative judgments that are specific to a project from the qualitative transformation to value (worth) that can be reused from one project to another. The qualitative risk area measurement scale used to quantify the qualitative assessment for any risk area i is shown in Fig. 3. This scale incorporates nine performance levels at the bottom of the scale, which has been matched with a numerical index value x_i (1–9) to allow a simple shorthand way to refer to any particular risk area using a single number.

The 1D value (worth) functions for all the risk areas have the same generic form shown in Fig. 4. This functional form consists of three linear regions defined by two points, P1 and P2, which are different for each risk area. As shown in Fig. 3, P1 is the minimum acceptable risk area performance level that reflects the highest point on the performance scale where a risk area has minimum value (that is, 0 worth points). As shown in Fig. 3, P2 reflects the lowest point on the performance scale where a risk area is worth its maximum (that is, 100 worth points). These two points divide the performance scale into three regions: a low flat region (A), an intermediate region (B), and a high flat region (C). Region A ("low flat") indicates unacceptable performance. Thus, the risk area being evaluated does not need to be a "complete disaster" in order to be worth zero points. Region C ("high flat") indicates that the risk area's performance is high enough to have maximum worth. Thus, a risk area does not need to be "perfect" in order to be worth 100 points. Region B ("intermediate") represents the "gray" area between unacceptable and completely acceptable performance.

All of the P1 and P2 values for the eight risk areas were estimated by the study group. The line connecting P1 and P2 represents the value curve that transfers the qualitative assessment

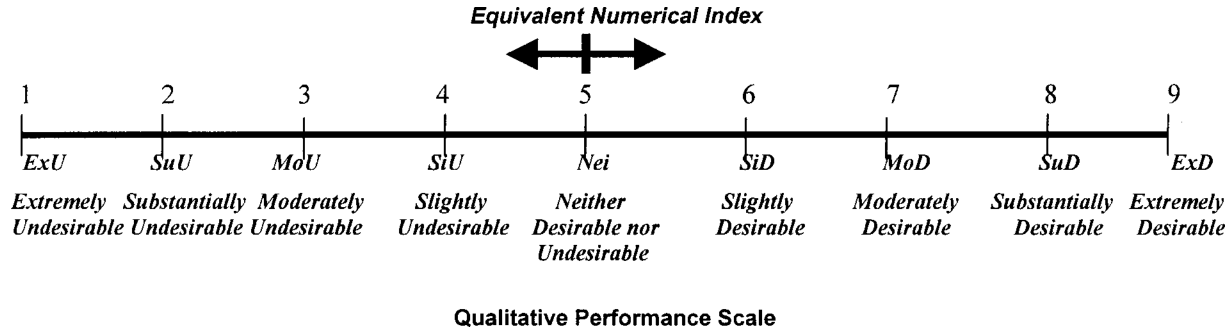


Fig. 3. Qualitative BOT risk areas performance scale

of risk areas to quantitative if their performance lies in region B. Seven selected BOT projects were evaluated by this study group: Plymouth County, Wyatt Detention Facility, State Route 91 express lanes, Dulles Greenway, Wijker Tunnel, Indian Power Plant, and Confederation Bridge. For more details about these BOT projects, the reader is referred to Menheere and Pollalis (1996). Given a risk-area performance level x_i (assessed for a specific project), the pairs of P1 and P2 that were collected from the study group were used to determine the worth (value) of this risk area $V_i(x_i)$ for every study group's individual.

Risk Areas' Weights (W_i)

The risk area weights were obtained by performing the following procedure:

1. A pairwise comparison was performed between the main risk areas of the BOT projects. The study group evaluated all eight risk areas and estimated a relative importance weight for each risk area against the other in each pair. This methodology provided a pairwise comparison matrix for each individual in the study group.
2. The eigenvector or weighting vector for each matrix was developed using the eigenvalue method. Saaty (1980) developed this method as part of the analytic hierarchy process (AHP). Due to space limitations in this paper, the reader can refer to Saaty (1980) and Dias and Ioannou, (1996) for more details. This method is an analytical method of calculating the risk area weights using the pairwise comparison matrix.
3. Finally, the weight W_i for each risk area was calculated for use in the risk index (F) model.

