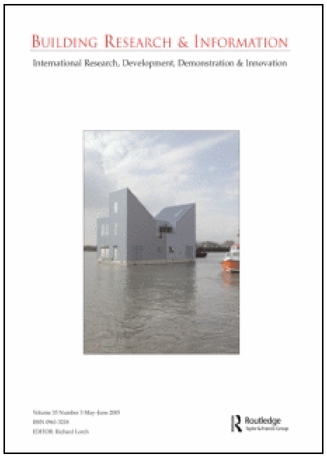

Building Research & Information

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713694730

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Online Publication Date: 01 March 1999
To cite this Article: Lam, Ka Chi and Chow, Wing Sing (1999) 'The significance of financial risks in BOT procurement', Building Research & Information, 27:2, 84 - 95
To link to this article: DOI: 10.1080/096132199369552
URL: http://dx.doi.org/10.1080/096132199369552

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The significance of financial risks in BOT procurement

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This paper explores the significance of the financial risk characteristics of Build-Operate-Transfer (BOT) projects. The objective was to identify and discuss the significance of the types of financial risk variables in conjunction with the different phases of procurement. A survey was therefore conducted to investigate the nature of the relationships between the financial risk variables and the different phases of BOT projects. 'Interest rate fluctuation' was the most significant financial risk variable in the pre-investment phase. For the implementation phase, both the variables 'design deficiency' and 'time overrun' were found to be highly statistically significant. The variable 'time overrun' was found to be the most statistically significant in the construction phase. The majority of the risk variables were considered to be moderately significant in the operations phase; these included 'competition', 'currency exchange restrictions' and 'defective products or facilities'. A mathematical model employing discriminant analysis was established to demonstrate the classification of financial risk variables in relation to the five BOT project phases.

Cet article s'intéresse à la signification des caractéristiques des risques financiers associés aux projets de construction-exploitation-transfert (BOT). Il s'agissait de recenser et d'examiner la signification des types de variables en matière de risques financiers en regard des différentes phases d'approvisionnement. On a donc procédé à une enquête sur la nature des relations entre les variables des risques financiers et les différentes phases des projets BOT. Les 'fluctuations des taux d'intérêt' constituent la variable la plus importante lors de la phase de préinvestissement. Pour la phase de mise en oeuvre, les deux variables les plus significatives sont les 'défauts de conception' et les 'retards dans l'exécution des travaux'. Cette dernière est, statistiquement, la plus importante lors de la phase de construction. On considère que, dans leur ensemble, les variables ont une signification modérée lors de la phase d'exploitation; ces variables comprennent la 'concurrence', les 'restrictions relatives au change' et 'les produits ou moyens défectueux'. On a élaboré un modèle mathématique basé sur l'analyse discriminante pour établir le classement des variables des risques financiers par rapport aux cinq phases des projets BOT.

Keywords: financial risk, Build-Operate-Transfer projects, risk analysis, procurement, private finance, Hong Kong.

Introduction

The term Build-Operate-Transfer, or BOT, refers to a project procurement process similar to privatization, i.e. a sponsor from the private sector undertakes to build and operate an item of infrastructure or a facility that would normally be procured and constructed by government after a fixed period (the concession period), the ownership of the facility is then transferred to the government at no cost or at a pre-agreed price. Investment paid by the lenders such as shareholders is repaid by revenues generated from the operation of the facility.

Renault (1989) suggested that from the point of view of the sponsor, it is important to know what the risks will be and their extent, particularly if the involvement in a BOT project is in a foreign and developing country. Tiong (1990) stated that the sponsor is normally expected to assume all risks and responsibilities throughout the construction and operating periods, including provision of guarantees in terms of insurance or liquidated damage for the completion and operating risks. BOT projects also vary in nature in terms of the degrees of sharing of the investment between the sponsor, contractor and the government. Hence, it is essential for the sponsor to acquire, before committing to any BOT project, a good understanding of the nature of the BOT project to be undertaken and its associated risks.

Objectives and methods

Much research has been conducted on the procedural arrangements of BOT projects and on risk analysis methods for traditionally procured construction projects. No extensive study has been conducted concerning the quantification of risks associated with BOT projects. In view of this situation, the objectives of this paper are:

- to identify the financial risks associated with BOT projects;
- to study the significance of the financial risks associated with BOT projects; and
- to establish a risk classification model based on the results of the above.

To achieve the above-stated objectives, two major procedures are involved: the development and implementation of a questionnaire survey and subsequent data analysis. Both of these were been carefully designed and examined in order to obtain representative data from the industry to process the collected data appropriately.

BOT project risks

Tiong *et al*. (1992) cited that BOT projects can be divided into five phases, namely 'Pre-investment', 'Implementation', 'Construction', 'Operations' and 'Transfer'. Figure 1 shows the inter-relationship between the individual phases of a typical BOT project.

