Concession Renegotiation Models for Projects Developed through Public-Private Partnerships

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Abstract: Contractual agreements between public agencies and private companies in the form of public-private partnerships (PPPs) have proven to be beneficial to both the public and private sectors. However, PPPs expose the concessionaire to a number of potential risks over the long concession period and the concessionaire may not be able to recover the large initial investment and obtain a reasonable rate of return if significant difficulties occur in the concession period. Hosting governments normally allow concession renegotiations when certain serious risk scenarios occur. International PPP practices have shown conflicting results from renegotiations, and many renegotiations have raised serious questions about the viability of the PPP approach. To facilitate renegotiations between the public and private sectors, this research has developed a concession renegotiation framework and compensation models for three common compensation measures, namely, toll adjustment, contract extension, and annual subsidy or unitary payment adjustment. The key issue in developing a quantitative compensation model is to estimate future cash flows, in which future traffic demand and operation and maintenance costs are important stochastic variables. Time-series models have been used to forecast these stochastic variables. **DOI: 10.1061/(ASCE)CO.1943-7862.0000843.** *© 2014 American Society of Civil Engineers.*

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Introduction

Public-private partnerships (PPPs) are contractual agreements between public agencies and private companies. Under such an agreement, a private company or a consortium (hereinafter referred to as concessionaire) of several companies [e.g., financial institutes, construction companies, and operation and maintenance (O&M) companies] is granted a concession to finance, build, and operate a public project and to provide the corresponding product or service and collect ensuing revenues. Project revenues can be used to repay the debt, recoup equity investment, and achieve a reasonable level of profit. The most common PPP models are build–operate–transfer, build–own–operate–transfer, and design–build–finance–operate (Ashuri et al. 2012), which have been widely applied worldwide in different types of projects, including highways, railways, ports, tunnels, airports, power plants, water-sewage plants, and water-supply facilities.

The PPPs have proven to be beneficial to both the public and private sectors since they were first proposed in the mid-1980s (Shen et al. 2002). The PPPs can accelerate public-infrastructure development, improve the quality of public services and achieve better risk sharing between public and private sectors (Shen et al. 2007) by allowing the participation of the private sector in delivering public works and services, which had previously been the government's responsibilities. However, PPPs expose the concessionaire to a number of potential risks over the long concession period (often 30 years or more) and the concessionaire may not be able to recover the large initial investment in the project and obtain a reasonable rate of return if some significant difficulties occur in the concession period. To attract private finance, governments normally allow renegotiations of the concession terms when some serious risk scenarios occur. Core concession clauses frequently renegotiated are substantial changes in tolls/tariffs (excluding standard and scheduled toll/tariff adjustments and periodic toll/tariff reviews), investment arrangements, exclusivity rights, guarantees, lump-sum payments or annual fees, coverage targets, service standards, and contract periods (Guasch et al. 2008).

International PPP practices have shown conflicting results in concession renegotiations. On the one hand, renegations have enabled public and private partners to reduce future uncertainties, share the risks and opportunities, and maximize joint utility in a number of PPP projects (De Brux 2010). On the other hand, many renegotiations have raised serious questions about the viability of the PPP approach (Guasch and Straub 2006). Renegotiations between the concessionaire and the host government without a competitive atmosphere often provide room for opportunistic behavior such as a concessionaire submitting a bid much lower than a reasonable price with an aim of winning a project and then taking advantage of future renegotiation opportunities for much better concession terms. Some scholars argued that perverse renegotiations and huge public financial guarantees had caused massive public resources to be devoted to covering private sector losses in PPP projects (Albalate and Bel 2009).

The incomplete nature of concession contracts and unforeseeable events arising during the long concession period make concession renegotiations inevitable for many PPP projects (Cruz and Marques 2013). This was confirmed by Guasch et al. (2008) who found high percentages of renegotiation in PPP projects in the transportation sector (54.7%) and the water and sanitation sector (74.4%) in Latin America and the Caribbean.

The high percentages of renegotiation in PPP projects and the conflicting results from such renegotiations make it all the more important to study concession renegotiation mechanisms and the

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various issues involved, to successfully implement future PPP projects and achieve win–win outcomes for both public and private sectors. In this regard, a concession renegotiation model has been developed.

