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International Journal of Project Management xxx (2007) xxx–xxx

INTERNATIONAL JOURNAL OF PROJECT MANAGEMENT

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A simulation model for optimizing the concession period of public–private partnerships schemes

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Abstract

Public–private partnerships (PPP) are becoming an increasingly popular option of project delivery. Under the concession-based PPP arrangement, the private partner is responsible for funding the scheme, while their capital investment will be recovered through the operation revenue over the concession period. Therefore, calculating an appropriate investment return over the concession period becomes a very important aspect that influences success of the PPP project, particularly so as the concessionaire may be tempted to increase their toll/tariff should the revenue fall short of their expected. However, due to the difficulties in estimating the long-term uncertainties and wider-risk profiles at the tendering stage, the government would conduct the traditional net present value and payback period analyses to determine the concession period. In this paper, a simulation model which aims to assist the public partner to determine an optimal concession period is proposed. A hypothetical example is worked through to illustrate the concept of the simulation model. The results show that the risks and uncertainties, such as a change in inflation rate, traffic flow and operation cost, could influence the decision on the concession period. With the help of the simulation model, the impact of risk can be taken into account when establishing an ideal concession period.

Keywords: Concession period; Public–private partnership; Simulation; Toll/tariff regime

1. Introduction

There is a growing trend for governments and other clients in the construction industry to place major projects into the private sector [1]. According to Miller and Evje [2], purely public and purely private delivery mechanisms are unreliable, unstable and averse to innovation. A disparity between the desperate needs for social facilities/services and the constricted public spending has given rise to an increasing use of public–private partnerships (PPP) [3]. The PPP approach has been applied to infrastructure [4–6], sports stadia [7,8], hospital [9], prison [10] and maintenance [4,11,12] projects. Many studies have claimed that significant cost saving can be achieved through such an arrangement [9,12–14].

According to Zhang and Kumaraswamy [15], the most popular PPP option is the concession-based type such as build-own-operate-transfer in which the private partner (concessionaire) undertakes to finance, design, construct, operate and maintain the facility during a concession period that is usually determined by their public counterpart at the outset. In return, the concessionaire will recover their capital investment through the operation revenue over the concession period. Establishing an appropriate concession period is important to the success of a PPP project. Being protected by an assured minimum 'revenue stream', the concessionaire is entitled to raise the toll/tariff in case their actual profit falls short of the anticipated return. Projects with a shorter concession period could hence result in a higher toll/tariff regime, and this is obviously not desirable from the users' standpoint.

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doi:10.1016/j.ijproman.2007.05.004

From the government's perspective, granting an excessively lengthy concession period could mean a loss in public interest especially when the facility would reach the peak of its economic life towards the end of the concession period. Therefore, it is necessary for the government to identify an optimum concession period so that it is long enough to warrant an attractive financial return for the concessionaire but yet soon enough for the facility to be handed over to the government for subsequent operation. While common financial management techniques can help project the pay back period (PBP) of the scheme, the risks associated with the prospective incomes and expenditures must be duly considered to reflect the possible changes in market condition and external environment. To shortcut the decision process, decision-makers may rely on the PBP and value-for-money tests to determine the concession period for a PPP project.

With the ability to predict the consequences under different circumstances, simulation can be conducted to unveil the effects of risks on the concession period. Based on the expected rate of return, decision-makers can establish the corresponding concession period distribution based on the simulated costs and revenues of the project. The aim of this paper is to explore the potential of applying the simulation techniques for deducing the optimal concession period which should help balance the interests of both the government and investor. The paper begins by outlining the features of the simulation model. A hypothetical example is then applied to the model to illustrate its operation and performance. The results indicate that the simulation model can result in an optimal concession period which is otherwise difficult to be approximated by merely referring to the PBP of the project.