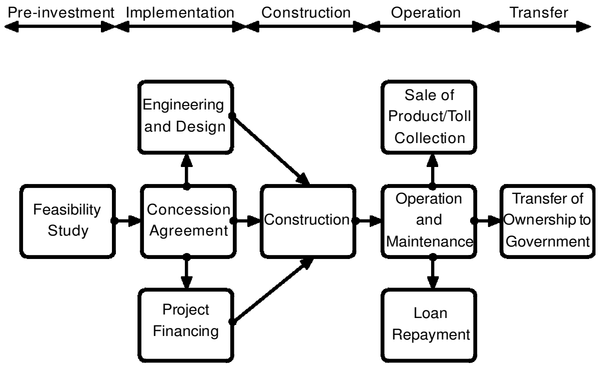

Fig. 1. Typical BOT Project Phases (Source: Tiong, Yeo and McCarthy, 1992).

In terms of the risk/return relationship, BOT projects rely heavily on financial support from investors and lenders during the construction stage. Therefore, the level of support provided depends on an evaluation of the concession company's repayment capacity over a long concession period.

Risk can be defined as the chance of injury, damage or loss. Erikson (1979) offered a working definition of risk in construction as 'Exposure to possible economic loss or gain arising from involvement in the construction process'. These definitions imply that risk is perceived as a variability measure of the possible outcomes of a proposed economic activity. Jones (1976) described the concept of risk as follows: 'Risk is measured by the distribution of the returns or revenues from an investment. This is also called a risk profile and is a probability distribution.' In this regard, statistical methods can be used to simulate risks and to incorporate them into an investment assessment.

The identification of risks and the assessment of their significance are the corner stones of financial risk analyses and, in general circumstances, are essential to the success of a project. Woody and Pourian (1992) have identified a number of specific risks associated with project financing as shown in Fig. 2. These risks have broadly been categorized into five groups. They are the start-up-cost risk, operating risk, technology risk, market risk and political risk. Park (1979) listed 12 major risks which contractors often face: (1) weather; (2) unexpected job conditions; (3) personnel problems; (4) errors in estimation, scheduling, etc.; (5) delays; (6) financial difficulties; (7) strikes; (8) faulty materials; (9) faulty workmanship; (10) operational problems; (11) inadequate plans or specifications; and (12) disasters. Moreover, Erikson (1979) classified risks into contractual and construction risks.

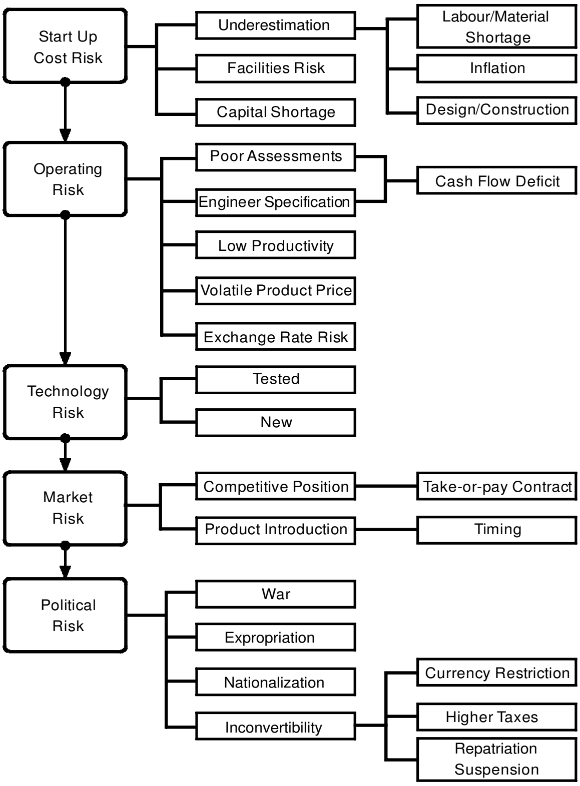

Fig. 2. Risk identification in project finance (Source: Woody and Pourian, 1992).

Contractual risk is primarily caused by a lack of contract clarity, an absence of perfect communication between the parties involved, and problems of timeliness in contract administration. Improving contract clarity and contract administration, at little additional cost, can reduce contractual risk. Construction risk, inherent in the work itself, can only be reduced marginally. Factors listed as being responsible for this class of risk include weather, differing site conditions, acts of God, resource availability, etc.

Similarly, Ernst and Pham (1995) identified a number of risks with regard to BOT project financing. These included:

- Construction risks;
- Performance/technology risks;
- Force-majeure risks; and
- Economic performance risks.

After consolidating the above-mentioned risks, a number of risk factors were identified as being particularly suitable for this objective the survey described herein. All identified risks are listed in Table 1.

Surveying the significance of financial risks

Gareis (1979) and Lau (1994) pointed out that in Hong Kong and other countries, research on the use of risk analysis methods has revealed that 'experience' was the most popular method used to determine the magnitude of risks associated with a project. Notwithstanding this, identification of the significance of different types of risks would assist the sponsor/investor in deciding whether or not to invest in a BOT project.