Concession Renegotiation Framework

The circumstances under which renegotiation is warranted and the general procedures on how to conduct renegotiation have been discussed in particular government guidelines, for example, *Standardization of PFI contract* in the U.K. (HM Treasury 2007) and *Commercial principles for social infrastructure* in Victoria, Australia (Council of Australia Governments 2008). A general concession renegotiation framework is illustrated in Fig. 1. A brief explanation of this framework is summarized as follows.

The occurrence of a risk can influence a PPP project's financial performance, which can be measured by certain quantitative financial indicators, including debt-service coverage ratio, loan-life coverage ratio, shareholder's internal rate of return (IRR), minimum revenue, minimum traffic demand, least present value of revenue, and least present value of net revenue. A serious risk scenario (e.g., a force majeure event) means that a risk that has occurred and consequently caused one or more of these financial indicators to be below the corresponding thresholds, which are predetermined jointly by both public and private sectors. If one or more risk scenarios occur and push one or more financial indicators below the threshold, concession renegotiation will be opened. Otherwise, there will be no renegotiation if none of the financial indicators are below the threshold, even if one or more risks occur. If renegotiation is initiated, the public and private participants will negotiate on which measure(s) should be taken to compensate for any loss by the concessionaire due to the occurrence of one or more serious risk scenarios. Common compensation measures are toll adjustment, contract extension, annual subsidy or unitary payment adjustment, tax waiver, and reduction in concessionaire's investment obligations (Guasch et al. 2008). In practice, one or more measures may be taken depending on the actual situation of the PPP project. This study only considers the first three compensation measures.

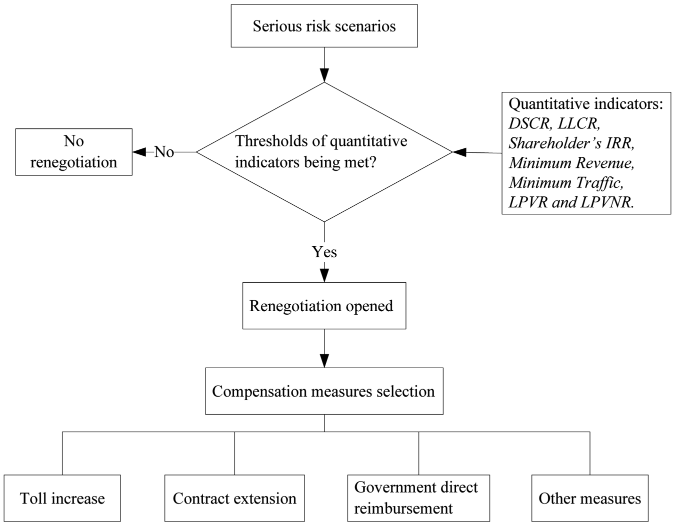

Fig. 1. General framework of renegotiation in PPP projects; DSCR = debt-service coverage ratio; LLCR = loan-life coverage ratio; LPVNR = least present value of net revenue; LPVR = least present value of revenue

Methodology for Developing Quantitative Compensation Models

The key issue in developing a quantitative compensation model is to estimate future cash flows, and the net present value (NPV) method is used in this study. The NPV method has been widely used to structure financial models in PPP research (Kakimoto and Seneviratne 2000; Pantelias and Zhang 2010; Seneviratne and Ranasinghe 1997; Wibowo and Kochendörfer 2005; Zhang 2005). When computing the future cash flows in a PPP project, there are many stochastic variables, among which future traffic demand and O&M costs are the most important. Time-series analysis is used in this study to forecast the two stochastic variables and determine the future trends of the data series based on past values and corresponding errors. It is a suitable approach for developing predictive models, because renegotiated PPP projects normally have historical data for traffic demand and O&M costs. In summary, quantitative compensation models can be developed for different compensation measures used in renegotiations by combining the NPV and the time-series analysis methods. Details for developing such models are discussed in the following sections.