2. Practice in determining the concession period

Like any other capital investment programs, a PPP project must be financial viable and a scheme would be considered attractive to the concessionaire only if it attains a reasonable return rate. Consequently, a number financial evaluation techniques such as the cost–benefit analysis [16], net present value (NPV), NPV-at-risk [17], public sector comparator [18,19] and so on have been initiated. Using conventional NPV methods the PBP is calculated by discounting the net cash flow of the investment, and an investment is paid back when the NPV is equal to zero. In the absence of any uncertainty in the cash flow estimation, the PBP is an ideal concession period for the scheme, as the concessionaire will gain a desirable financial return (Fig. 1). Therefore, the government would be inclined to count on the PBP to determine the concession period of PPP projects [20].

However, cash flow estimation is overshadowed by risks and uncertainties such as fluctuations in interest rate, inflation, cost and revenue. These issues could have profound effects on PBP prediction [21]. An overly optimistic estimation could mean the return rate expected by the concessionaire may never be realized during the agreed concession period. Merna and Smith [22] advocated that mutually acceptable procedures should exist, under which the conditions in the contract can be renegotiated from time to time. Allowing the concession period to be adjusted according to the changing external environment is however uncommon practice, as it would not just transfer much of the financial risk to the government but could also dissuade the concessionaire from identifying cost saving measures. Excessive renegotiation could also be costly to both sides.

Instead, there are mechanisms in the concession contract to allow the concessionaire to increase the toll/tariff (rather than extending the concession period) if they can provide evidence that their revenue falls short of the anticipated level during the operation stage [23]. Nevertheless, this is contradictory to the government's goal of keeping the toll/tariff within a level that is tolerable to the users. The pressure from the general public could result in lengthy inquiries and negotiations even when a slight increase in toll/tariff is initiated. For instance, the concessionaire of the Hong Kong Eastern Harbor Crossing entered into arbitration with the Hong Kong Government in 1995 when the public partner rejected their toll increase application and it took almost two years for the concessionaire to win the arbitration proceedings.

Many public clients are trying to develop a better toll/tariff adjustment mechanism for their PPP projects. For instance, the toll/tariff can be automatically adjusted according to some occurrences that would have been stip-

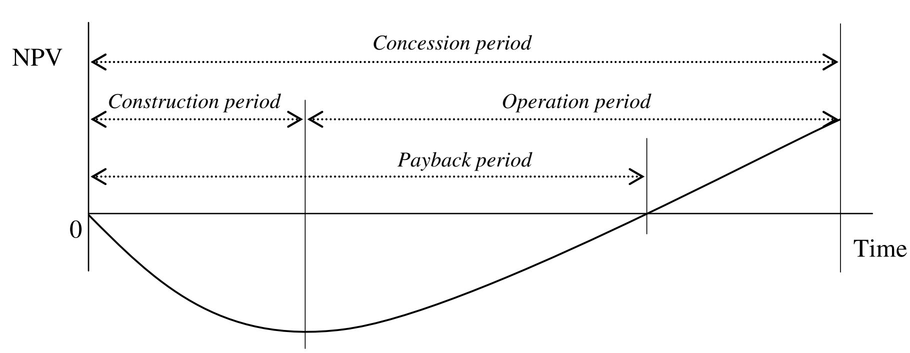

Fig. 1. Relationship between the concession period and NPV.

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ulated by the two sides [15]. However, this kind of mechanism could give rise to an even more frequent increase in the toll/tariff to protect the return rate of the concessionaire. To avoid the financial risks from being transferred to the government or users, an appropriate concession period with due consideration of the effect of risks and uncertainties on the return rate of concessionaire would be indispensable.

3. Simulation model

Many researchers have applied simulation techniques to analyze and depict the effects of risks, and one of the most commonly used approaches is Monte Carlo simulation. While Monte Carlo simulation is commonly known for analyzing the time/cost risks of construction projects [24], it can also be applied to unveil the risks associated with capital investments [25]. A simulation model was developed by Malini [21] in order to determine the financial viability of PPP projects based on different policy parameters, such as concession period and toll rates. In Malini's model, the policy parameters were deterministic input, implying that one can only select a concession period from some finite scenarios. The model also assumed that some macro-economic indicators, such as interest and inflation rates, can be estimated without uncertainty. However, in reality these macro-economic indicators could in turn be major risks for some projects.