A structured questionnaire (see Appendix) was developed, following the risk identification as discussed above, in order to evaluate the significance of various types of financial risks arising at various stages of a BOT project. This questionnaire was sent by post to industry experts including government officials, consultants, contractors, developers and bankers. The respondents (industry experts) were invited to respond with regard to BOT project classification and the degree of significance of various financial risks.

For the industry experts to be included in the sample, it was a prerequisite that they had been involved in BOT projects within the last 5 years. A total of 70 individuals were selected for the survey; among them, 9 were government officials, 15 were engineering consultants, 10 were contractors, 25 were developers and 11 were bankers. The combination of respondents ensured that the survey was capable of soliciting reasonable and representative opinions from the industry.

The survey was carried out between December 1996 and January 1997. A total of 26 replies were received, giving a response rate of 37%. The response rate was considered satisfactory, considering that the BOT concept is still 'new' to the Hong Kong construction industry. In addition, the number of BOT projects that have been successfully implemented is small compared to the number of construction projects let under the traditional type of government contract. Many respondents who declined to participate in the survey stated that they were not sufficiently experienced to give any opinions. Among the

Table 1. Characteristics of risks

Risks	Characteristics
Engineering:	
A : Labour/material fluctuation	This risk will lead to cost and time overruns and, as a result, debt arrangements with banks and investors may be adversely disrupted.
B : Engineering design deficiency	A poor engineering design will disrupt the progress of the construction works, leading to time and cost overruns.
C : Low productivity	Low productivity is one of the factors involved in operating cost overruns.
D : Time overrun	Construction delays may seriously jeopardize the cash flow expected for meeting the debt repayment in the operations stage.
E : Poor quality of works	The quality of work affects the future maintenance cost of the facility which, in turn, affects the expected debt arrangement.
F : Defective product/facilities	This risk results in a decreased output form the finished product and thus delays the debt repayment.
Finance:	
G : Inflation fluctuation	This is a critical factor in determining various financial indices, such as the interest rate, rate of return, currency exchange rate, etc. A change in inflation will significantly affect the financial arrangement.
H : Shortages of investment capital	Shortages of capital lead to delays in both the construction and operations stages of the project and the expected cash flow.
I : Poor credit ability	Credit risk is the risk that the counterparty (partner of the joint venture) to any financial transaction will not be able to fulfil its obligation on the due date. If this risk arises, the debt capacity of the company will be reduced.
J : Interest rate fluctuation	Brick and Palmon (1992) stated that the interest rate is the key factor in the intensity of debt and IRR and consequently affects the feasibility, construction and operation of a project.
K : Liquidity	Shleifer and Vishny (1992) noted that liquidity risk exists where cash-flow needs and maturities do not match, typically where controlled by a treasury-funding unit. Liquidity risk arises when there is a delay in loans from banks and investors.
L : Currency exchange restriction	Currency restrictions arise from political instability and/or international trading disputes.
M : Counterparty	Any transaction between two or more parties to a contract contains a risk that one counterparty (partner of joint venture) will default on an obligation and not be able to fulfil a commitment when it becomes due. The major issue arising from this risk is a failure in the financing of the required cash flow.
N : Exchange rate fluctuation	This is the risk that a project will face a market change due to an international trading agreement. A guarantee from the government on a fixed exchange rate is helpful in mitigating this risk.
O : Cost overrun	The risk that the construction cost is higher than the expected project costs, leading to difficulties in the debt arrangements and delays in the operations stage of the project.
P : Higher taxes	Apparently, high taxes in the operating stage will jeopardize the debt repayment.
Q : Equity resale	The saleability of a finished product or service is important in financial rearrangement, especially in the operations stage. Higher equity reliability results in higher bargaining power in a profitable debt rearrangement.
Political and social:	
R : Sovereign	The risk that a government's action may prevent repayment of a debt and/or the raising of funds from financial institutions.
S : Force majeure	Acts of God that make the project impossible to complete.
T : Competitive position	An early introduction of finished products or services is crucial in occupying the market and meeting the debt repayment.

26 respondents, 4 were government officials, 4 were bankers, 5 were contractors, 9 were developers and 4 were engineering consultants. The distribution of different types of respondents is shown in Table 2. It may be noted from this figure that the majority of responses (36%) came from developers, implying that they were more interested in the investment risks in BOT projects.

To safeguard the collected data against any possible bias from the respondents, a *viability test* was conducted. This was carried out by asking the respondents to complete a question-

Table 2. Percentages of different types of respondents

Respondents	Original sample		Returned sample	
	No.	(%)	No.	(%)
Government officials	9	12.8	4	15.3
Engineering consultants	15	21.4	4	15.3
Contractors	10	14.2	5	19.2
Developers	25	35.7	9	34.6
Bankers	11	15.7	4	15.3
Total	70	99.8[a]	26	99.7[a]

[a]Error due to rounding

naire again. A total of 11 respondents out of 26 have returned the questionnaire. It was found that similar answers were given in the second return. This ensured that all of the collected data were valid and suitable for analysis. The data collected were then checked using reliability function analysis.