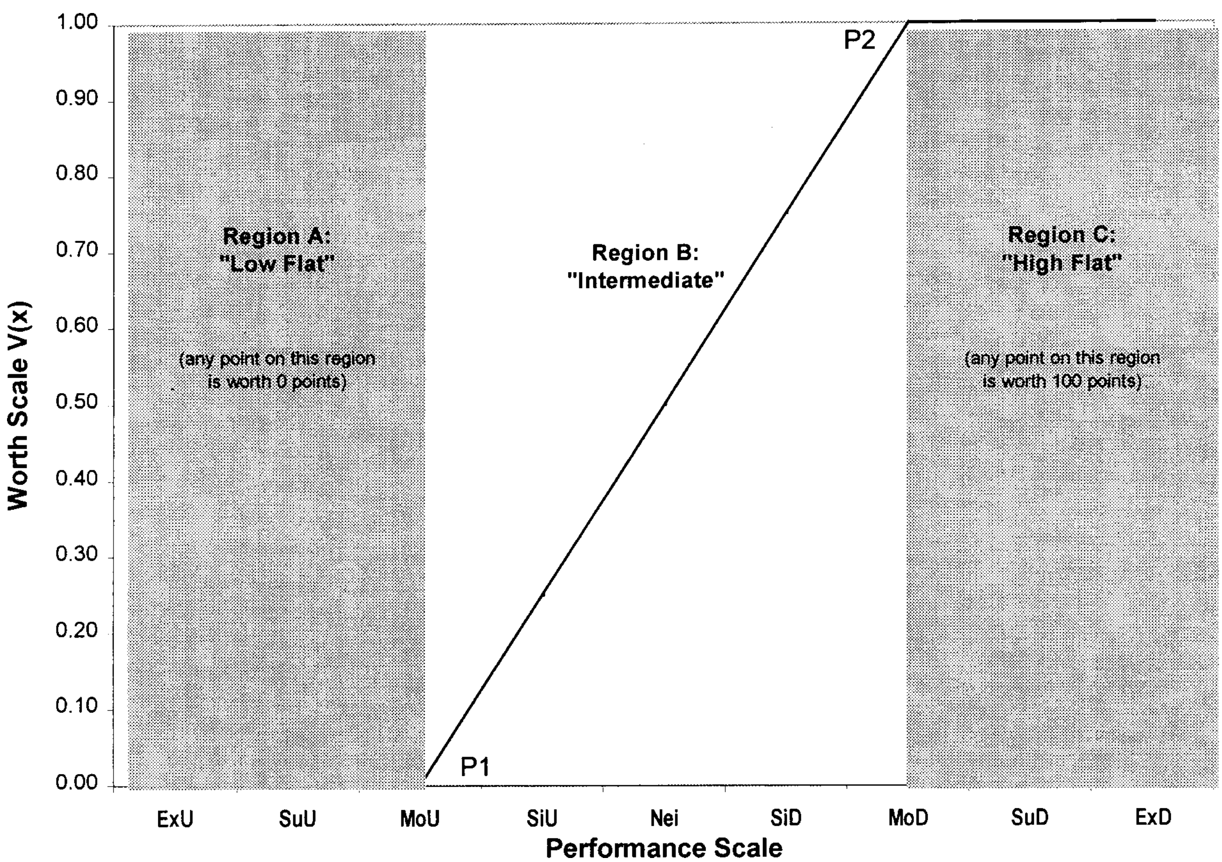


Fig. 4. Dias and Ioannou (1996) value curve

This is a fixed part of the risk index (F) that does not change with the project type. The term W_i does not change from one project to the other because it represents the relative importance of each risk area to the other. Consequently, the project type does not affect this relative importance because it is general and not project-specific. The eigenvalue method was used to quantify the evaluation of the risk qualitative risk areas. The results of this method were the risk areas' weights out of 1.0 or 100 points. Each risk area's weight represents the relative importance of that risk area among the other risk areas that affected each BOT project.

Delta (δ) Factor Validity in BOT Risk Model

Based on the previous depiction of δ, this term is not necessarily used in the risk index (F) model for several reasons. First, it is meaningless because each risk area is important and has a value in the risk model even if it is very slight. Second, the BOT risk areas are not similar to qualification factors where a factor might have no effect on the decision. Third, there is no P1 in the new developed approach model to compare delta with. This is discussed in the following section. Consequently, the following model (2) is used to determine the risk index (F) instead of model (1):

$$F=\sum_{i=1}^{n} W_i * V_i(x_i) \tag{2}$$

In conclusion, model (2) is the adaptation of Dias and Ioannou (1995) model to determine the risk index (F) for BOT projects. The eigenvalue method is used to calculate the risk areas' weights, the performance scale is used to calculate the worth score of each risk area, and δ is not included in the adaptation for the above reasons.