NPV Method

The principle used in different financial models for PPP projects is that the concession period should bring a certain level of return on investment and/or NPV to the investor (Shen et al. 2002). Assuming a PPP project has a concession period of T_c years, including a construction period of m years, the general NPV model is shown as follows:

$$\mathrm{NPV}_a^{(1)} = -\sum_{t=1}^{m} \frac{C_t}{(1+r)^t} + \sum_{t=m+1}^{T_c} \frac{p_t Q_t - C_t}{(1+r)^t} \tag{1}$$

where $\mathrm{NPV}_a^{(1)}$ = the guaranteed minimum accumulated NPV of the cash flows; C_t = planned costs; p_t = planned toll rate; Q_t = planned traffic demand; and r = planned discount rate. For Greenfield projects, $\mathrm{NPV}_a^{(1)}$ provides only a very rough estimation because the forecasting of future costs and traffic demand is not sufficiently accurate in most sectors, due to limited information available (Flyvbjerg et al. 2006).

In renegotiations, the government has to decide how to compensate the concessionaire. No matter whether toll increase, contract extension, annual subsidy or unitary payment adjustment, or a combination of these methods is adopted, the compensation measure should bring a certain level of NPV to compensate for the concessionaire's losses in serious risk scenarios. That is, whether these methods are used separately or in combination, the actual accumulated NPV should be equal to the guaranteed minimum accumulated NPV in the whole concession period

$$\mathrm{NPV}_a^{(1)} = \mathrm{NPV}_{a-p}^{(2)} = \mathrm{NPV}_{a-T}^{(2)} = \mathrm{NPV}_{a-S}^{(2)} \tag{2}$$

where $\mathrm{NPV}_{a-p}^{(2)}$ = actual accumulated NPV of the cash flows after the application of the toll-adjustment method; $\mathrm{NPV}_{a-T}^{(2)}$ = actual accumulated NPV of the cash flows after the application of the contract extension method; and $\mathrm{NPV}_{a-S}^{(2)}$ = actual accumulated NPV of the cash flows after the application of the annual subsidy or unitary payment–adjustment method.

Assuming renegotiation occurs in the year $m+n$, the NPV models for different compensation measures are indicated as follows:

$$\begin{aligned}\mathrm{NPV}^{(2)}_{a-p} &= f(\Delta p, Q'_t, C'_t)\\ &= -\sum_{t=1}^{m}\frac{C'_t}{(1+r)^t}+\sum_{t=m+1}^{m+n}\frac{p'_tQ'_t-C'_t}{(1+r)^t}\\ &\quad+\sum_{t=m+n+1}^{T_c}\frac{(p_t+\Delta p)Q'_t-C'_t}{(1+r)^t}\end{aligned} \tag{3}$$

$$\begin{aligned}\mathrm{NPV}^{(2)}_{a-T} &= g(\Delta T, Q'_t, C'_t)\\ &= -\sum_{t=1}^{m}\frac{C'_t}{(1+r)^t}+\sum_{t=m+1}^{m+n}\frac{p'_tQ'_t-C'_t}{(1+r)^t}\\ &\quad+\sum_{t=m+n+1}^{T_c+\Delta T}\frac{p_tQ'_t-C'_t}{(1+r)^t}\end{aligned} \tag{4}$$

$$\begin{aligned}\mathrm{NPV}^{(2)}_{a-S} &= h(\Delta S, Q'_t, C'_t)\\ &= -\sum_{t=1}^{m}\frac{C'_t}{(1+r)^t}+\sum_{t=m+1}^{m+n}\frac{p'_tQ'_t-C'_t}{(1+r)^t}\\ &\quad+\sum_{t=m+n+1}^{T_c}\frac{p_tQ'_t-C'_t+\Delta S}{(1+r)^t}\end{aligned} \tag{5}$$

where C'_t = actual costs; p'_t = actual toll rate; Q'_t = actual traffic demand; C''_t = estimated costs; Q''_t = estimated traffic demand; Δp = value of toll adjustment; ΔT = value of contract extension; ΔS = value of annual subsidy or unitary payment adjustment; r = discount rate, which is set as the base IRR of the whole concession. As shown in Eqs. (3)–(5), there are three cash-flow components: the actual cash flows during the construction period, the actual cash flows during the operation period before the renegotiation, and the estimated cash flows during the remaining concession period after the renegotiation. The first two parts are recorded in the concessionaire's financial statements and the third part can be estimated using the time-series analysis method.