Reliability analysis

In many areas of research, the precise measurement of hypothesized processes or variables poses a challenge by itself. Reliability analysis has been used to construct reliable measurement scales, to improve existing scales, and to evaluate the reliability of scales already in use. The definition of reliability is straightforward: a measurement is reliable if it reflects mostly a true score, relative to the error. We may define an index of reliability in terms of the proportion of true score variability that is captured across subjects or respondents, relative to the total observed variability. In equation form, this can be written as

$$\alpha = (k/(k-1))[1 - \Sigma(s_i^2)/s_{\text{sum}}^2] \qquad (1)$$

This is the formula for the most common index of reliability, namely, Cronbach's coefficient alpha (α). In this formula, the s_i^2 denotes the variances for the k individual items; s_{sum}^2 denotes the variance for the sum of all items. If there is no true score but only error in the items (which is esoteric and unique, and therefore, uncorrelated across subjects), then the variance of the sum will be the same as the sum of variances of the individual items. Therefore, the coefficient α will be equal to zero. If all items are perfectly reliable and measure the same thing (true score), then the coefficient α is equal to 1.0. After analysing the data, the reliability coefficient α was found to be 0.8087, which confirmed that all of the data were highly reliable.

Frequency distributions

When summarizing large masses of raw data, it is often useful to distribute the data into classes, and to determine the number of individuals belonging to each class, i.e. to generate a frequency distribution. One important outcome of this exercise is that a mode is produced for a risk. All respondents were invited to rate the degree of significance of risks in accordance with the five-point scale, as defined in the questionnaire. By using Frequency Distributions, the mode for each risk was found, indicating the most likely degree of significance of a risk, with definitions as shown in Table 3.

Produced from an analysis of the data, Figs 3 to 6 show the distribution of responses to the levels of significance of risks in the respective project phases. Pertaining to the pre-investment phase, Fig. 3 illustrates the response rate of each risk with respect to the risk significance. For this phase, the majority of respondents (11) considered that 'Interest rate fluctuation' is a risk with a moderate significance whereas 7 respondents indicated that 'Shortage of investment capital' was insignificant. All of the other risks were of slight significance. Similarly, in the implementation phase, both 'Design deficiency' and 'Time overrun' were found to be highly significant risks whereas 'Counter party', 'Shortage of investment capital' and 'Currency exchange restriction' risks were found to be moderately significant. The remaining types of risks, i.e. 'Inflation fluctuation', 'Interest rate fluctuation', 'Exchange rate

Table 3. Definition of mode with respect to risk significance

Mode	0	1	2	3	4
Significance	Insignificant	Slightly significant	Moderately significant	Highly significant	Extremely significant

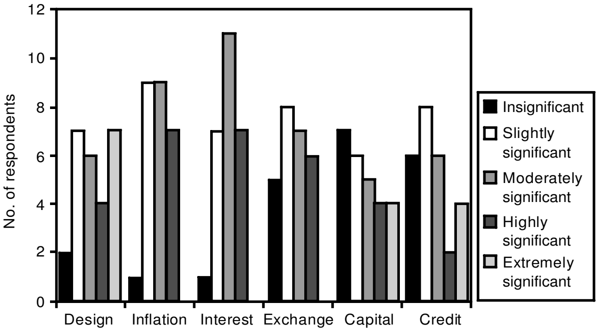

Fig. 3. Distribution of risk significance in the pre-investment phase.

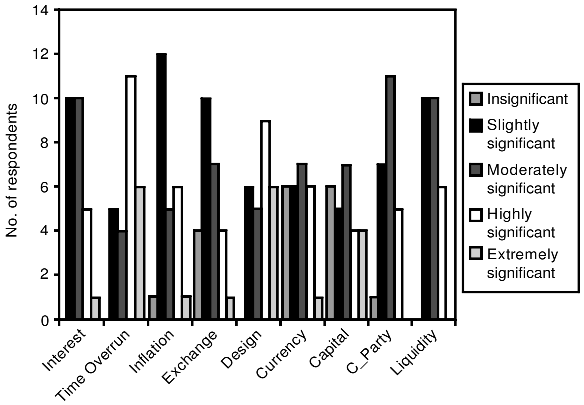

Fig. 4. Distribution of risk significance in the implementation phase.

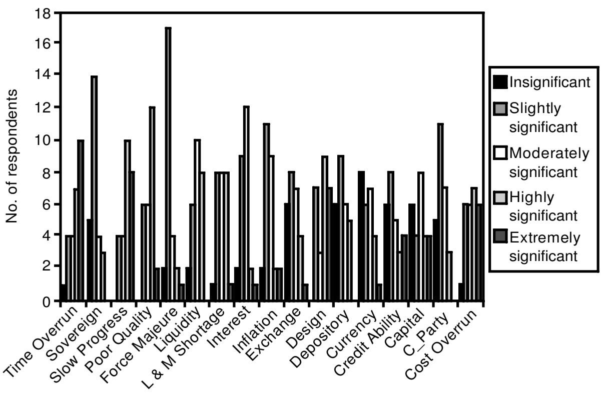

Fig. 5. Distribution of risk significance in the construction phase.

fluctuation' and 'Liquidity' were all slightly significant in this project phase. In the construction phase, it was found that 'Time overrun' tended to be an extremely significant risk. Other risks such as 'Cost overrun', 'Design deficiency', 'Poor quality of works' and 'Slow construction progress' were classified as highly significant.