Risk Index (F) Assessment Using New Approach

The Dias and Ioannou (1996) approach was considered in building the new model in terms of its adaptability to BOT projects risk. Two modifications had been made in the Dias and Ioannou (1996) approach to be considered in this study. The first concern was the worth scale shape and whether it was reasonable to use it, and the other was the term δ and its validity in developing the risk index (F). The worth scale shape was deemed unusable for the following reasons:

1. P1 and P2 indicate that risk areas that are lower than P1 have zero effect on risk. Moreover, risk areas that are higher than P2 have the same 100% effect on risk even though they may have different weights. This is not reasonable when thinking in terms of risk because each risk area has its own effect on risk even if it is very slight, and it is of course not necessarily similar to other areas.
2. The Dias and Ioannou (1996) worth scale means that if there is a project with all the risk areas lower than P1, this project has no risk. This is, of course, logically false. On the other hand, if there is a project where all risk areas are higher than P2, this project will be 100% risky; this also is logically false. Each risk area has its effect on each BOT project, even though it may be a very slight effect. The model cannot neglect some risk areas even though they have a slight effect on the risk because of their contribution to the project risk environment and their interrelationship with the other risk areas.

Therefore, the value curve for BOT risk is represented by a line that connects the first point (1: zero value) in the performance scale of (1–9) points and the last point (9:100% value). Fig. 5 shows this new approach for the BOT risk value curve in the worth scale. This figure shows that P1=0% and starts at point 1 of the scale of 9 points [extremely undesirable (ExU)]. On the other hand, P2=100% and ends at the last point of the performance scale [extremely desirable (ExD)]. Thus, the value curve starts from the first point and ends at the last point of the performance scale. This worth scale chart is different from that was used by Dias and Ioannou (1996) because of the above two reasons. Consequently, there is no need for P1 and P2 in the new approach worth scale.

Accordingly, the new approach modifies the Dias and Ioannou (1996) model in two different items: the value curve and the δ term; it eliminates the δ term and changes the concept of the value curve to cope with risk characteristics. Both the modified Dias and Ioannou and the new developed approaches have been implemented for BOT risk to test their capability to represent the risk problem. This application is shown in the following section.

Models Application

Data were collected from the study group through a questionnaire that contained four questions. The first question collected a pairwise comparison matrix from each member of the study group for the eight BOT risk areas. Each individual in the study group evaluated the eight BOT risk areas against each other. The second question asked for an evaluation of P1 and P2 for each BOT risk area; it asked each individual to assign a value for P1 and P2 for each BOT risk area. The third question asked for a holistic evaluation for the seven BOT projects according to BOT risk. A holistic evaluation estimates each BOT project's risk as a whole with a number out of 1.0 (100), depending on personal judgment considering the project features. The fourth question asked for an evaluation of each BOT risk area in every project and provided the evaluation of each risk area in every project on a scale from 1 to 9 points (performance scale). The risk index (F) in model (2) was implemented in this study through the determination of two terms: W_i and $V_i(x_i)$. The determination of both terms is described in the following sections.

$V_i(x_i)$ *Determination*

The collected data were analyzed to determine the best model fit for BOT project risk. Table 1 shows the average subjective evaluations of the eight main risk areas for the seven BOT projects and their standard deviation. These subjective evaluations were estimated according to a performance scale of (1–9) points based upon the analysis of the fourth questionnaire question. For example, the revenue and market risk area is the highest in the Plymouth County project, having 5.6 points out of 9 and a standard deviation of 2.51 points. The slightly lower operating and financial risk areas have an equal weight of 5.4 points, where the standard deviation is 1.95 points. The Wyatt Facility project also had market and revenue risk as the highest risk area with an evaluation of 7.4 points and the financial risk as the second highest risk area of 6.8 points. The same areas have a similar rank for the Dulles Greenway and State Route 91 projects where the revenue and market risk area has 5.8 and the financial risk area has 5.7 points for the Dulles Greenway. The construction risk is the highest risk area for the Wijker Tunnel, Indian Power Plant, and Confederation Bridge projects with 5.6, 6.8, and 5.4 points, respectively. Table 1 also shows the average values of P1 and P2

