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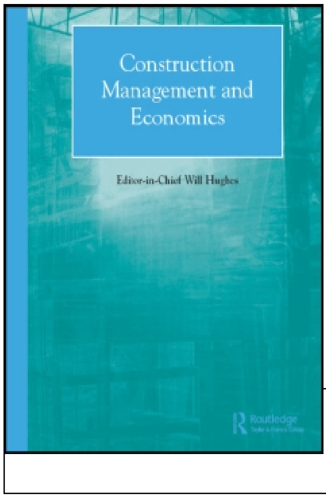

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The effect of concession period design on completion risk management of BOT projects

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The effect of concession period design on completion risk management of BOT projects

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The design of concession period for build–operate–transfer (BOT) projects is crucial to financial viability and completion risk management. A systematic analysis shows that concession period design involves the design of concession period structure, the determination of the concession period length and incentive schemes. The concession period may have a single-period structure or a two-period structure, its length may be fixed or variable, and it may be combined with incentive schemes. Different designs reflect different risk control strategies for completion time overruns. The single-period concession structure requires the project company to assume completion risk, while the two-period concession structure could, to some extent, reduce the completion risk exposure to the project company, depending on the incentive schemes. Through Monte Carlo simulation, this paper evaluates the mean net present value (NPV), variance and NPV-at-risk of different concession period structures so that both the government and the concessionaires can understand their risk exposure and rewards. The paper then analyses the influence of project characteristics on concession period design to evaluate the feasibility of the design. It is concluded that a well-designed concession period structure can create a 'win–win' solution for both project promoter and the host government.

Keywords: Concession period structure, incentive scheme, privately financed infrastructure, BOT, completion risk management, simulation

Introduction

Over the past two decades, a great number of infrastructure projects have been developed under concession contracts. According to the ninth annual survey conducted by Public Works Financing (2000), over 1370 infrastructure concessions, with estimated capital costs of over $US575 billion, have been proposed, awarded or completed under various forms of public–private partnership in over 100 countries around the world since 1985. At the same time, a considerable number of studies on privately financed infrastructure projects have been presented in seminars, conferences and journals, which cover a wide range of topics from project evaluation, risk management and concession design to regulation. Among them, concession period design is an interesting topic of concern to both the public and private sectors, and closely related to project participants' financial returns and completion risk management.

This paper systematically explores the types of concession structures for BOT projects (build–operate–transfer – a type of privately financed infrastructure project) and evaluates the effectiveness of different concession period structures on financial return and completion risk management through mathematical analyses and computer simulations. Finally, the paper recommends possible concession period structures for four categories of privately financed projects in the hope of providing some insight into creating a 'win–win' concession period design for project promoters and host governments.

The design of concession period

The design of concession period involves the design of period structure, the determination of period length and incentive schemes.

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Structures of concession period

The development of a privately financed infrastructure project goes through three phases, namely the pre-development phase, the construction phase and the operation phase. The pre-development phase ends with the award of a concession contract. Only the construction and operation phases are included in the concession period. Therefore, there are two possible period structures: (1) the single-period concession, which defines a concession period beginning from awarding the concession agreement to transferring the project back to the government; and (2) the two-period concession, which defines a construction period plus an operation period. The former combines the construction phase and operation phase together, whereas the latter separates the operation period from the construction period. Thus, the period structure of concession is to address the relationship between the construction period and the operation period in order to manage time-overrun risk in project construction.

The length of concession period

Each concession has its duration, which may be fixed or variable. The choice depends on various risk factors such as completion time, product prices and market demands. Usually, the concession has a fixed period, in which risk factors are managed through tariff design supplemented by other measures. Sometimes, the concession has a variable period, which may be extended if the specified risk factors are worse than expected or shortened if they are better than expected. For example, in order to deal with demand risk, the concession period can be varied according to the market demand. If the market demand is lower than expected, the concession period will be extended to allow the concessionaire to earn a reasonable return, and vice versa. Based on this concept, Engle *et al.* (1998) suggested the least-present-value of revenue method to determine the concession period of toll roads so that the franchise length is adjusted endogenously to demand realization. The Dartford bridge is an example, in which rises in toll charges are permitted no more than once a year and are pegged to the rate of inflation. The maximum period is set at 20 years, but the bridge and tunnels will be handed back to the Government as soon as the debt charges and costs have been recovered (Walker and Smith, 1995). As a result, the single-period structures may have a fixed term or a variable term, and the construction period and the operation period in the two-period structure may each have a fixed term or a variable term.

The length of concession period is mainly related to the recovery of investment and return required by the concessionaires. The general principle of determining the concession-period length is that the concession period should be long enough to allow the concessionaire to recoup investment costs and earn reasonable profits within that period (Smith, 1995). Since it is closely related to tariff design, the determination of period length was excluded from the scope of the paper. If the two-period concession structure is adopted, the contracted completion time is determined by both the contracting parties through bidding and/or negotiation by referring to the mean completion time or the most likely completion time of similar projects. It can be any time other than the mean completion time or the most likely completion time, as long as both the parties agree. It is reasonable to assume the most likely completion time as the contracted completion time for the purpose of analysis in this paper.

Incentive schemes

Whether a project is completed on time largely depends on the commitment of participants if other things are equal. The more resources and effort the participants commit to a project, the higher likelihood the project will be completed ahead of the schedule. In order to reduce the possibility of time overruns, incentive schemes are usually introduced: bonuses to motivate early completions and penalties to deter delay. That is, if the project is completed ahead of schedule, the project company will be rewarded a bonus; if behind schedule, a delay penalty will apply (note that incentive schemes may also be introduced to stimulate contractors to improve their performance in the operation period). Therefore, it is reasonable to assume the incentive scheme is a function of completion time, t, and other various control factors, $\lambda_1, \lambda_2, \ldots \lambda_m$, denoted by $B(t, \lambda_1, \lambda_2, \ldots \lambda_m)$.