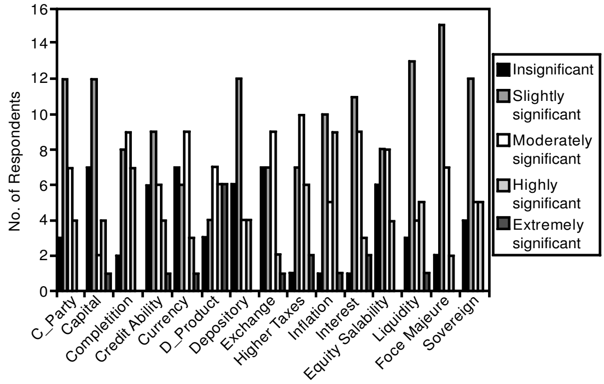

Fig. 6. Distribution of risk significance in the operations phase.

'Shortage of investment capital', 'Interest rate fluctuation' and 'Liquidity' risks were of moderate significance. With regard to the operations phase, 'Competition', 'Currency exchange restriction', 'Defective product/facilities', 'Exchange rate fluctuation' and 'Higher taxes' were found to be moderately significant. All of the other risks were slightly significant. In summary, the significance of each risk is provided in Table 4.

Discriminant function analysis

The SPSS manual (1997) states that Discriminant function analysis is a technique which aims at statistically distinguishing between two or more groups on the basis of quantifiable information on a number of variables. Basically, it combines scores obtained in respect of the variables in such a way as to distinguish between the groups involved; it uses weighted scores on the basis of the importance of each variable. While the *t*-test does a similar thing on a single variable, it is not useful when there is more than one variable. Also, the composite scores built into a Discriminant Function Analysis can be used to classify the people or objects into different groups, given a set of variables which clearly distinguish the groups.

Wilks' lambda λ significance

Wilks' lambda is the proportion of the total variance in the discriminant scores not explained by the differences among groups. It is equal to the ratio of the within-groups sum of squares to the total sum of squares. In a way, the Wilks' lambda and the chi-square work in opposite directions. At

Table 4. The significance of risk variables in the BOT procurement process

Construction phase	Significance of risk variables				
	Extremely significant	Highly significant	Moderately significant	Slightly significant	Insignificant
Pre-investment			• Interest rate fluctuation • Exchange rate	• Design deficiency • Inflation fluctuation capital fluctuation Poor credit ability	• Shortage of investment
Implementation		• Design deficiency • Time overrun	• Counter party • Shortage of investment capital • Currency exchange restriction	• Inflation fluctuation • Interest rate fluctuation • Exchange rate fluctuation • Liquidity	
Construction	• Time overrun	• Cost overrun • Design deficiency • Poor quality of works • Slow construction progress	• Shortage of investment capital • Interest rate fluctuation • Liquidity	• Labour/material shortage • Inflation fluctuation • Exchange rate fluctuation • Poor credit ability • Depository • Sovereign • Force majeure • Counter party	• Currency exchange restriction
Operations			• Competition • Currency exchange restriction • Defective product/facilities • Exchange rate fluctuation • Higher taxes	• Inflation fluctuation • Interest rate fluctuation • Shortage of investment capital • Poor credit ability • Depository • Liquidity • Low equity saleability • Sovereign • Force majeure • Counter party	

each successive function, while the Wilks' lambda increases, the chi-square decreases. When the chi-square is not significant, there is not enough discriminating power left among the variables and the derivation of any more functions is not warranted because such functions do not give any further information needed to discriminate among the groups.

The analysis first defined the group variables by phases and showed that in total, 101 data points were used in the analysis. Canonical discriminant function analysis was then conducted to show the Wilks' lambda and *F*-ratio. If $\lambda = 1$, this implied that the means of the risks between phases were equal. If $\lambda < 1$ and close to zero, this implied that there were significant differences between the means of the risks between phases. From this analysis, a summary of significance was produced, and is shown in Table 5. It may be noted from this table that the risks of 'Shortage of investment capital', 'Exchange rate fluctuation', 'Inflation fluctuation' and 'Interest rate fluctuation' had similar levels of significance between phases as λ tended to 1. On the contrary, 'Cost overrun', 'Competition', 'Defective product/material', 'Higher taxes', 'Labour and material shortage', 'Poor quality of works', 'Slow