Fig. 2 portrays a new simulation model that could cater for the complex implication of various risks associated with PPP projects. In this model, the concession period is an output rather than an input parameter. Since the attainment of a desirable return is the most important consideration, it is sensible to assume that a reasonable toll/tariff regime and an expected internal return rate (IRR) can be established in advance. By inputting the toll/tariff regime and the IRR into the simulation model, the exact concession period in each simulation cycle can be computed according to the simulated cost and revenue. With sufficient numbers of iteration, a frequency distribution curve related to the concession period can be established to guide decision making.

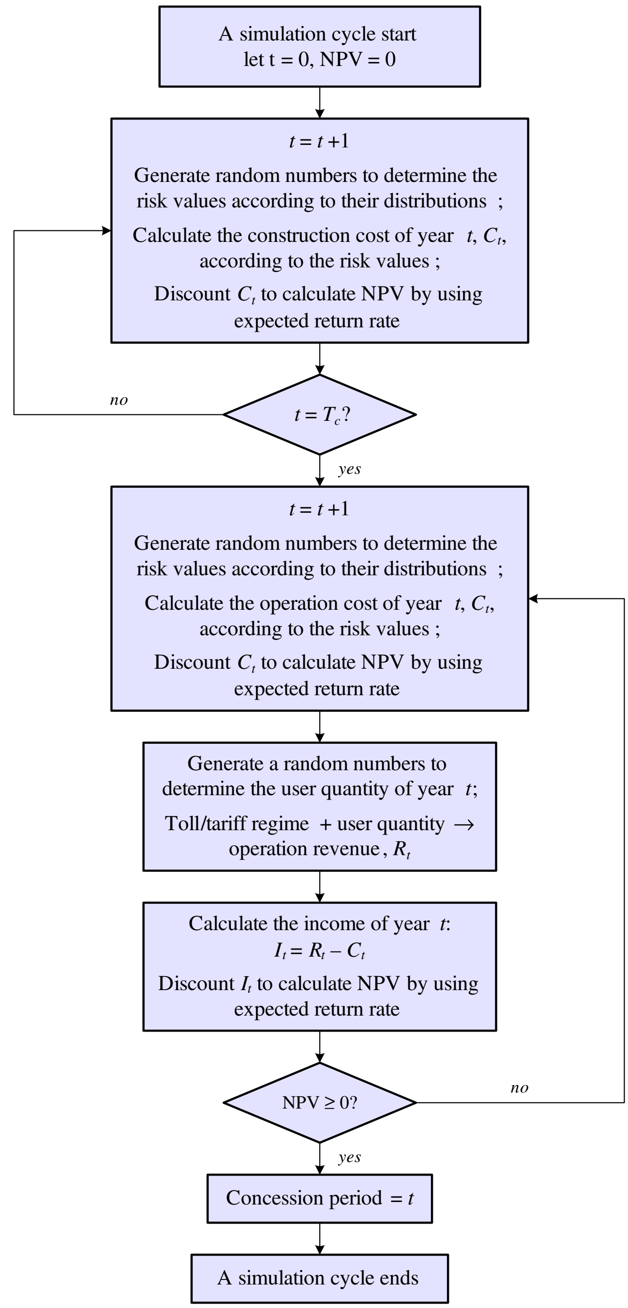

Fig. 2. Simulation flow diagram for determining the concession period.

3.1. Deterministic parameters

3.1.1. Construction period (T_c)

The concession period is composed of the construction and operation periods. Under normal circumstance the time required for completing the construction may not be totally certain, as project delay is a common phenomenon in practice. Despite that, the construction period can be treated as a deterministic input during the simulation process because the concessionaire would make every endeavor to convert the identified risks into opportunities. In a PPP project, the concessionaire would enjoy a longer operation period by shortening the construction period given that the concession period remains the same. Therefore, the input data can simply be the most likely construction period as estimated by the government.