The incentive schemes can be designed in several ways. One approach is to prepare a fund for the purpose of awarding bonuses. An alternative incentive scheme is to share the gains resulting from early completion and bear the losses resulting from completion delay between the principal and the project company. That is, the early completion bonus is the percentage (λ_1) of the earnings generating in the period ahead of the scheduled completion time. And the penalty may be the percentage (λ_2) of the losses resulting from the period behind the scheduled completion time. Thus, the incentive scheme can be presented by:

$$B(t, \lambda_1, \lambda_2, R) = \begin{matrix} \lambda_1 R(T_s - t) & (0 \le t < T_s) \\ \lambda_2 R(T_s - t) & (T_s \le t < \infty) \end{matrix} \qquad (1)$$

where T_s is the scheduled completion time and R is the net income designed to be generated from the project per unit time (e.g. week or month).

To further control time-overrun risk, a ceiling of bonus and penalty may be introduced, that is, bonuses

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shall not exceed the net income earned in the possible earliest completion time T_e, and penalties shall not exceed the lost income in the allowed latest completion time T_l. Eq. 1 is revised as the following formula:

$$B(t, \lambda_1, \lambda_2, R) = \begin{cases} \lambda_1 R(T_s - T_e) & (0 \le t < T_e) \\ \lambda_1 R(T_s - t) & (T_e \le t < T_s) \\ \lambda_2 R(T_s - t) & (T_s \le t < T_l) \\ \lambda_2 R(T_s - T_l) & (T_l \le t < \infty) \end{cases} \quad (2)$$

Types of concession period design

The logical categories of concession period design are three-dimensional in the sense that the period structure, the period length and the incentives can be combined together. The combination forms eight cells, each of which represents a type of concession period design (Figure 1). Since the paper focuses on managing completion time risk, the emphasis will be placed on the following four types of concession period designs:

(1) fixed-term, single-period structures without incentive schemes (note that 'no incentive schemes' means that the structure has no exogenous incentives; it does not mean that the structure itself has no built-in incentives, such as revenue gains and losses);
(2) fixed-term, single-period structures with incentive schemes;
(3) two-period structures without incentive schemes with a fixed operation period; and
(4) two-period structures with incentive schemes with a fixed operation period.

Since incentive schemes may vary from project to project, there are many varieties for the single-period structure with incentive schemes and the two-period structure with incentive schemes (note that, for convenience, they are referred to without the word 'fixed').

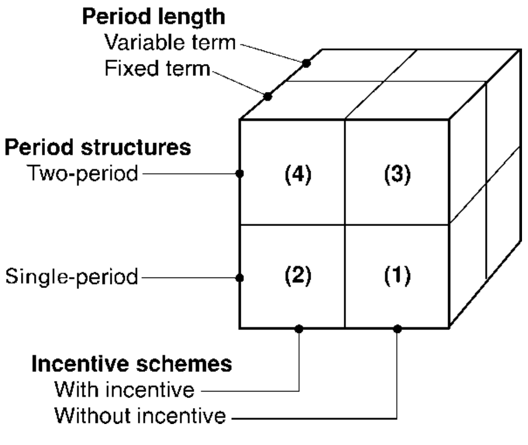

Figure 1 Type of concession period design

Concession period design and financial viability

To choose an appropriate concession period design for a given project, understanding the effect of period structure and incentive scheme on the financial viability of the project is necessary.

The characteristics of completion time

Due to various endogenous and exogenous factors, there is a possibility that the actual completion time may be earlier or later than the scheduled construction time. By recognizing the randomness of completion time, this possibility can be described by a probability density function $f(t)$ if it is viewed as a continuous random variable or $p(t)$ if it is viewed as a discrete random variable.

Completion time distributions are usually left-truncated at 0 and right-skewed because the construction of a project needs a certain period of time (time is always greater than 0) and may be prolonged infinitely (the project is abandoned). The characteristic of completion time may be described by various probability distributions. Among them the beta distribution achieved a certain prominence. According to Bratley *et al.* (1983), the assumption that activity times are approximately beta distributed is at best a convenient one, not the literal truth. However, Fente *et al.* (2000) claimed that the beta distribution is ideally suited for the description of subjective time estimates of activity duration because of its extreme flexibility. As Mooney (1997) described, the beta distribution is a very flexible distribution with its probability density functions ranging from highly right-skewed, to uniform, to approaching normality, to highly left-skewed, and even to bimodal distributions. A change in its parameters will fundamentally alter the properties of the distribution. Therefore, the estimation of parameters is very important because there are significant errors if the parameters are assigned wrong values. According to Weiler (1965), errors resulting from mismatched distribution type are likely to be small compared with the errors caused by wrong values of parameters.

The actual completion time to a large extent depends on the performance of contractors. An appropriate incentive scheme would stimulate contractors to improve their performance. In turn, the improvement in performance would increase the likelihood of completion on schedule. As a result, the completion time has a new probability distribution, which is further skewed to the left and has a smaller variance. In fact, the actual distribution for a given project may be too complicated to be described by a single theoretical probability distribution function. In reality, construction contractors may have

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their own accurate distribution curves, but more often than not, they just have (a) the minimum completion time, (b) the most likely completion time, and (c) the maximum completion time, based on their past experiences. In this case, the BetaPERT(a, b, c) distribution, a version of beta distribution that uses the same assumption about the mean as PERT networks, may be the best choice.