Table 5. Significance of Wilks' lambda

Risk variables	Wilks' lambda
Cost overrun	0.2427885
Counter party	0.5576021
Shortage of investment capital	0.9701564
Competition	0.2588840
Poor credit ability	0.7369467
Currency exchange restriction	0.7060903
Defective product/material	0.2974824
Depository	0.5484351
Design deficiency	0.4724449
Exchange rate fluctuation	0.9914832
Higher taxes	0.2373038
Inflation fluctuation	0.9859874
Interest rate fluctuation	0.9865741
Low equity saleability	0.4140342
Labour and material shortage	0.2370892
Liquidity	0.5055598
Force majeure	0.4891228
Poor quality of works	0.1679077
Slow progress of works	0.1490058
Sovereign	0.5031253
Time overrun	0.2426765

progress of works' and 'Time overrun' were those risks having very different degrees of significance between phases, and λ tended to 0.

Classification of risks between project phases

The Fisher's linear discriminant functions were established with the classification function coefficients identified as shown in Table 6. After consolidating the data from Table 6, the following mathematical model was generated to simulate the classification functions between project phases:

$$F_1 = 1.3544332\,\alpha + 0.1462213\,\beta - 0.1401877\,\chi - 0.3984091\,\delta - 0.6102294\,\varepsilon - 0.0613356\,\eta - 0.585457\,\varphi - 2.4427523 \quad (2)$$

$$F_2 = 0.5927039\,\alpha - 0.5652063\,\beta - 0.5458450\,\chi + 2.8628563\,\delta - 2.1545127\,\varepsilon - 5.7564892\,\eta + 7.0166243\,\varphi - 13.7777234 \quad (3)$$

$$F_3 = 0.2052939\,\alpha - 0.4995445\,\beta - 0.5570651\,\chi + 2.6210337\,\delta + 7.1685372\,\varepsilon + 7.5492845\,\eta - 0.8434225\,\varphi - 21.8430361 \quad (4)$$

$$F_4 = 0.8757643\,\alpha + 6.4307827\,\beta + 9.2481120\,\chi + 0.7707563\,\delta - 0.3174600\,\varepsilon - 0.1339954\,\eta - 0.1212211\,\varphi - 19.4484180 \quad (5)$$

where F_1 = Pre-investment phase; F_2 = Implementation phase; F_3 = Construction phase; and F_4 = Operations phase; α = Poor credit ability; β = Defective product; χ = Higher taxes; δ = Liquidity; ε = Poor quality of works; η = Slow progress; and φ = Time overrun.

These classification functions classify the raw data directly i.e. the significance of the risk. For example, if a set of risk significance data is substituted into the above functions (data value from 0 to 4), the function with greatest value will be the phase to which the set of risks belong. That is if $F_1 = 5$, $F_2 = 1$, $F_3 = 4$ and $F_4 = 10$, then this set of risks can be classified as the risks in the operations phase.

Classification of risks by use of the canonical discriminant function

Referring to the canonical discriminant functions coefficients shown in Table 7, Function 1 had the

Table 6. Fisher's linear discriminant function coefficients

Risk variables	Construction phases			
	Pre-investment F_1	Implementation F_2	Construction F_3	Operations F_4
Poor credit ability	1.3544332	−0.5927039	−0.2052939	0.8757643
Defective product	0.1462213	−0.5652063	−0.4995445	6.4307827
Higher taxes	−0.1401877	−0.5458450	−0.5570651	9.2481120
Liquidity	−0.3984091	2.8628563	2.6210337	0.7707563
Poor quality of works	−0.6102294	−2.1545127	7.1685372	−0.3174600
Slow progress of works	−0.613356	−5.7564892	7.5492845	−0.1339954
Time overrun	−0.0585457	7.0166243	−0.8434225	−0.1212211
Constant	−2.4427523	−13.7777234	−21.8430361	−19.4484180

Table 7. Standardized canonical discriminant function coefficients

Risk variables	Function 1 Eigenvalue = 9.9995	Function 2 Eigenvalue = 7.0177	Function 3 Eigenvalue = 2.6848
Poor credit ability	0.15146	0.13709	−0.41156
Defective product	0.50120	0.43749	0.29543
Higher taxes	0.53393	0.46715	0.38964
Liquidity	−0.19108	−0.11170	0.53935
Poor quality of works	−0.44647	0.39877	0.12054
Slow progress	−0.51462	0.73906	−0.15714
Time overrun	0.09432	−0.87841	0.65492

largest eigenvalue of 9.9995 which revealed that this function was more effective in discriminating data.