3.1.2. Discount rate

While discount rate is used in NPV analysis to bring the future cash flow into present money terms, the expected IRR is any discount rate that results in a NPV of zero of a series of cashflows. As the return could vary according to the risks and uncertainties associated with the scheme, investors would like to identify the bottom-line return rate for reference. Being the average costs for a company to raise finance through different types of capital such as equity and debt, the weighted average capital cost may be regarded as the minimum return rate for an investment [26]. However, from the investors' perspective they will strive to maximize their profit by increasing the revenue and/or lowering the costs. The maximal return rate can be seen as the targeted return set by a company after considering the strengths, weaknesses, opportunities and threats of the scheme. Once the minimum, expected and maximal return rates are determined, the data can be fed into the simulation model as discount rates for analysis.

3.1.3. Toll/tariff regime

The toll/tariff regime can be based on (i) the statistical data gathered from similar projects; (ii) how much the public is prepared to pay; and (iii) the micro economic forecast [21]. One can set different toll/tariff regimes for different scenarios to facilitate comparison.

3.2. Uncertain parameters

3.2.1. Cost in year 't' (C_t)

The cost should embrace all the expenses incurred in designing, constructing, operating, managing and maintaining the facility. It is considered necessary to (i) identify the major risk factors that could have serious effects on the cost; (ii) establish an empirical or assumed distribution for each of the identified risk factor (in any discrete or continuous form); and (iii) examine the effects of the risk factors on the cost (*cf:* [27]). In the proposed model, the estimated cost could be influenced by many risk factors such as changes in inflation rate. Here, normal distribution is assigned to represent the inflation rates fluctuation. The annum operation and maintenance cost shall follow a uniform distribution in an interval between a pessimistic and an optimistic estimation.

3.2.2. Operation revenue in year 't' (R_t)

The income of a PPP project is determined by the number of users as well as the toll/tariff regime. While the toll/tariff regime is a deterministic parameter, the number of users could vary depending upon the economic growth within the locality, toll/tariff level, availability of alternatives, etc. [21]. In concession-based PPP projects where the user/volume risk is foreseen and borne by the private sectors, the number of users could be projected according to the statistical data of similar facilities. Then normal distribution can be assumed to describe the user/volume risk. Fig. 3 illustrates the annual traffic flow of a concession-based PPP project. From which, the growth rate and stochastic errors can be established through the linear regression method for instance. This data could be the source of basic parameters to estimate the trend in facility usage.

3.2.3. Income in year 't' (I_t)

The annual income in the operation period is the difference between the revenue and cost in the corresponding year.

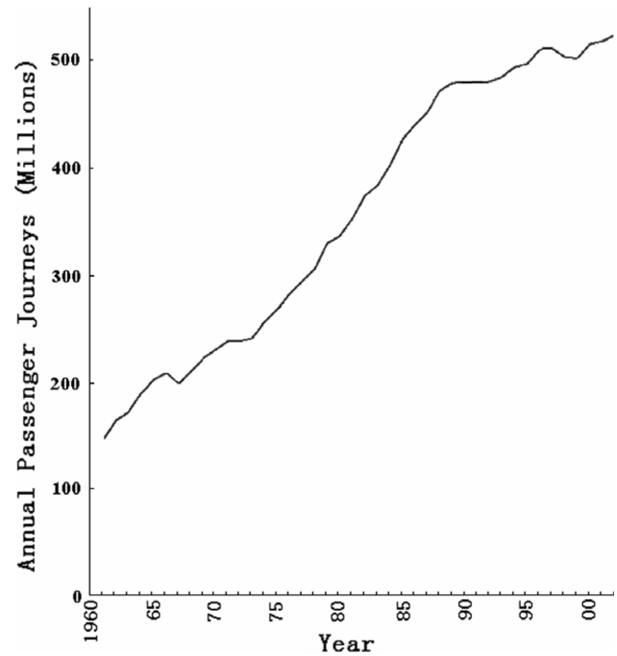

Fig. 3. Annual traffic flow of Crossing Harbor Tunnel in Hong Kong.