Concession period structures and financial viability

The financial viability of a privately financed infrastructure project largely depends on the length of operation period. In a single-period concession structure, the operation period depends upon the completion of the project (Figure 2). It transfers the completion time risk to the project company. The project company will enjoy the gain generated from earlier operation if the project is completed ahead of the schedule, but bears the loss of revenues resulting from delayed operation if the project is completed behind schedule (Figure 2a). This built-in incentive would stimulate contractors to perform better. If a project is urgently needed, exogenous incentive schemes may be introduced: the project company may be awarded extra bonuses for early completion besides revenue gains and may have to pay delay penalties if the project is completed behind schedule (Figure 2b).

In the two-period concession structures, the operation period is fixed (note that a variable operation period may be used for other reasons, but this has not been considered in this paper) and independent from the construction period (Figure 3). From Figure 3a it can be seen that the time-overrun risk is transferred to the government. In this case, the project company will have a fixed operation period regardless of actual completion time. In contrast, Figure 3b shows that there is an extra operation period if the project is completed ahead of the schedule, in which the operating incomes generated will be shared between the government and the project company, depending on the design of incentive schemes.

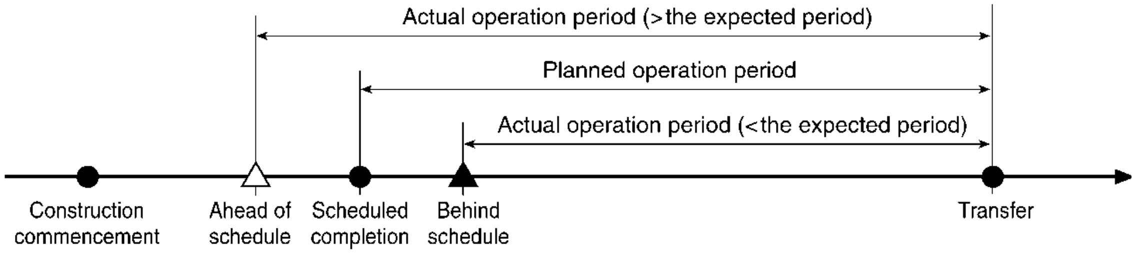
Incentive schemes and financial viability

As mentioned above, incentive scheme is a function of completion time and other factors. If the other factors, such as the percentages (λ_1 and λ_2) and the net income generated in a unit time (R), are independent from completion time, the bonus (penalty) is a linear function of completion time. By recognizing the randomness of completion time, the effect of incentive schemes on financial viability will be measured by the expected bonus (penalty), which is the weighted average of possible bonuses and penalties (weighted by their probabilities). That is, the expected bonus $E[B(t)]$ can be given by Eq. 3 if completion time has a probability density function $f(t)$ or by Eq. 4 if completion time has a probability mass function $p(t)$.

$$E[B(t)] = \int_0^\infty B(t)f(t)dt \tag{3}$$

$$E[B(t)] = \sum_{\text{all } t_i} B(t_i)p(t_i) \tag{4}$$

(a) Single-period concession structure without incentive scheme



(b) Single-period concession structure with incentive scheme

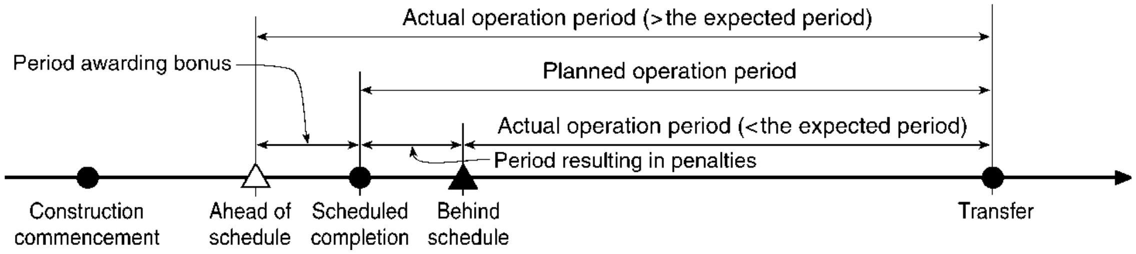


Figure 2 Single-period concession structures and operation periods: (a) without incentive scheme; (b) with incentive scheme