All of the raw data (data values from 0 to 4) were able to be discriminated by the aforesaid functions. Figure 7 shows these functions graphically. Group 1 referred to the pre-investment phase, group 2 referred to the implementation phase, group 3 referred to the construction phase and group 4 referred to the operations phase. As can be seen from this graph, all four of these phases were easily discriminated. With reference to Function 1, group 4 was in the ranges of −7 to −3 and group 3 was in the range of 2 to 7. With reference to Function 2, group 2 was in the range of −7 to −2 and group 1 was in the range of −2 to 0. Apparently, Function 1 was effective in discriminating the data of groups 3 and 4 whereas groups 1 and 2 were more appropriately discriminated by Function 2.
The above coefficients can be expressed in a mathematical format as follows:

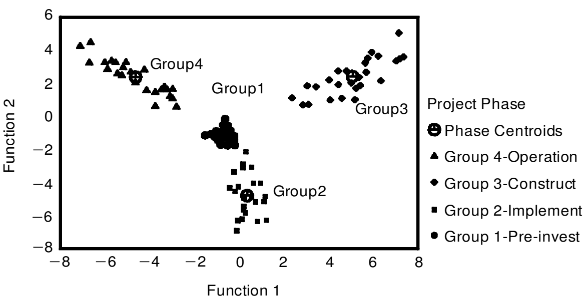

Fig. 7. Canonical discriminant functions for risks in BOT projects.

$$F_1 = 0.15146\,\alpha + 0.50120\,\beta + 0.53393\,\chi - 0.19108\,\delta - 0.44647\,\varepsilon - 0.51462\,\eta - 0.09432\,\varphi \quad (6)$$

$$F_2 = 0.13709\,\alpha + 0.43749\,\beta + 0.46716\,\chi - 0.11170\,\delta + 0.39877\,\varepsilon + 0.73906\,\eta - 0.87841\,\varphi \quad (7)$$

$$F_3 = -0.41156\,\alpha + 0.29543\,\beta + 0.38964\,\chi + 0.53935\,\delta + 0.12054\,\varepsilon - 0.15714\,\eta - 0.65492\,\varphi \quad (8)$$

where F_1 = Pre-investment Phase; F_2 = Implementation Phase; F_3 = Construction Phase; and F_4 = Operations phase, also, α = Poor credit ability; β = Defective product; χ = Higher taxes; δ = Liquidity; ε = Poor quality of works; η = Slow progress; and φ = Time overrun.

The correlation function coefficients between the discriminated risks and canonical discriminant functions are shown in Table 8. It may be observed that each function has its own significant risks that will have the largest effect on the respective function. Finally, the canonical function describes the classification results. It was concluded that 100% of the pre-investment-phase data were correctly predicted. With respect to the implementation phase, 23 sets of data were correctly predicted, but there were two sets of data which fell into the pre-investment phase, implying that there were two types of risks that should be grouped in the pre-investment phase. With regard to the construction phase, 24 sets of data were correctly predicted. However, two sets of data fell into the pre-investment phase and, similarly, these two types of risks should be associated with the pre-investment phase. In the operations phase, 100% of the data were correctly predicted. These classification results are shown in Table 9.

Conclusions

There is no doubt that financial risks critically affect the procurement processes of a BOT project. This paper has investigated the significance of the different types of risks associated with the respective phases of the project procurement process. In addition, the relationships between the risks of different phases have also been studied.

One limitation that has not been addressed in this paper is the significance of risk for different countries. This is because the significance of risk would be variable owing to the culture, and to social and political differences. It is therefore

Table 8. Correlation between discriminated risks and canonical discriminant functions

Risk variables	Function 1	Function 2	Function 3
Slow progress	−0.66075[a]	0.40072	0.28538
Poor quality of works	−0.61549[a]	0.37327	0.26584
Cost overrun	−0.43002[a]	0.11938	0.28512
Higher taxes	0.42917[a]	0.38225	0.35945
Defective product	0.36787[a]	0.32766	0.30811
Design deficiency	−0.11201[a]	0.01142	0.05262
Labour/materials shortage	−0.34110	0.36620[a]	0.00905
Sovereign	0.13235	0.30506[a]	0.26236
Poor credit ability	−0.02846	0.19511[a]	−0.17444
Shortage of investment capital	0.06806	−0.13856[a]	−0.05212
Inflation fluctuation	−0.01079	−0.13289[a]	0.12582
Exchange rate fluctuation	−0.00726	−0.11812[a]	0.02649
Time overrun	−0.41809	−0.23668	0.60407[a]
Liquidity	−0.08055	0.01398	0.58275[a]
Counter party	−0.03951	−0.00676	0.43159[a]
Competition	0.20247	0.20031	0.39740[a]
Depository	0.10084	0.28736	0.29086[a]
Currency exchange restriction	−0.00074	−0.06122	0.21854[a]
Force majeure	0.01943	0.16777	0.20709[a]
Low equity saleability	0.16782	0.16392	0.20577[a]
Interest rate fluctuation	−0.02685	−0.13122	0.20180[a]

[a]Denotes largest effect on the respective function

Table 9. Classification of results

Phases	No. of Case	Predicted Phase Membership			
		Pre-investment	Implementation	Construction	Operations
	25	25	0	0	0
Pre-investment		100%	0%	0%	0%
	25	2	23	0	0
Implementation		8%	92%	0%	0%
	26	2	0	24	0
Construction		7.7%	0%	92.3%	0%
	26	0	0	0	26
Operations		0%	0%	0%	100%

recommended that similar risk significance research be conducted for each country so that a clear picture of the significance of risks in respective countries can be created. Another limitation is the sample size of the research; it would be desirable if more experts in BOT projects were made available so that the analysis results could be more realistic. Notwithstanding, this paper has successfully established a risk significance table showing the significance of risks in each phase of a BOT project, particularly with respect to Hong Kong. Furthermore, a Fisher's linear discriminant function model has been developed for the classification of different types of risks with regard to the different project phases. Moreover, the canonical discriminant functions developed provide a method for discriminating different types of risks.