4. Simulation output

Having established the deterministic and uncertain parameters, the simulation can proceed by inputting these parameters. By repeating the simulation cycle a number of times, the cumulative frequency distribution of the concession period as shown in Fig. 4 can be generated. The iteration was set at 1000 times as the mean and standard deviation of the output concession periods tends to be close to stable at this iteration rate. Furthermore, the cumulative probability for each possible concession period can also be identified (Table 1).

With the simulation results, the public partner can determine a concession period that would guarantee the concessionaire to gain the anticipated IRR under the proposed toll/tariff regime with a particular confidence level. For

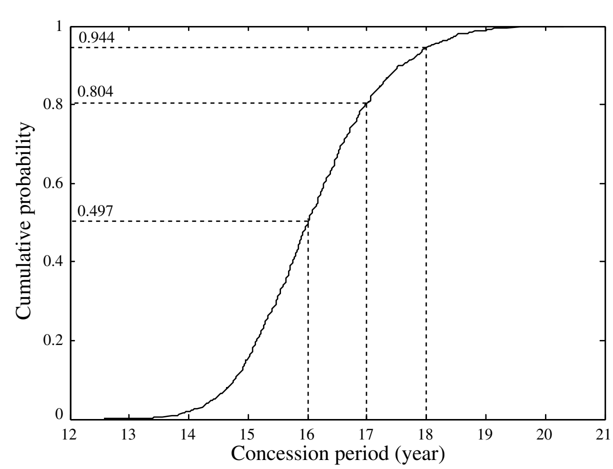

Fig. 4. Simulated frequency distribution of concession period.

Table 1
Cumulative probability of concession period

Year	13	14	15	16	17	18	19	20	21
IRR	0.001	0.020	0.152	0.497	0.804	0.944	0.988	0.999	1.000

example, by referring to Fig. 4 (i.e. the cumulative frequency distribution) and Table 1 (i.e. the cumulative probability), the government might wish to fix the concession period to 17 years, as there is a 80% confidence that the concessionaire can attain the desired return rate. However, in order to ensure a probability of not less than 90% to realize the designated IRR, the concession period must be set at 18 years.

So far, only the expected IRR is considered in the simulation process. However, the public partner can introduce different IRR to reflect the minimum (IRR_{min}), expected ($IRR_{expected}$) and maximum (IRR_{max}) return rates acceptable to the concessionaire. In this hypothetical example, the simulation output would include the cumulative probability of all the three different IRR, and the criteria for determining an appropriate concession period would now be extended to cover the following:

- to ensure the concessionaire would realize the $IRR_{expected}$ with a reasonable probability;
- to ensure the concessionaire would realize the IRR_{min} with a relatively high probability; and
- to ensure the concessionaire would have a relatively low probability in gaining an excessive IRR_{max}.

Besides, different scenarios could be considered during the simulation process. For instance, many series of IRR and toll/tariff regime could be set to facilitate the decision-makers to tradeoff amongst the concession period, toll/tariff regime and IRR.

5. Simulation example with variables

In order to demonstrate how the simulation model works, the following hypothetical road project example is used:

- The construction period is 5 years.
- The construction cost is $100,000,000 (which will be apportioned in accordance with a 5-year construction period at 10%, 20%, 30%, 20% and 20% respectively).
- The annum operation and maintenance cost is 15% of the annum operation revenue.
- The estimated traffic volume and proposed toll regime is as shown in Table 2.
- The discount rate is 14%.
- The concession period is 15 years.