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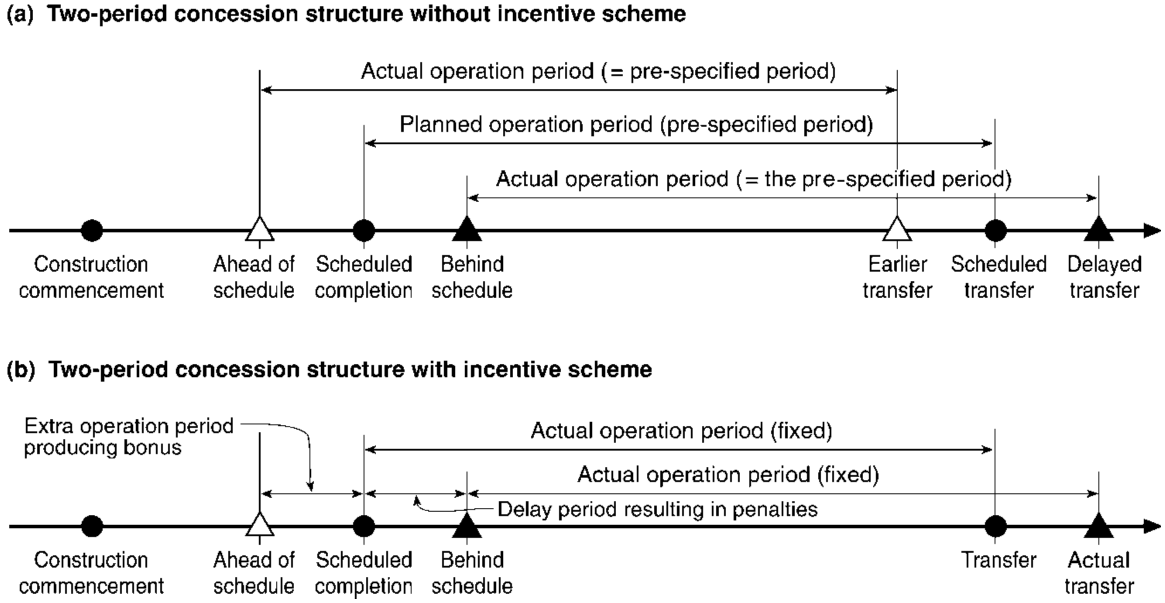

Figure 3 Two-period concession structures and operation periods: (a) without incentive scheme; (b) with incentive scheme

When completion time probability distribution is known, the expected bonus can be obtained from Eqs 3 or 4. For example, if the completion time is normally distributed as $N(T_s, \sigma^2)$ and left truncated at 0, and no ceiling is put on both early completion bonus and delay penalty, the expected bonus (or penalty) can be obtained from Eqs 1 and 3 as follows:

$$E[B(t)] = \frac{R\sigma}{\sqrt{2\pi}}[\lambda_1 - \lambda_2 - \lambda_1 e^{-T_s^2/2\sigma^2}] \quad (5)$$

When $\lambda_1 = \lambda_2$, the expected bonus is:

$$E[B(t)] = -\frac{R\sigma}{\sqrt{2\pi}}\lambda_1 e^{-T_s^2/2\sigma^2} \quad (6)$$

From the above equations, it can be seen that the effect of an incentive scheme on project cash flows depends on the estimation of construction time, other things being equal. For a given project, the longer the scheduled completion time (T_s), the greater the expected bonus would be when $\lambda_1 > \lambda_2/(1 - e^{-T_s^2/2\sigma^2})$, or the less the penalty would be when $\lambda_2 > (1 - e^{-T_s^2/2\sigma^2})\lambda_1$. It is because there is a higher likelihood of completing the project earlier. Another noticeable effect is that the larger the standard deviation (σ), the greater the expected bonus if $\lambda_1 > \lambda_2$ and, conversely, the greater the expected penalty if $\lambda_2 > \lambda_1$. The larger standard deviation means that there is more uncertainty in completion time, which leads to the possibility of earning a higher bonus or paying a bigger penalty.

The formula also indicates that the larger the percentage of bonus (λ_1), the greater the expected bonus will be; and that the larger the percentage of penalty (λ_2), the greater the possible penalty will be. If the percentages of bonus and penalty are equal, the formula shows that there will be a negative expected bonus (i.e. penalty). This results from the fact that any project cannot be completed earlier than its commencement (completion time < 0), but it may be delayed indefinitely. That is why the percentage of the penalty is, in practice, usually smaller than that of the bonus. By recognizing the fact that the project company will experience the loss of revenue and increase in debt interest charges if the project is completed behind schedule, the percentage of penalty (λ_2) is usually much smaller than the percentage of bonus (λ_1). For example, in the Shajiao B power project, the Chinese government awarded all the net income generated in a period ahead of the scheduled operation date to Hopewell Holding Limited as an early completion bonus but required no penalty for completion delay, that is, $\lambda_1 = 1$ and $\lambda_2 = 0$. Both λ_1 and λ_2 are usually determined through negotiations between the government and the project company. How to optimize λ_1 and λ_2 is excluded from the scope of this paper.

Effectiveness of different concession period designs

As the complexity of distributions increases, Eqs 3 and 4 become more intractable. According to Shannon (1976, cited by Monroe, 1985), simulation would be suitable when analytical methods are theoretically available but the mathematical procedures are so complex and arduous that simulation provides a simpler method of solution.

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Table 1 Key contractual data of the Laibin B power project in China

	Key contract data
Project size	Capacity: 2 × 360 MW (gross); estimated cost: $US616 million
Concession period	18 years, including 36 months of construction period (single-period structure)
Debt/equity ratio	75%:25% (debt:equity)
Debt finance	$US300 million of French export credit and $US190 million of commercial loan
Reference foreign exchange rate	$US1.00 = RMB8.332
Power purchase	Guaranteed power purchase of 3500 million kWh per year (over 60% of the designed rated capacity)
Tariff structure	Total tariff = Operating tariff for minimum net electrical output + Operating tariff for additional net electrical output + Fuel tariff where: Operating tariff for minimum net electrical output = Floating portion of operating tariff + Fixed portion of operating tariff. Fixed portion of operating tariff will increase from RMB0.2824 kWh^{-1} in the first operation year to RMB0.3708 kWh^{-1} in the last year of concession, as established in the Power Purchase Agreement.
Tariff adjustment (indexed to foreign exchange rate)	Floating portion of operating tariff = (Operating tariff factor) × (Exchange rate factor) where: Operating tariff factor will increase from RMB0.2824 kWh^{-1} in the first operation year to RMB0.3708 kWh^{-1} in the last year of concession, as established in the Power Purchase Agreement.
Tariff adjustment (adjusted to fuel)	Fuel tariff = 21110 × (Base coal energy price) × (Fuel tariff factor for coal) + (Base oil price) × (Fuel tariff factor for oil)