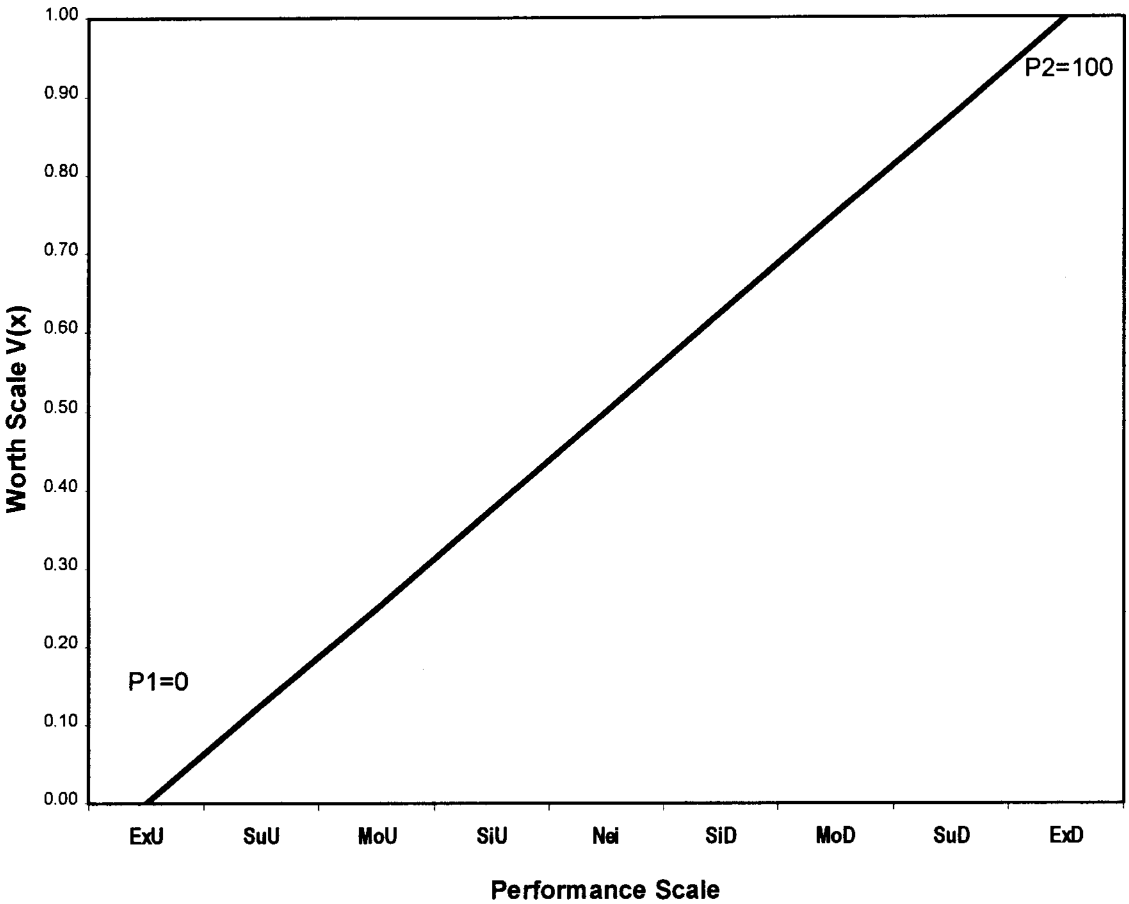


Fig. 5. New developed approach value curve

collected by the second questionnaire question. It is noticed that approximately all the projects' risk areas evaluations lie between the average values of P1 and P2. The promoting and procurement risk areas subjective evaluations are close to 4 out of 9 in most of projects, but the case is different for financial, construction, and revenue and market risk areas where they are widely spread. The collected information from this question was used to evaluate the worth score for each risk area in every project.

The worth scores $V_i(X_i)$ of the risk areas for each BOT project are calculated using the performance scale. Two approaches have been applied to the data: the first is the new developed approach, and the second is the adapted approach of Dias and Ioannou (1996). Table 2 shows the values resulting from the application of the latter approach. The revenue and market risk is the highest worth score in the Wyatt Facility project; it has a value of 1, which is the maximum worth scale score. Table 2 also shows that the construction risk has its highest contribution in the Indian Power Plant project, with 0.94 score. The Indian Power Plant project has approximately the highest values for almost all the entire risk areas. Note that the construction risk is zero for the Plymouth County and the Wyatt Facility projects. This seems unreasonable because these projects should have a construction risk, even if it is very slight. In addition, the revenue and market risk has a zero value in the Wijker Tunnel, Indian Power Plant,

Table 1. BOT Projects Main Risk Areas and Their Subjective Average Evaluation [Numbers Based on Scale of (1–9)]

Number	Risk areas	Plymouth County project	Wyatt Facility project	Dulles Greenway project	State Route 91 project	Wijker Tunnel project	Indian Power Plant project	Confederation Bridge project	Average P1	Average P2
1	Political	3.80	4.80	3.80	4.40	4.40	5.40	4.60	3.50	6.80
2	Financial	5.40	6.80	5.70	5.20	5.00	5.80	4.60	4.80	7.80
3	Revenue and market	5.60	7.40	5.80	5.40	4.20	4.60	4.60	4.75	7.40
4	Promoting	4.00	4.40	3.80	3.80	3.70	4.80	4.30	2.90	6.50
5	Procurement	4.20	4.60	3.80	4.00	4.00	4.80	4.40	3.00	6.50
6	Developmental	4.40	5.00	4.00	5.20	4.20	5.60	4.80	3.67	6.40
7	Construction	3.40	3.40	3.80	4.20	5.60	6.80	5.40	3.67	7.00
8	Operating	5.40	5.60	4.40	4.60	4.40	5.00	4.00	3.33	6.33