The above data had been fed into the simulation model developed in Matlab™ in which conventional NPV analysis was conducted. The results of simulation reveal that the NPV is $8,038,600 while the PBP is 13.42 years. The relationship between the NPV and concession period is shown in Fig. 5. The initial analysis shows that this scheme is viable (NPV > 0) and the concessionaire can recover their investment before the end of the concession period (PBP < 15).

Table 2
Estimated traffic volume and proposed toll regime

Vehicle type	Estimated number of vehicles (million)	Estimated annual growth rate (%)	Basic toll rate per trip ($)
Cars/vans	0.47	5	10
Buses	0.51	4	20
Trucks	0.26	5	20
Motorbikes	3.71	5	2

5.1. Incorporating risk factors in the simulation process

Assuming that the following are the major risk factors that could affect the cash flow of the above hypothetical example:

- Inflation rate – the rate of change follows a normal distribution with mean and standard deviation equivalent to 2.5% and 2% respectively.
- Traffic flow – the estimated average annual traffic volume follows a normal distribution with standard deviation equal to 20% of the first year's traffic volume.
- Operation cost – the annum operation and maintenance costs follow a uniform distribution in an interval $[0.13, 0.17]$.

In this project, the minimal, expected and maximal IRR that the concessionaire would accept are set as 0.13, 0.14 and 0.15 respectively, and these three IRR values become the discount rates for the simulation. By running the simulation procedure a thousand times, the cumulative frequency distribution (Fig. 6) and cumulative probability (Table 3) are derived.

From Table 3, it is apparent that the cumulative probabilities of the IRR_{min}, $IRR_{expected}$ and IRR_{max} in the 15th year are 0.551, 0.149 and 0.012 respectively (see column 3

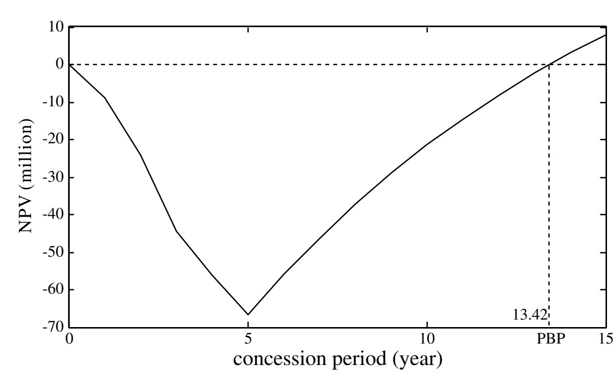

Fig. 5. Determining concession period according to payback period.

of Table 3). The results illustrate that the initial decision of fixing the concession period to 15 years is indeed rather risky to the concessionaire, as such a period can only just ensure the expected IRR ($IRR_{expected} = 14\%$) be realized at a probability of 14.9%. In other words, there is 85.1% possibility that the IRR will not reach the expected level. The minimal IRR that the concessionaire would accept ($IRR_{min} = 13\%$) is realized at a probability of 55.1%. Therefore, the scheme is unlikely to be accepted by the concessionaire, and it will be difficult for the two sides to arrive at an agreement based on this concession period.

According to the criteria set for determining the concession period, the probabilities of realizing the IRR_{min}, $IRR_{expected}$ and IRR_{max} should be high, reasonable and low respectively. Therefore, the decision-makers would favor the extension of the concession period to 16 years, as the cumulative probability of realizing the three different IRR in 16 years is 0.878, 0.48 and 0.094 respectively (refer to the dotted lines in Fig. 6 and bold in Table 3). Therefore, the concessionaire can gain the minimum IRR ($IRR_{min} = 13\%$) with a probability of 87.8%; the expected IRR ($IRR_{expected} = 14\%$) with a probability 48%; and an extremely low possibility (i.e. 9.4%) of gaining the maximum IRR ($IRR_{max} = 15\%$). A concession period of 16 years is, therefore, less risky to the concessionaire when compared with the initial decision of 15 years.