In this study, the Laibin B power project in China was used as the object to simulate the effectiveness of different concession period designs on the net present value (NPV). The base-case data of the Laibin B project are shown in Table 1. For the purpose of comparison, assume that the most likely completion time is the scheduled completion time and assume that there are different minimum and maximum completion times so as to form three probability distributions, namely BetaPERT(1.5, 3, 4), BetaPERT(2.5, 3, 3.7), and BetaPERT(1.5, 3, 6). It is worth noting that, although this study uses a BOT power project to compare the effect of different concession period designs, the analyses can be extended to other types of project as long as they involve a construction period and an operation period.

The output of simulations was the cumulative distribution of NPV. Besides the mean value and the variance, the results were also analysed by using the NPV-at-risk method developed by Ye and Tiong (2000a), which is defined as a particular NPV that is generated from a project at some specific confidence level. According to the method, the NPV-at-risk with a 95% confidence level was used as one of the indicators of the concession period design performance.

Simulation scenarios

The concession period of the Laibin B power project is 18 years, including a three-year construction period, i.e. a single-period without incentives. To demonstrate the effect of concession period structures on NPV, six hypothetical varieties of concession period structure are created. Together with the original concession period design, there are five concession period designs: (1) single-period without incentives; (2) two-period without incentives; (3) single-period with delay penalty ($\lambda_2 = 0.3$); (4) two-period with bonus and penalty ($\lambda_1 = 1$ and $\lambda_2 = 0.3$); and (5) two-period with early bonus ($\lambda_1 = 1$).

Simulation results and analyses

Table 2 summarizes the results of the simulations. Based on the table, the effectiveness of each concession period can be evaluated through comparing their mean NPV, the variance and the value of NPV-at-risk design under the three completion time distributions.

The impact of uncertainty of completion time

From Table 2, it can be seen that the mean NPV of the single-period without incentives decreases from $US89.88 million under BetaPERT(1.5, 3, 4) to $US67.86 million under BetaPERT(1.5, 3, 6), and the mean NPV of the two-period structure without incentives also decreases from $US86.9 million under BetaPERT (1.5, 3, 4) to $US69.38 million under BetaPERT(1.5, 3, 6). The mean NPV of the other concession period designs decrease to some extent when the completion time distributions change from BetaPERT(1.5, 3, 4) to

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Table 2 NPV-at-risk and mean NPV of different concession period designs for Laibin B power project

Concession period structure	Incentive coefficient		Completion time distribution								
			BetaPERT(1.5, 3, 4)			BetaPERT(2.5, 3, 3.7)			BetaPERT(1.5, 3, 6)		
	λ_1	λ_2	Mean	Variance	NPV-at-risk	Mean	Variance	NPV-at-risk	Mean	Variance	NPV-at-risk
Single-period without incentives	–	–	89.88	1093	31.77	80.60	104	60.00	67.86	3268	−34.82
Two-period without incentives	–	–	86.90	692	39.55	80.00	54	64.20	69.38	2061	−13.70
Single-period with delay penalty	–	0.3	83.72	1672	4.09	76.12	244	43.03	29.55	12 637	−207.96
Two-period with bonus and penalty	1	0.3	85.23	1498	11.67	77.05	201	47.25	35.29	11 049	−186.60
Two-period with early bonus	1	–	91.39	969	39.35	81.53	79	64.20	73.54	2553	−13.70

BetaPERT(1.5, 3, 6). Moreover, the single-period with delay penalty is very sensitive to the possibility of delay: its mean NPV is reduced by more than half when the mean completion increases by 8%. Similarly, the two-period with bonus and penalty is also sensitive to the possibility of delay. The two-period with bonus still has a good financial performance when completion time distribution has a delay tendency. It can be concluded that, for a given concession period design, its mean NPV will decrease as the possibility of delay increases (the mean completion time becomes greater and greater). The reason is that delay in completion is not good for any concession period design. Figure 4 shows the NPV distribution of the single-period without incentives under the three completion time distributions.

The effect of concession period design

Under a given probability distribution of completion time, different concession-period designs have different mean NPV, variances and values of NPV-at-risk. Under BetaPERT(1.5, 3, 4) distribution, whose most likely completion time is greater than its mean completion time), there are more possibilities for the project to be completed ahead of the scheduled completion time. In this case, the single-period without incentives has a greater mean NPV than the two-period without incentives, but its variance is higher than the counterpart of the two-period without incentives by 58%. Among the other designs, the two-period with early completion bonus has the highest mean NPV and the lowest variance, while the single-period with delay penalty ($\lambda_2 = 0.3$) has the lowest mean NPV and the highest variance. The two-period with bonus ($\lambda_1 = 1$) and penalty ($\lambda_2 = 0.3$) is somewhere between.