Table 2. Worth Value $[V_i(x_i)]$ Values for Each Project Using Dias and Ioannou Approach

BOT projects	BOT risk areas							
	Political	Financial	Revenue and Market	Promoting	Procurement	Developmental	Construction	Operating
Plymouth County	0.0910	0.2000	0.3210	0.3100	0.3420	0.2700	0.0000	0.6900
Wyatt Facility	0.3940	0.6670	1.0000	0.4200	0.4600	0.4900	0.0000	0.7600
State Route 91	0.2730	0.1333	0.2500	0.2500	0.2900	0.5600	0.1600	0.4233
Dulles Greenway	0.0910	0.3000	0.4000	0.2500	0.2300	0.1200	0.0390	0.3600
Wijker Tunnel	0.2720	0.0667	0.0000	0.2220	0.2900	0.1940	0.5800	0.3600
Indian Power Plant	0.5800	0.3330	0.0000	0.5300	0.5140	0.7100	0.9400	0.5600
Confederation bridge	0.3333	0.0000	0.0000	0.3900	0.4000	0.4140	0.5200	0.2333

and Confederation Bridge projects. This also is unreasonable because these projects should have some revenue problems. The strangest observation is that the financial risk has a worth of zero in the Confederation Bridge project, which is impossible. These unreasonable issues are disadvantages of this approach's application in the BOT risk area.

The new developed approach application reformed these disadvantages and treated them in a reasonable way. Table 3 shows the worth scores of different risk areas for each BOT project using the new developed approach. No worth scores have zeros, so that all the areas have an effect on the risk, even if it is very slight. The revenue and market risk is the highest worth score in the Wyatt Facility project, with a value of 0.8222 out of 1.0. It also shows that the construction risk has its highest contribution in the Indian Power Plant project, with a value of 0.7556 out of 1.0. The Indian Power Plant project has approximately the highest values for almost all of the entire risk areas. The procurement and developmental risk areas have close worth scores for the entire set of projects. On the contrary, the construction, revenue and market, and financial risk area worth scores are widely spread.

The new developed approach took into account all the disadvantages of the adapted Dias and Ioannou approach. There is no zero effect for any risk area, but every area has its effect, even if it is very slight. The new developed approach is very logical because it considers the effect of each risk area. In addition, it matches the holistic evaluation nature of high and low risk projects. For example, the new developed approach resulted in the Indian Power Plant project being the highest-risk project in the construction, developmental, procurement, promoting, and political risk areas. On the other hand, the Dulles Greenway project is the lowest-risk project in the operating, developmental, procurement, promoting, and political risk areas. It also indicates that the Wyatt Facility project is the highest in the operating, revenue and market, and financial areas of risk. These observations match the holistic nature of each project. Therefore, the new approach is good in representing the nature of each project and in enhancing the disadvantages of using the adapted Dias and Ioannou (1996) approach to BOT projects risk. This discussion is supported by the model validation argument below.

W_i Determination

The first questionnaire question collected a pairwise comparison matrix from every individual in the study group. The eigenvalue method of AHP (Saaty 1980) was used to analyze the pairwise comparison matrices in order to conclude the relative weight vector for each. This weight vector consists of the relative weights of each risk area compared to the others. In other words, the summation of these weights in each vector is 1.0. The average weight and standard deviation for each risk area was calculated to represent W_i in the risk index (F) model. Table 4 shows each risk area average weight and its boundaries of $\pm$ standard deviation. It is clear that the procurement and political risks have the highest weight of 0.1578 and 0.1568, respectively. The construction and developmental risk areas have a considerable risk weight, but they have a very small standard deviation.

The third questionnaire question collected the holistic risk evaluations for the seven BOT projects from the study group members. Holistic is a method of evaluating the project risk as a whole by one number using a scale from 1 to 10 relying on personal judgment. Table 5 shows the average holistic risk evaluation and its boundaries of ± 1 standard deviation. The highest

Table 3. Worth Value $(V_i(x_i))$ Values for Each Project Using Developed New Approach

BOT projects	BOT risk areas							
	Political	Financial	Revenue and Market	Promoting	Procurement	Developmental	Construction	Operating
Plymouth County	0.4222	0.6000	0.6222	0.4444	0.4667	0.4888	0.3777	0.6000
Wyatt Facility	0.5333	0.7555	0.8222	0.4888	0.5111	0.5555	0.3777	0.6222
State Route 91	0.4889	0.5777	0.6000	0.4222	0.4440	0.5777	0.4666	0.5111
Dulles Greenway	0.4222	0.6333	0.6444	0.4222	0.4222	0.4444	0.4222	0.4889
Wijker Tunnel	0.4888	0.5555	0.4666	0.4111	0.4444	0.4667	0.6222	0.4888
Indian Power Plant	0.6000	0.6444	0.5111	0.5333	0.5333	0.6222	0.7556	0.5556
Confederation Bridge	0.5111	0.5111	0.5111	0.4778	0.4889	0.5333	0.6000	0.4444