These models are based on the following assumptions: first, the application of these measures does not significantly influence the traffic demand. Loo (2003) and Matas and Raymond (2003) show that the toll elasticity of traffic projects is low, so it is reasonable to assume that the toll adjustment will not influence the traffic demand significantly. The measures *contract extension* and *annual subsidy or unitary payment adjustment* pertain to the risks by the government and do not affect the end user, so they also do not influence the traffic demand. Second, for simplicity, some stochastic variables, such as inflation risk, currency exchange risk, and so on, are not considered in this study.

Δp, ΔT, and ΔS can be determined as follows:

$$\Delta p = f^{-1}_{\Delta p}(\mathrm{NPV}^{(2)}_{a-p}, Q''_t, C''_t) \tag{6}$$

$$\Delta T = g^{-1}_{\Delta T}(\mathrm{NPV}^{(2)}_{a-T}, Q''_t, C''_t) \tag{7}$$

$$\Delta S = h^{-1}_{\Delta S}(\mathrm{NPV}^{(2)}_{a-S}, Q''_t, C''_t) \tag{8}$$

$\mathrm{NPV}^{(1)}_a$ can be obtained according to the project agreement and $\mathrm{NPV}^{(2)}_{a-p}$,$\mathrm{NPV}^{(2)}_{a-T}$, and $\mathrm{NPV}^{(2)}_{a-S}$ according to Eq. (2). Therefore, the core of a renegotiation compensation model is to accurately forecast traffic demand (Q''_t) and O&M costs (C''_t).

Time Series–Forecasting Models

Appropriateness of Using Time Series to Forecast Traffic Demand and O&M Costs

Time-series analysis has been adopted in a variety of disciplines such as economics, medical science, natural sciences, and engineering (Box et al. 1976; Brockwell and Davis 2002). For example, it has been used to forecast construction cost indexes (Ashuri and Lu 2010; Hwang 2011; Wang and Mei 1998), tender price indexes (Ng et al. 2004), property prices and housing market prices (Park and Hong 2012; Wilson et al. 2002), building costs and material costs (Hwang et al. 2012; Taylor and Bowen 1987), and traffic demand (Marazzo et al. 2010; Van Der Voort et al. 1996; Vlahogianni et al. 2006).

In traditional NPV models for feasibility studies of Greenfield projects, traffic demand and O&M costs are often estimated by comparing similar existing projects. The accuracy level of this kind of estimation methods is low. In addition, traffic demand and O&M costs are usually assumed to increase at a fixed growth rate from an estimated value at the beginning of the concession period (Pantelias and Zhang 2010). Uncertainties which could significantly affect traffic demand and O&M costs in a long concession period are ignored. For renegotiation cases in this study, the historical data of both traffic demand and O&M costs are observed at successive times and spaced at uniform time intervals. These observed historical data are essential to the development of time series–forecasting models, which may be more accurate than the estimation methods in traditional NPV models.

Selection of Time-Series Models

Depending on the number of series items, time-series models are classified either as autoregressive moving average [ARMA (p, q)] models or as multivariate autoregressive [VAR (p)] models. The ARMA model is used to represent the time-lagged relationship of autocorrelated observations within a single series. The VAR model simultaneously accounts for both the autocorrelation within a single series and the time-lag relationship of correlated observations among interrelated multiple series (Brockwell and Davis 2002). The ARMA model is used in this study because it requires a single input variable for creating and calibrating the model. By contrast, the historical data of certain factors (such as inflation rate and gross domestic product) that influence traffic demand and/or O&M costs are often not readily available for the creation of VAR models (Ashuri and Lu 2010).

The ARMA (p, q) model combines both the AR and MA approaches, where p is the order of the AR model and q is the order of the MA model. The AR (p) model estimates the stochastic process underlying a time series where its values exhibit a nonzero autocorrelation, while the MA (q) model estimates the process where the current value is related to the random errors from previous periods (Ng et al. 2004). The former forecasts by means of past values, while the latter forecasts through corresponding past errors.