In contrast, under BetaPERT(1.5, 3, 6) distribution, whose mean completion time is greater than the most likely completion time by 8.3%, there are more possibilities for the project to be completed behind the scheduled completion time. In this case, the two-period structure

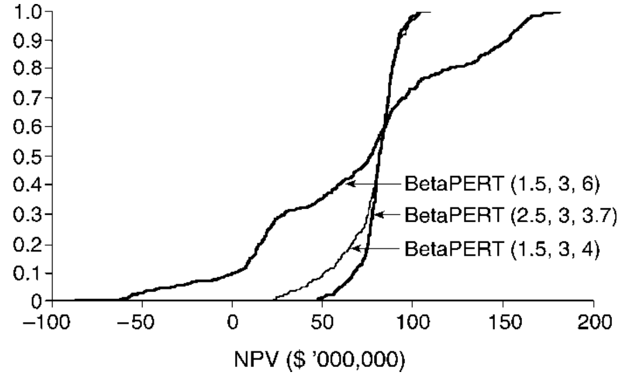

Figure 4 Single-period without incentives under different distributions

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can reduce the impact of completion risk much more effectively than its counterpart of the single-period structure, though the mean NPVs are also reduced to some extent. For example, the NPV-at-risk of a two-period structure without incentives is 250% as much as its counterpart, but its mean NPV is about 10% less than its counterpart. This is because there is a trend for the project to be completed behind the scheduled completion time and the two-period structure can reduce the impact of delay on financial viability. Figure 5 shows the mean NPV of each concession period design under completion time distribution of BetaPERT(1.5, 3, 6).

Under BetaPERT(2.5, 3, 3.7) distribution, the mean completion time is very close to the scheduled completion time (1% greater than the scheduled time). In this case, there are slight differences among the different concession period designs. It can be seen from Table 2 that the mean NPV is within the range from $US76.12 million for the single-period with delay penalty ($\lambda_2 = 0.3$) to $US81.53 million for the two-period with early completion bonus. Their variances vary from 54 for the two-period without incentives to 244 for the single-period with delay penalty ($\lambda_2 = 0.3$) and their NPV-at-risk values vary from $US43.33 million for the single-period with delay penalty ($\lambda_2 = 0.3$) to $US64.20 million for the two-period with or without early completion bonus.

To sum up, the effects of different concession period designs on the financial viability of a project are slightly different when there is small uncertainty in completion time. The reason is obvious: the choice of concession period structure does not matter if the project can be completed on schedule. In contrast, concession period design has significant impact on financial viability when there is great uncertainty in completion time.

Comparison between different concession period structures

Under any completion time distribution, the single-period structure without incentive always produces a higher mean NPV with smaller variance and a higher value of NPV-at-risk than does the single-period structure with delay penalty. This is because, under a single-period concession structure, the project company will suffer the loss of revenue and the increase of debt interest payment when the project is completed behind schedule. If penalties have to be paid for delay in completion, project performance will become worse.

Compared with the two-period structure without incentives, the two-period structure with early completion bonus has a slightly higher mean NPV (about 5% higher), but its NPV-at-risk is more or less the same as its counterpart. This is because the early completion bonus only increases the possibility of greater revenues but cannot prevent the project from being completed behind schedule. As a result, both structures face the same completion delay risk.

Compared with the two-period with bonus and penalty, the mean NPV and the NPV-at-risk of the two-period with bonus is much higher than its counterpart under any completion time distributions. Under the two-period with bonus and penalty, the incentive scheme makes the NPV distribution spread in a wider range: the early completion bonus provides opportunities to earn extra revenues so that the upside part of its cumulative curve is nearly the same as that of the curve of the structure with early completion bonus, while the delay penalty exposes the project to the possibility of paying delay penalties so that it has a longer downside tail.

The two-period structure without incentives generally has a higher value of NPV-at-risk than the single-period

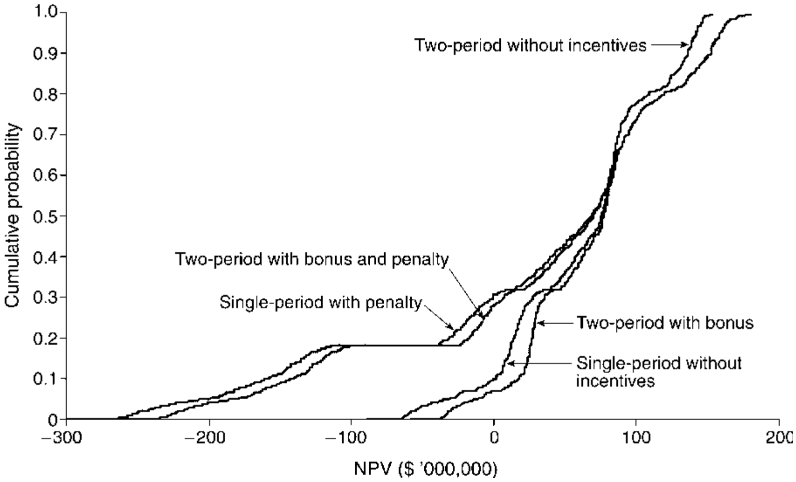

Figure 5 Different period designs under BetaPERT(1.5, 3, 6)

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structure without incentives, particularly when the mean completion time is much greater than the scheduled completion time. Its mean NPV will be smaller than its counterpart if there is an obvious trend for the project to be completed behind the scheduled completion time, but its mean NPV will be greater than its counterpart if there is an obvious trend for the project to be completed ahead of the scheduled completion time. When the gains resulting from earlier completion are entirely assigned to the project company (λ_1=1), the financial viability of the two-period with bonus is better than the single-period without incentives under any distribution. This reason is obvious: the two-period structure with bonus has the same effect as the single-period structure without incentives if the project is completed earlier; however, unlike the single-period structure without incentives the two-period structure with bonus will still have a fixed operation period if the project is completed behind schedule.

In this study, three completion time distributions were employed to represent three possible general cases: (1) a higher possibility of being completed ahead of schedule; (2) completion approximately around the scheduled time; and (3) a higher possibility of being completed behind schedule. Since the completion time distribution of any project may fall into one of the three categories of distribution, a similar conclusion would be obtained regardless of the case being used.