Table 4. BOT Projects Risk Area' Weights (W_i)

BOT risk areas	Risk areas' weights Lower Limit (average−STD)	Central (average)	Upper Limit (average+STD)
Political	0.0901	0.1568	0.2235
Financial	0.0599	0.1247	0.1895
Revenue and market	0.0144	0.0792	0.1439
Promoting	0.0281	0.0994	0.1707
Procurement	0.0812	0.1578	—
Developmental	0.1063	0.1163	0.1263
Construction	0.1256	0.1325	0.1393
Operating	0.0687	0.1334	0.1981

Note: STD=standard deviation.

Table 5. BOT Projects' Holistic Risk Evaluation

BOT projects	Holistic evaluation Lower Limit (average−STD)	Central (average)	Upper Limit (average+STD)
Plymouth County	0.2782	0.4867	0.6952
Wyatt Facility	0.4726	0.6083	0.7440
State Route 91	0.3431	0.5417	0.7402
Dulles Greenway	0.3953	0.5417	0.6880
Wijker Tunnel	0.2922	0.5033	0.7145
Indian Power Plant	0.5227	0.6967	0.8706
Confederation Bridge	0.2854	0.5467	0.8079

Note: STD=standard deviation.

risk project, as a whole, is the Indian Power Plant, with a holistic average of 0.6967 out of 1.0. The second rank is the Wyatt Facility Project, with a 0.6083 out of 1.0. Three other projects share the third rank: Confederation Bridge, State Route 91, and the Dulles Greenway Project, with approximately 0.54 out of 1.0.

Being determined, both terms, W_i and $V_i(x_i)$, were substituted in the risk index (F) formula in model (2) to assess the level of risk in each case study project. Model (2) was implemented in the two terms based on the two studied approaches. Fig. 6 shows the final outcome of both approaches and the holistic evaluation. The new developed approach results were very close to the holistic evaluation.

Model Prevalidation Process

Dias and Ioannou (1996) mentioned that the use of external criteria to objectively assess the validity of the evaluation models is a difficult issue because multiattribute decision models are essentially subjective in nature. Therefore, past research has relied on indirect approaches, such as convergent validation, predictive validation, and axiomatic validation methods. Convergent validation consists of comparing the results obtained by a multiattribute model with the holistic (that is, direct) evaluations made by the decision makers. Thus, several alternatives are defined (for example, projects) and then evaluated by both the model and the decision maker. These evaluations are then compared as to how they rate and/or rank these alternatives. A high positive correla-