Furthermore, the terms stationary and seasonality represent two important properties of any time-series model. Loosely speaking, a time series $\{X_t, t = 0, \pm 1, \dots\}$ is stationary if (1) the time-series data have a constant mean; and (2) the covariance between any two data points with lag 1 in the data set depends only on the time difference or the lag 1 between them (Ashuri and Lu 2010). Strictly speaking, a time series $\{X_t, t = 0, \pm 1, \dots\}$ is stationary if $(X_1, \dots, X_n)' \overset{d}{=} (X_{1+h}, \dots, X_{n+h})'$ for all integers h and $n \geq 1$ (Brockwell and Davis 2002). (Here $\overset{d}{=}$ is used to indicate that two random vectors have the same joint distribution function and d is the order of differencing.) Any nonstationary time-series data must be judged and transformed into stationary data before an ARMA (p, q) model can be applied. An ARIMA (p, d, q) model is an autoregressive integrated moving average model for a nonstationary time series (Box et al. 1976). An ARIMA (p, d, q) is described as follows (Ashuri and Lu 2010):

$$(1-B)^d X(t) = \mu + \frac{\theta(B)}{\phi(B)} Z(t) \qquad (9)$$

where B = backshift operator, that is, $BX(t) = X(t-1)$; d = the differencing order; μ = mean value of transformed stationary time series $(1-B)^d X(t)$; $\phi(B)$ = AR operator, that is, $\phi(B) = 1 - \phi_1 B^1 - \phi_2 B^2 - \cdots - \phi_p B^p$; $\theta(B)$ = MR operator, that is, $\theta(B) = 1 - \theta_1 B^1 - \theta_2 B^2 - \cdots - \theta_q B^q$; and $Z(t)$ = white noise time series sampled from a random variable with mean 0 and finite variance $\sigma^2 < \infty$.

The term *seasonality*, by contrast, indicates certain cyclical or periodic behavior in the time-series data (Ashuri and Lu 2010). A seasonal ARIMA model can be further developed based on a regular ARIMA (p, d, q) model. In this study, neither traffic demand nor O&M costs are seasonal, as yearly data are used.

An Illustrative Example of Applying Time-Series Models

In this section, a hypothetical PPP project (Project A) is used to illustrate the procedures of applying time-series models to forecast the traffic demand and O&M costs. The software *ITSM 2000* (Brockwell and Davis 2002) is used to conduct the time-series analysis, and the time-series analysis procedures recommended in Brockwell and Davis (2002) are adopted.

Profile Project A

Project A is a harbor tunnel road crossing procured through a build–operation–transfer contract in 1993, expiring in 2023. The planned concession length is 30 years, including a 5-year construction period. In the operation stage, the actual traffic was much lower than the estimated minimum traffic. The project agreement indicated that if the actual revenue was lower than the guaranteed minimum revenue, a renegotiation would be triggered and a toll increase applied. The tolls in Project A had increased five times by 2011. Because of frequent toll increases, people chose either of the other two existing harbor crossings whose toll rates were almost 50% lower. Consequently, the traffic for the other two harbor crossings has become excessively heavy, while Project A has a very low traffic volume. To optimize the traffic distribution among the three harbor crossings, the government considered *contract extension* and *annual subsidy or unitary payment adjustment* instead of *toll adjustment*.

The performance data of Project A from 1998 to 2011 are shown in Table 1. The total investment in Project A was $7 billion. For sample illustration, the toll rate is the average toll rate of all vehicle types in proportion to their traffic volumes. The daily traffic demand has increased in general, even though it experienced small fluctuations at the early operation stage. The revenue has increased due to the increase of both the toll rate and the daily demand, but it is still much lower than the guaranteed minimum revenue. The O&M costs have also increased gradually, and the net cash flow has an increasing trend in the long run. The base case discount rate is assumed to be 10%. The accumulated NPV in 18 years is $-4.57 billion, so there is a long way to go for Project A to reach the break-even point.

Time Series–Forecasting Procedures

The procedures for applying time-series models to forecast traffic demand and O&M costs of Project A are shown in Fig. 2. Details are discussed in the following sections.