The simulation should continue by entering another series of IRR values into the model to generate the "what-if" scenarios. For instance, the public client could mimic the negotiation process by assuming that the concessionaire is prepared to lower the IRR_{min} and $IRR_{expected}$ to 0.125 and 0.135 respectively with the IRR_{max} remains unchanged at 0.15 after negotiation. Fig. 7 shows the simulation results and it is apparent that the probability of attaining the IRR_{min} and $IRR_{expected}$ of 0.125 and 0.135 in 16 years is higher than that of the preceding scenario. Therefore, the public client may decide to maintain the concession period of 16 years should they satisfy that the identified risks are very likely to occur.

However, in order to strike a balance between the interests of the government and the concessionaire, the concession period may be set at 15.5 years as the cumulative probability of realizing the three different IRR in 15.5 years is 0.901, 0.533 and 0.052 respectively (refer to the dotted lines in Fig. 7) which is comparable to the previous scenario.

The decision-makers might further estimate the impact brought by different toll regimes as might be proposed by another investor to the concession period. Table 4 shows the toll regime which is 20% higher than the preceding scenario while the cumulative probability curves are illustrated in Fig. 8. According to the simulation output, the

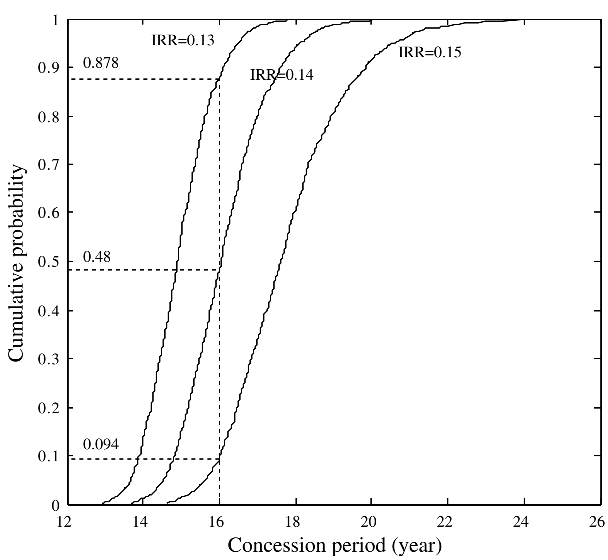

Fig. 6. Cumulative probability curves for the base scenario.

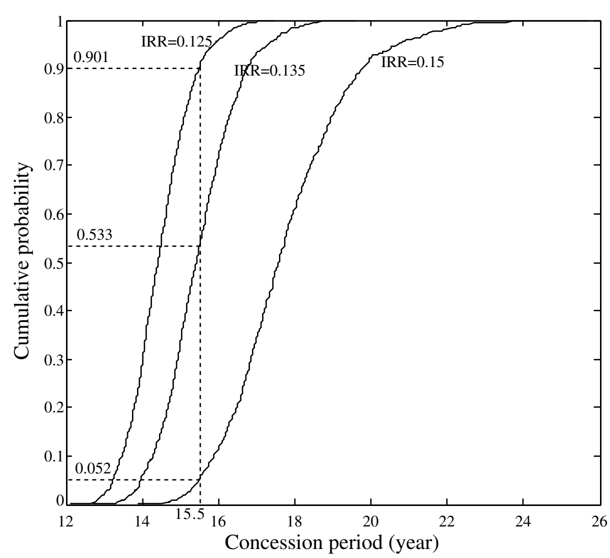

Fig. 7. Cumulative probability curves for reduced IRR_{min} and $IRR_{expected}$.