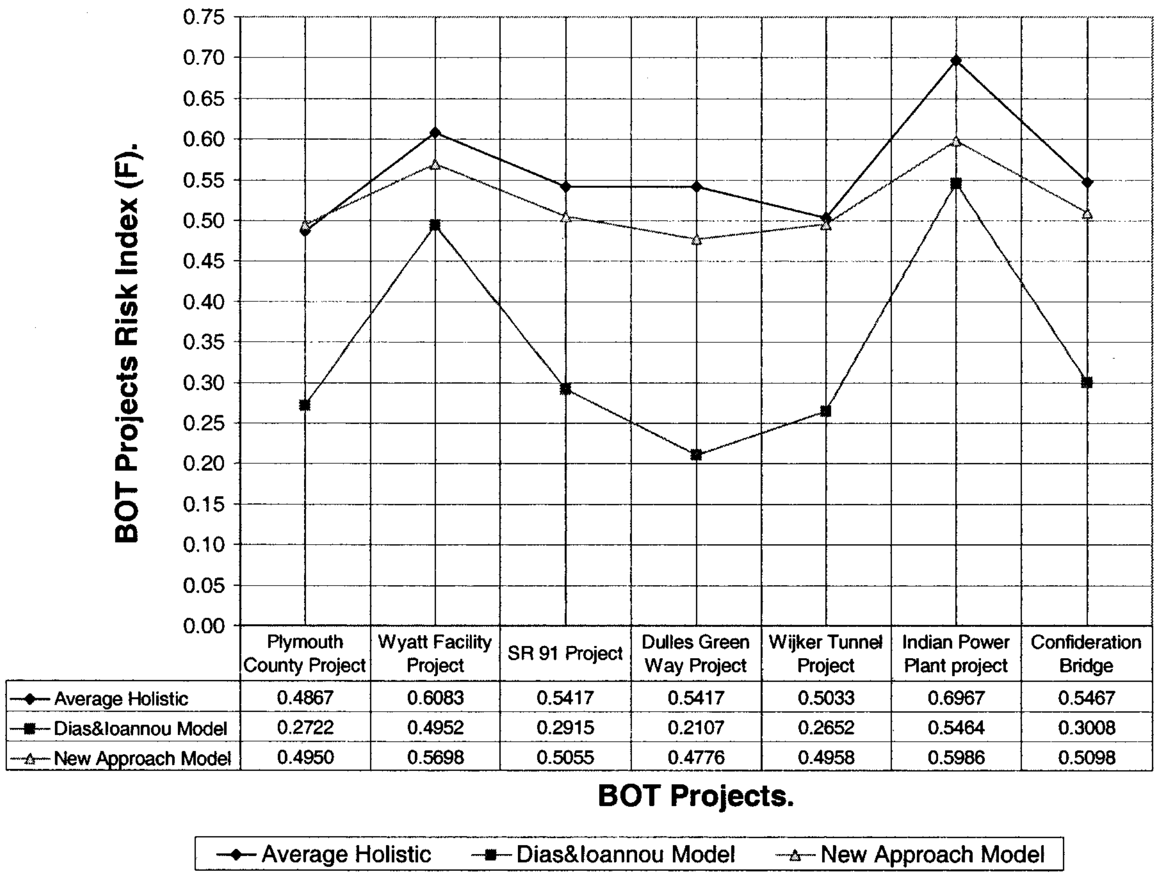
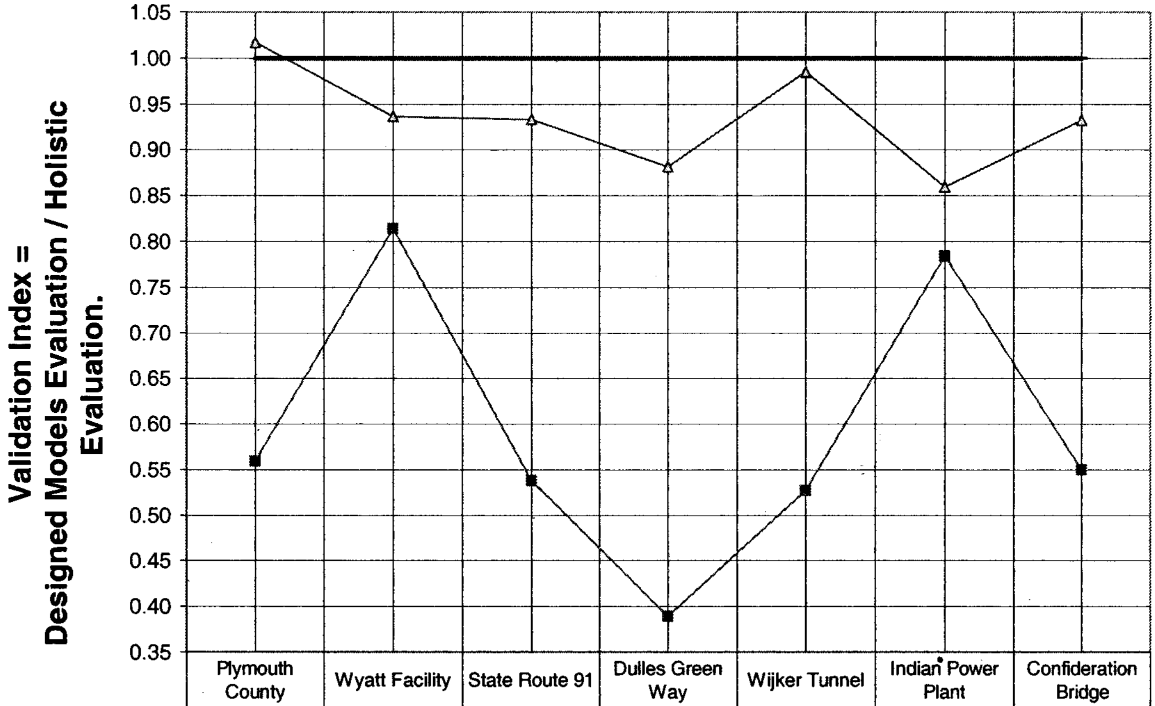


Fig. 6. BOT-designed risk models prevalidation chart



	Plymouth County	Wyatt Facility	State Route 91	Dulles Green Way	Wijker Tunnel	Indian Power Plant	Confideration Bridge
New Approach	1.0172	0.9367	0.9332	0.8817	0.9850	0.8593	0.9325
Dias&Ioannou	0.5593	0.8140	0.5381	0.3891	0.5268	0.7843	0.5502
Holistic	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

BOT Projects.

New Approach — Dias&Ioannou — Holistic

Fig. 7. Correlation between designed models and holistic evaluations

tion between the holistic and the model evaluations is expected to occur if, in fact, the model is capturing the decision maker's holistic evaluation preferences.