With the above models developed, risks can then be classified with respect to the BOT project phases. This should allow developers to acquire a better understanding of the nature of risks and should improve the decision regarding investment in a BOT project. With the significance of risks and their correlation in each procurement phase having been identified, it is also suggested that further research be extended to the actual implications of risk significance upon some of the established risk analysis methods. These include probability, Monte Carlo Simulation, Fuzzy Sets, etc. In particular, the conversion of the significance of risks into some kind of 'index' which could be used in risk analysis should be addressed.

One crucial factor that is also worthy of investigation is political risk. Ashley and Bonner (1987) advised that before entering into a BOT project, the country's political situation (e.g. Thailand is risky, Hong Kong is stable) must be recognized and investigated extensively; appropriate action can then be taken to account for this risk.

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Appendix: Questionaires

A typical BOT project can be classified into 5 phases. These 5 phases and the corresponding construction processes are as follows:

Pre-investment	Implementation	Construction	Operation	Transfer
Feasibility study	• Engineering and design • Concession agreement • Project financing	Construction	• Sale of product/toll collection • Operation and maintenance • Loan repayment	Transfer of ownership to government

Please note that the last phase 'Transfer' will not be covered in this research.
Please complete one questionnaire for one project.

Please ✔ as appropriate:

1. Your role is: Government ☐ Sponsor ☐ Contractor ☐
2. Investment party/parties: Government ☐ Sponsor ☐ Contractor ☐
3. Project cost (million USD): ⩽250 ☐ 251–500 ☐ 501–750 ☐ 751–1000 ☐ >1000 ☐
4. Sponsor's equity (%): ⩽15 ☐ 16–30 ☐ 31–45 ☐ 46–60 ☐ 61–75 ☐ >75 ☐
5. Contractor's equity (%): ⩽15 ☐ 16–30 ☐ 31–45 ☐ 46–60 ☐ 61–75 ☐ >75 ☐

Please ✔ as appropriate to indicate the degree of *significance of risks* in the following aspects:

Extremely significant	Highly significant	Moderately significant	Slightly significant	Insignificant
4	3	2	1	0

6.0	*Risks in the pre-investment phase*:	
6.1	Engineering design deficiency	0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐
6.2	Inflation fluctuation	0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐
6.3	Interest rate fluctuation	0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐

6.4	Exchange rate fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
6.5	Shortage of investment capital	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
6.6	Poor credit ability to bank	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.0	*Risks in the implementation phase:*					
7.1	Engineering design deficiency	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.2	Inflation fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.3	Interest rate fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.4	Shortage of investment capital	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.5	Exchange rate fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.6	Currency exchange restriction	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.7	Liquidity (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.8	Counter party (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7.9	Time overrun	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.0	*Risks in the construction phase:*					
8.1	Labour/Material shortage	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.2	Engineering design deficiency	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.3	Slow construction progress	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.4	Cost overrun	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.5	Time overrun	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.6	Poor quality of works	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.7	Inflation fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.8	Interest rate fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.9	Shortage of investment capital	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.10	Exchange rate fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.11	Currency exchange restriction	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.12	Poor credit ability to bank	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.13	Depository (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.14	Liquidity (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.15	Sovereign (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.16	Force majeure	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8.17	Counter party (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.0	*Risks in the operation phase:*					
9.1	Defective product/facilities	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.2	Inflation fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.3	Interest rate fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.4	Shortage of investment capital	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.5	Exchange rate fluctuation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.6	Currency exchange restriction	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.7	Poor credit ability to bank	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.8	Depository (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.9	Liquidity (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.10	Higher taxes	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.11	Low equity saleability	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.12	Sovereign (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.13	Force majeure	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.14	Counter party (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9.15	Competition (see page 4)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

Definition of some uncommon risks:

Counterparty: Two or more parties entered into a contract contains a risk that one counterparty will default on an obligation and not be able to fulfil a commitment when it becomes due.

Depository: The potential for loss where operating accounts or capital are maintained or lodged with an external body.

Liquidity: Any business must control its liquidity such that it can meet its obligations and liabilities as and when they fall due. Liquidity risk exists where cash flow maturities do not match and is typically controlled by a treasury funding unit.

Sovereign: The risk that a government's action may prevent repayment of a debt and/or raising fund from financial institutions.

Competition: The products or facilities in a highly competitive market. For example a new tunnel in an area where many alternatives can be used.