Table 3
Cumulative probability of concession period to realize different IRR

IRR	Year													
	13	14	15	16	17	18	19	20	21	22	23	24	25	26
IRR_{min}	0.004	0.129	0.551	**0.878**	0.982	0.998	1	1	1	1	1	1	1	1
$IRR_{expected}$	0	0.013	0.149	**0.480**	0.798	0.941	0.986	0.996	1	1	1	1	1	1
IRR_{max}	0	0	0.012	**0.094**	0.338	0.605	0.804	0.914	0.964	0.984	0.994	0.998	0.999	1

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Table 4
A 20% increase in toll regime

Vehicle type	Basic toll rate per trip ($)
Cars/vans	12
Buses	24
Trucks	24
Motorbikes	2.4

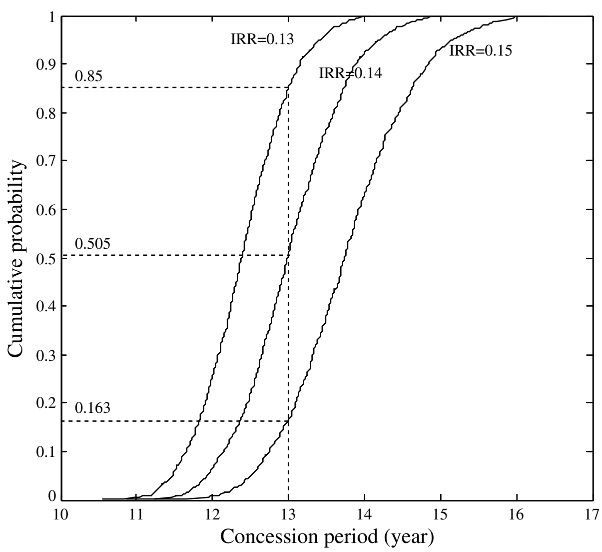

Fig. 8. Cumulative probability curves for a higher toll regime.

public client may allow 13 years as the concession period for this scenario. The cumulative probability of realizing the three different IRR in 13 years is 0.85, 0.505 and 0.163 respectively (refer to the dotted line in Fig. 8). Comparing the results with the initial scenario, one can easily tell that the concession period is very sensitive to the toll regime as the concession period can be shortened by 3 years if the toll regime is increased by 20%.

6. Conclusions

PPP are becoming increasingly common and are a means of providing infrastructure without directly impacting upon a country's public sector. In this paper, a simulation model for determining an appropriate concession period has been developed. The model can incorporate the complex impact of many different risks that could affect a PPP project. A list of deterministic and uncertain parameters which are considered essential for simulating the concession period is outlined. The deterministic parameters include the construction period (T_c), discount rate and toll/tariff regime. In contrast, the cost (C_t), operation income (I_t) and revenue (R_t) are considered as uncertain parameters in the simulation process.

The simulation process has been illustrated through a hypothetical example. The proposed simulation model could assist the decision-makers to come up with a concession period for a PPP project that is beneficial to both sides; i.e. (i) to ensure the concessionaire could gain a reasonable rather than an excessive return, and (ii) to allow the public client to reclaim the facility at an appropriate time. The results of simulation show that by considering the minimum, expected and maximum IRR, a concession period that is less risky to the concessionaire can be identified. Furthermore, the simulation model also allows the decision-makers to establish the sensitivity of some parameters (e.g. toll/tariff regime, IRR, etc.) to the concession period and thereby providing them with a basis for negotiation.

While the proposed simulation model could provide users with useful information for establishing an optimal concession period for a PPP project, further improvement may be needed to make the simulation process more practical. For instance, it may not be easy for decision-makers to accurately predict the uncertain parameters and the risk attitude of the concessionaire. Further research shall be carried out using the proposed simulation model to examine the impact of other risk factors. Besides, as it is not uncommon for appraisers to employ qualitative criteria and linguistic variables during the decision-making process, combining the quantitative results deduced from the simulation model with the fuzzy sets theory is considered to be a way forward for comprehensive proposal evaluation.

Acknowledgements

The authors acknowledge The University of Hong Kong for their financial support through the CRCG Seed Funding for Basic Research (Grant No.: 10206791) and the Internal Award for the Chinese Academy of Sciences Award (Grant No.: 10300122).

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