The choice of concession period designs

Creating a win–win concession period design means to design a concession period structure that benefits both the government and the project company. In general, different concession period designs demand different commitments (for example, risk assumption) from the government and the project company and provide different rewards. Both the parties try to strike a trade-off between the commitments and the rewards. Therefore, concession period structure for a given project should take the risk exposure of completion time into consideration. Since the costs to assume completion risk by the government are different from the costs by the project company, an optimal concession period design can create a 'win–win' situation.

Factors influencing concession period design

There are various factors influencing the design of concession period. Among them, the complexity of construction and the nature/source of revenues play an important role. Whether a project is completed on schedule largely depends on the accuracy of the estimated completion time which, in turn, depends on the complexity of construction. For a simple project, it is not difficult to estimate construction time accurately and to complete the project on schedule. As a result, there is less uncertainty in completion time. In contrast, it is difficult to estimate an accurate completion time for a complex project. As a result, the actual completion time may deviate very much from the estimated completion time. In the parlance of statistics, the estimated completion time for simple construction projects will have a smaller variance, while the estimated completion time for complex construction projects will have a larger variance. Here, assume that the completion time has the same type of distribution and the probability functions have similar shape.

The actual completion time to a large extent depends on the performance of contractors, which is influenced by incentive schemes, including built-in incentives. The design of incentive schemes largely depends on the nature of revenues. When the project has contract-led revenues, the fund for early completion bonuses may come from the purchase contract payment. In contrast, when the project has market-led revenues, it may be difficult for the government to prepare extra funds for early completion bonuses. Moreover, in revenue-sharing schemes, the public sector needs more information to control the project company's revenues. When the project has contract-led revenues, the public sector can control the project company's revenues through controlling the purchase contracts. But it may be difficult for the public sector to control the project company's revenues when the project has market-led revenues.

Therefore, privately financed infrastructure projects can be broadly classified into four categories according to the complexity of construction and the nature/source of revenue of projects. The choice of concession period design for each category of project is discussed in the following sections.

Concession period design for projects with low construction complexity

The completion time distribution of a project with low construction complexity has a small variance. This means that the project will be completed roughly on schedule. According to the simulation results, there is little difference among the four concession period designs and their varieties, each of which produces positive values of NPV-at-risk and mean NPV. This means that the four main concession period designs in Figure 1 are all suitable. In this case, the choice of concession period structure largely depends on the nature/source of revenues: contract-led or market-led.

Low construction complexity/contract-led revenue

When the project with low construction complexity has contract-led revenues, there are no constraints for the design of incentive schemes. Therefore, both single-period

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and two-period structures with or without incentives are suitable, depending on risk-return trade-offs of the contracting parties.

Most stand-alone facilities such as power stations, water/sewage treatment plants, belong to this type of project, in which the facilities can be built by using proven technology and their outputs are usually purchased by a single offtaker. Thus, they can adopt a wide range of concession period structures. For example, the Laibin B power project in China adopts a single-period concession structure without delay penalty. If the project is completed ahead of schedule, power generated before the schedule will be purchased at a pre-set tariff. If the construction work fails to meet a milestone date established in the project schedule, the project company shall only give a prompt notice to the government. In the Shajiao B power project in China, which adopts a two-period concession structure with early completion bonus. The construction period is 33 months and the operation period 10 years. If the project is completed ahead of schedule, the revenues generated before the schedule will be wholly assigned to the project company (the foreign partner only). If the project is completed behind schedule, the project company can still operate the plant for a 10-year period (Ye and Tiong, 2000b).

Another example is the Hub power project in Pakistan that adopts a two-period concession period structure with penalties and bonuses. The concession consists of a 47-month construction period and a 30-year operation period. If any one or more units are not completed on or before the scheduled completion date, Hubco, the project company, is required to pay Pakistan Water and Power Development Authority (WAPDA) a sum of $US45 662 per day ($\lambda_2 = 0.07$) as a delay penalty. The power generated before the scheduled completion date will be purchased by WAPDA at a pre-defined tariff and the resultant revenues belong to the project company ($\lambda_1 = 1$). Therefore, in order to stimulate the construction contractor to complete the project as early as possible, Hubco will grant the construction contractor about $US66 000 per day (about 10% of operating income) as a bonus for early completion with the aggregate limit of on this bonus of $US25.6 million.

The Da Chang water treatment plant project in China is an example in the water sector. Its construction was carried out in two phases. The first phase should be completed within 18 months after commencement of the construction work, and the second phase should be completed within 12 months after completion of the first phase. On completion, the project company will operate the facility for a period of 20 years (Chew, 1997).

Low construction complexity/market-led revenue

When the project with low construction complexity has market-led revenues, incentive schemes cannot be introduced if the fund is not available. In addition, the public sector needs more information to control the project company's revenues if revenue-sharing schemes are adopted. In this case, single-period without incentive may be the best choice. The single-period structure with delay penalty is riskier than the single-period structure without incentives. The two-period structure without incentives is less risky but there is no benefit if the project is completed ahead of the schedule.

The majority of toll roads that have relatively low construction complexity belong to this type of project, with the exception of large complex transportation projects, whose revenues come directly from the public – a less easily defined customer base. For example, 407 International Inc., the concessionaire of the Highway 407 project in Canada, was granted a 99-year ground lease of the project lands, including the construction of interchanges 407 West Extension and East Extension. If the concessionaire fails to open the interchanges on schedule, it will be charged $C60 000 per day for any delay in the opening of West Extension and $C23 000 per day for any delay in the opening of East Extension. The concession period is a single-period structure with delay penalty. Another example is the California AB 680 project in the USA, which adopted two-period structures. Each facility is financed and built by private developers. Each facility's developer will lease the facility back for a 35-year operation period to recover capital investments.