Convergent validation was performed by defining seven hypothetical project profiles that were subsequently evaluated holistically by the study group on a scale from 0 to 1.0, as shown in Table 5. The same profiles were also evaluated using the adapted Dias and Ioannou (1996) as well as the new developed approaches. This is a prevalidation process because the study group represents only the academic point of view. To perform real validation, the study group has to have practical experts' opinions; therefore, the developed model is called a prototype because it is a starting model. The results of the holistic and model evaluations are shown in Fig. 6. It shows the final risk index (F) for the seven projects using both approaches and the average holistic. The new developed approach assesses the risk index (F) very close to the holistic evaluation for almost all the studied projects. The holistic is very close to the new developed approach in evaluating the risk of the Plymouth County and Wijker Tunnel projects. Conversely, the adapted Dias and Ioannou (1996) approach looks unrealistic because the holistic is very remote from the model evaluation. This argument is very clear in Fig. 7, which shows the correlation between the designed models and the holistic evaluations. This correlation is represented by the validation index, which is calculated by dividing the designed model's evaluations by the holistic evaluation. There is no doubt that the new developed approach model is more valid than the adapted Dias and Ioannou (1996) approach. In fact, the validation index for five projects out of seven is more than 0.93 using the new approach. This means that the model assessment is 93% correlated with the holistic evaluation; the other two have more than a 85% correlation with the holistic.

Dias and Ioannou (1996) wrote that Von Winterfeldt and Edwards (1986) and Gardiner (1974) provided a summary of multiattribute decision models and show that typical correlations are in the range of 0.70 to 0.95. They interpret these findings as supporting the convergent validity of multiattribute models. Furthermore, they point out that these correlations tend to decrease as the number of attributes increases because the reliability of holistic judgments decreases as the number of model attributes increases. The BOT risk model has a small number of attributes in this general abbreviated form of risk areas. Therefore, the convergent validation of its results produced very high correlations with the new approach, which indicates its robustness and accuracy. On the contrary, the adapted Dias and Ioannou (1996) approach produced very low correlations with the holistic evaluation. It has only two projects that are 81 and 78% where the others are in the range of 30–50% correlation.

In conclusion, the preceding outcomes indicate that the new developed approach model captures the holistic evaluations quite well. In addition, the outcomes indicate that the adapted Dias and Ioannou (1996) approach is not reliable and does not capture the

Table 6. Project Rank Using Different Methods

BOT projects	Project rank: Holistic	Dias and Ioannou Approach	Developed New Approach	Rank Reversal (Saaty)
Plymouth County	7	5	6	5
Wyatt Facility	2	2	2	2
State Route 91	5	4	4	3
Dulles Greenway	4	7	7	7
Wijker Tunnel	6	6	5	6
Indian Power Plant	1	1	1	1
Confederation Bridge	3	3	3	4

holistic evaluation well. Consequently, the concepts of the new developed approach model are recommended in the BOT projects risk evaluation in future.

BOT Risk Index (F) as Project Ranking Method

The risk index (F) can be used as a tool for ranking BOT projects so that the company can select the least-risk project. The seven case study projects were ranked to indicate the most- and least-risk projects. The Indian Power Plant project was estimated as the riskiest project by the holistic and designed models, as shown in Fig. 6, while the Wyatt Detention Facility project ranked second. To test the risk index (F) as a ranking tool, another professional method of ranking the alternatives was also used to rank the seven projects. This method, based on the AHP, is the rank reversal method or the ratio scale estimation method (Harker and Vargas 1987). There is insufficient room in this paper to describe this method in detail; however, it is used to rank the seven case study projects, and the results are shown in Table 6. It shows the rank of the seven BOT projects using four methods: the holistic, new developed approach, adapted Dias and Ioannou (1996) approach, and rank reversal. The results indicate differences among the results of the four methods except for two projects: the Indian Power Plant and the Wyatt Facility. The Dulles Greenway project has an odd rank because all the analytical methods recorded it as the 7th and the holistic method recorded it as the 4th. Although this paper can offer no explanation for these results, the phenomenon should be addressed in future study.

Conclusions and Recommendations

This paper proposes a risk index (F) that performed two functions: To asses the risk and rank of BOT projects. The main areas of BOT project risk were identified and analyzed, and a model for calculating the risk index (F) was constructed and its components were discussed in detail. The accuracy and robustness of this model have been preverified by the good agreement of its results with the holistic evaluation. The new developed approach was more convenient than other approaches in dealing with BOT project risk.

Nevertheless, this study relied upon a small academic study group in collecting the evaluation data. It is recommended that the data collection zone be increased, with practicing professionals in BOT projects to improve the accuracy of the developed risk model.

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