Step 1: Plotting Time-Series Data and Transforming Them into Stationary Data

The time-series graphs of traffic demand and O&M costs for the period 1998–2011 are plotted in Fig. 3. Both data series show increasing long-term trends despite considerable short-term variations. The two time-series data sets are nonstationary and have to be transformed into stationary series by removing the trend component. Several methods can be used to transform the data series, including Box–Cox transformations, classical decomposition, and differencing. Box–Cox transformations are useful when

Table 1. Summary of Performance Data of Project A

Year	Traffic demand (vehicles)	Toll rate ($ per vehicle)	Revenue (million $)	Minimum revenue (million $)	Cost (million $)	NPV (million $)	Accumulated NPV (million $)
0	—	—	—	—	2,000	−2,000.00	−2,000.00
1	—	—	—	—	1,500	−1,363.64	−3,363.64
2	—	—	—	—	1,500	−1,239.67	−4,603.31
3	—	—	—	—	1,000	−751.32	−5,354.62
4	—	—	—	—	1,000	−683.01	−6,037.63
5	27,232	30	298.19	154.00	191.68	66.14	−5,971.50
6	37,625	30	411.99	201.00	186.02	127.56	−5,843.94
7	41,755	30	457.22	253.00	202.81	130.55	−5,713.39
8	40,988	35	523.62	506.00	215.33	143.82	−5,569.57
9	40,136	35	512.74	713.00	226.52	121.39	−5,448.18
10	37,620	35	480.60	794.00	246.67	90.19	−5,357.99
11	39,298	37	530.72	880.00	257.28	95.84	−5,262.15
12	39,540	40	577.28	1,190.00	255.92	102.40	−5,159.75
13	42,995	40	627.73	1,455.00	261.85	105.98	−5,053.77
14	46,984	40	685.97	1,549.00	327.82	94.31	−4,959.46
15	48,928	40	714.35	1,623.00	348.08	87.68	−4,871.78
16	46,943	45	771.04	1,876.00	341.27	93.53	−4,778.25
17	52,142	45	856.43	2,028.00	374.68	95.31	−4,682.94
18	54,929	50	1,002.45	1,892.00	389.33	110.28	−4,572.66

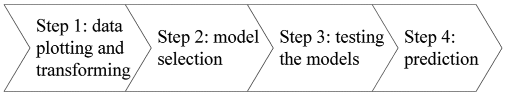

Fig. 2. Time series–forecasting procedures

the variability of the data increases or decreases with the level. Classical decomposition and differencing are techniques that can be used to remove seasonal components and trends (Brockwell and Davis 2002).

As illustrated in Fig. 3, the variability of traffic demand data decreases when its level increases, and the variability of the O&M cost data increases as its level increases. Box–Cox transformations are first applied for both data sets. Classical decomposition is then used to remove the quadratic trends for both data sets. Because neither the traffic demand data nor the O&M cost data display seasonality, it is not necessary to remove the seasonal components from these two data sets. Finally, the means of the data sets are subtracted. The transformed time-series data sets for both models are shown in Fig. 4.

Step 2: Model Selection

After the transformation from the original data series into stationary data series, an ARMA (p, q) model must be selected to fit the data series. In other words, the next step is determining the optimal parameters p and q. The method to determine parameters p and q takes advantage of the autocorrelation function (ACF) and the partial ACF (PACF). If the ACF and PACF values of a time series are equal to zero at all lag levels, the time series is white noise. If the PACF of a time series cuts off after lag p and the ACF reduces to the bounds $\pm 1.96/\sqrt{n}$, which are the upper and lower 95% confidence limits, the time series is AR (p). If the ACF of a time series cuts off after lag q and the PACF reduces to the bounds, the time series is MA (q). If both the ACF and PACF of a time series reduce to the bounds, the time series is ARMA (Ashuri and Lu 2010).

As shown in Fig. 5, the ACF and PACF graphs are computed based on the transformed data sets. For both the traffic-demand model and the O&M cost model, the ACF and PACF reduce to the bounds. Therefore, ARMA is appropriate for both models. The initial values of parameters p and q can be determined from the ACF and PACF graphs. In this regard, the traffic-demand model is initially defined as ARMA (0, 0) as both the ACF and PACF reduce to the bounds after lag 0; the O&M cost model is initially defined as ARMA (2, 2) as both the ACF and PACF graphs reduce to the bounds in around lag 2.