Concession period design for projects with high construction complexity

As the complexity of construction increases, the period of construction becomes more uncertain, that is, completion time distribution has a large variance. According to the simulation results, the value of NPV-at-risk of all the four main concession period designs, including their varieties, will significantly reduce as the mean completion time is much greater than the most likely completion time. Among them, two-period structures have higher NPV-at-risk than single-period structures do. In this case, it is better to separate construction periods from operation periods to mitigate time-overrun risk using two-period structures. To further allocate time-overrun risk between the government and the project company, incentive schemes in the form of early completion bonuses should be introduced.

High construction complexity/contract-led revenue

When the project with high construction complexity has contract-led revenues, it is suggested that the government and the project company share the gains and losses resulting from uncertainty of construction time to create

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a 'win–win' solution. In general, privately financed infrastructure projects with offtake contracts usually employ a two-period structure with incentive schemes.

High construction complexity/market-led revenue

When projects with high construction complexity, such as airports and large tunnels, have market-led revenues, two-period structures without incentives can be employed to reduce construction risk without the trouble of raising funds for early completion bonuses. In this case, liquidated damage may be introduced to prevent prolonged delay.

The choice of concession period design and project types

The choice of concession period structures will influence economic benefits and risk exposure of participants. From the concessionaire's perspective, two-period structures are more efficient than single-period structures for the purpose of addressing time-overrun risk, but they usually produce a smaller NPV. In contrast, from the concession authority's perspective, a single-period structure transfers more time-overrun risk to the promoter than do two-period structures. Moreover, both the two-period structure without incentives and the two-period structure with early completion bonus have no external mechanism to stop infinite completion delay, except their built-in penalties such as an increase in debt interest payment and delay in recovering capital investment. To prevent delay, delay penalties may be introduced to form the two-period with bonus and penalty design, or a liquidated damage payment may be introduced if delay exceeds the allowed latest completion date. Otherwise, the two-period structure without incentives is not an ideal choice from the concession authority's perspective.

As each concession period design has its strengths and weaknesses, the choice of concession period design for a given project depends on risk–return trade-offs of both the public and private sectors. Table 3 shows recommended concession period designs for the four categories of projects based on the complexity of construction and the nature/source of revenues.

Implication of the findings

The project company usually employs a date-certain, lump-sum turnkey contract for the construction of the project in order to reduce risk exposure. This contract strategy transfers completion delay risk to the construction contractor. To encourage the construction contractor to complete the project early, it is suggested that part of the revenue gain under a single-period structure or early completion bonus under a two-period structure should be passed on to the construction contractor. Similarly, the project company may also pass-through to the contractors all or part of the losses by introducing a delay penalty.

This strategy is adopted in practice. The Paiton power project in Indonesia is an example, which adopts a two-period concession structure with bonus but without penalty. The concession period consists of a 49-month construction period and 30-year operation period. The plant shall achieve commercial operation by the required commercial operation date, that is, 49 months from the financing date. If the project is completed prior to the required completion date, the revenues generated by the plant belong to the project company, which will pay the construction contractor $US325 000 per day as a bonus. If the commercial operation date shall not have occurred within 180 days of the required commercial operation date, Perusahaan Listrik Negara (PLN) may give notice to the project company to provide a remedial programme. If the project company fails to provide a remedial programme within 30 days, or to provide a manifestly incapable remedial programme, or fails to implement the remedial programme with due diligence, PLN may terminate the Power Purchase Agreement (PPA) on 30 days' notice. If the commercial operation date shall not have occurred within 335 days of the required commercial operation date, PLN may terminate the PPA on 30 days' notice.

Moreover, the assessment of concession period structures is also useful when the construction contract and the O&M contract are awarded separately to one party or two different parties. That can be viewed as a special case of two-period concession structures. The construction

Table 3 Recommended concession period designs and project types

Nature/source of revenue	Complexity of construction	
	Low	High
Market-led revenue	Single-period structure without delay penalty	Two-period structure without early completion bonus and delay penalty
Contract-led revenue	Single-period structure with/ without penalty Two-period structure with/ without incentives	Two-period structure with early completion bonus and/or delay penalty

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contract can be a fixed term or variable term with or without incentive schemes. In that case, the incentives for the construction contract are a bonus for early completion and penalty for delays, while ones for the O&M contract are a bonus for achieving a specified target and penalty for failing to achieve the target.

Conclusions

The design of concession period not only addresses the relationship between the construction period and the operation period but also deals with time-overrun risk in project construction. Combined with incentive schemes, different concession period structures expose the project company to different levels of completion risk and have different impact on financial viability. The single-period concession structure requires the project company to assume completion risk, while the two-period concession structure could, to some extent, reduce the completion risk exposure to the project company, depending on the incentive schemes. In designing a concession period for a given project, the characteristics of the project, such as construction complexity and market complexity, play an important role. Compared with projects with high construction complexity, projects with low construction complexity have a wider choice of period structures. Projects with contract-led revenues have a wider choice of incentive schemes than do projects with market-led revenues. After all, the choice of appropriate period structures and effective incentive schemes is largely based on risk–return trade-off of the contracting parties. A well-designed concession period can create a 'win–win' solution for both project promoter and the host government.

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