Even though the patterns of the ACF and PACF provide guidelines for model selection, the identification of the model type based on these functions is not always feasible, and it is often confusing (Hwang 2011). Therefore, this study develops various models with different orders and selects the best fitting model based on the Akaike information criterion (AICC). The AICC is widely used as a criterion in model-selection processes

$$\mathrm{AICC} = \mathrm{AIC} + [2k(k+1)]/(n-k-1) \tag{10}$$

$$\mathrm{AIC} = 2k + n\ln(\mathrm{RSS}/n) \tag{11}$$

where k = number of parameters; n = number of observations; and RSS = residual sum of squares.

The AICC is an estimation of the information lost when a given model is used to represent the process that actually generates the data. Therefore, the model with minimized AICC is the best fitting

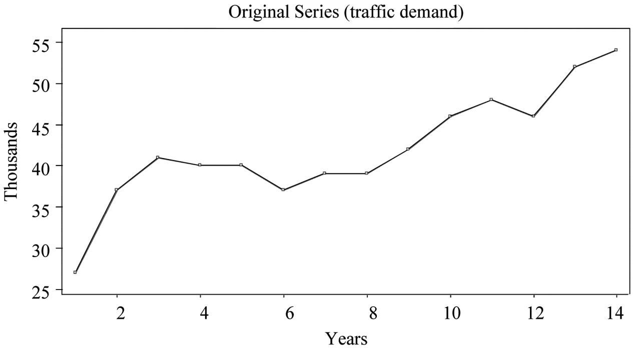

Fig. 3. Original data series of traffic demand and O&M costs of Project A

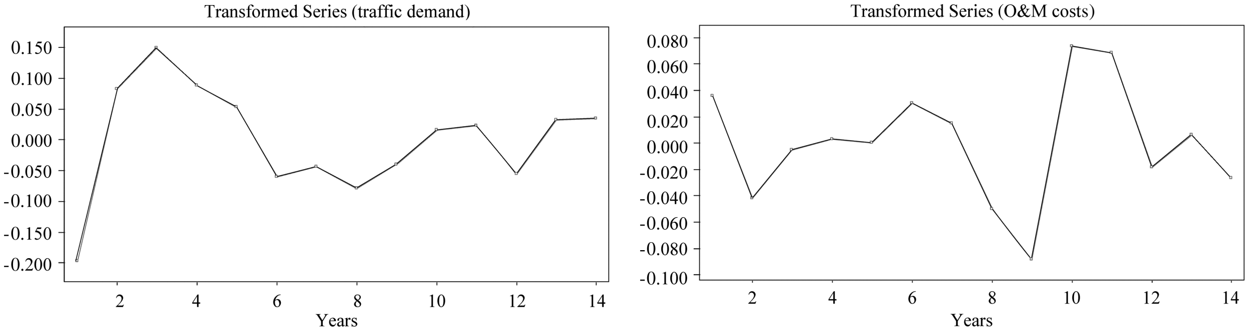

Fig. 4. Transformed data series of traffic demand and O&M costs of Project A

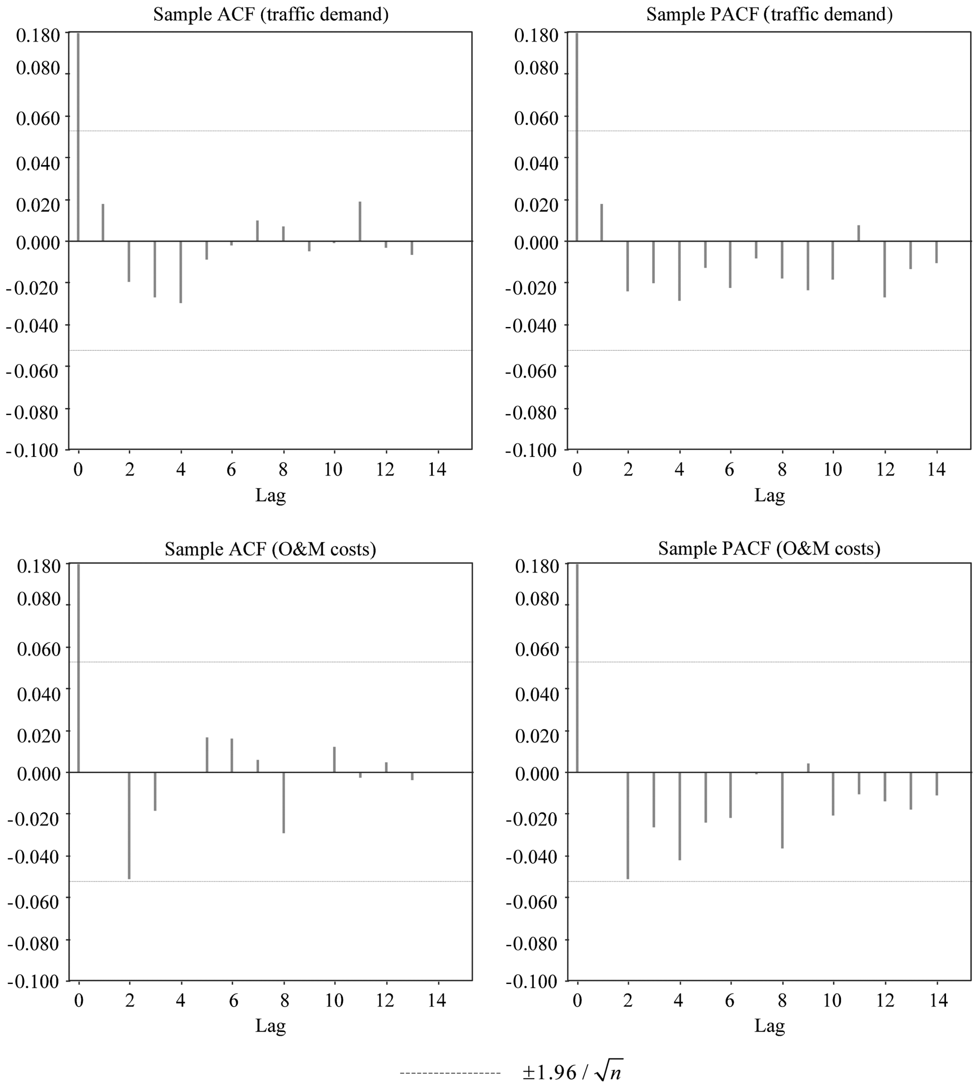

Fig. 5. ACF and PACF plots of traffic-demand model and O&M cost model

model (Brockwell and Davis 2002). Various models with different orders and corresponding AICC values are presented in Table 2. ARMA (0, 0) and MA (2) have been selected for the traffic-demand model and the O&M cost model, respectively, with the following functions:

$$X(t) = Z(t), \qquad Z(t) \sim N(0, 0.0070782^2) \tag{12}$$

$$Y(t) = Z(t) - 0.008231Z(t-1) - 0.9836Z(t-2),$$
$$Z(t) \sim N(0, 0.000729^2) \tag{13}$$

where $X(t)$ = traffic demand; $Y(t)$ = O&M costs.

Table 2. Summary of Selected Time Series Models

Traffic-demand model	AICC	O&M cost model	AICC
ARMA (0, 0)	−27.412	ARMA (2, 2)	−39.475
AR (1)	−25.288	ARMA (0, 0)	−46.205
MA (1)	−24.489	MA (2)	−49.071
ARMA (1, 1)	−21.355	AR (2)	−44.576

Step 3: Testing the Models

Once a model is selected, it is important to test its appropriateness. A time-series model is appropriate if the residuals form a white noise time-series data set. To check the appropriateness, a number of tests were introduced by Brockwell and Davis (2002). In this case, the ACF/PACF of the residuals is used. In particular, the sample ACF and PACF of the observed residuals should lie within the bounds $\pm 1.96/\sqrt{n}$. These bounds are displayed on the ACF/PACF graphs. Otherwise, the fitted model should not be regarded as appropriate (Brockwell and Davis 2002). As shown in Fig. 6, no correlations are outside the bounds in these two cases; therefore, both models are fitted appropriately.

Step 4: Prediction

After the models have been developed based on the historical data, the future traffic demand and O&M costs can be forecasted. This study forecasts the traffic demand and O&M costs of Project A in the following 20 years and presents the forecasted series with a 95% confidence interval, as shown in Fig. 7.

From the forecasted series, this study finds that the traffic demand of Project A increases steadily in 20 years and finally reaches a level of more than 100,000 vehicles per day, which is still much lower than the capacity of 180,000 vehicles per day. By contrast,

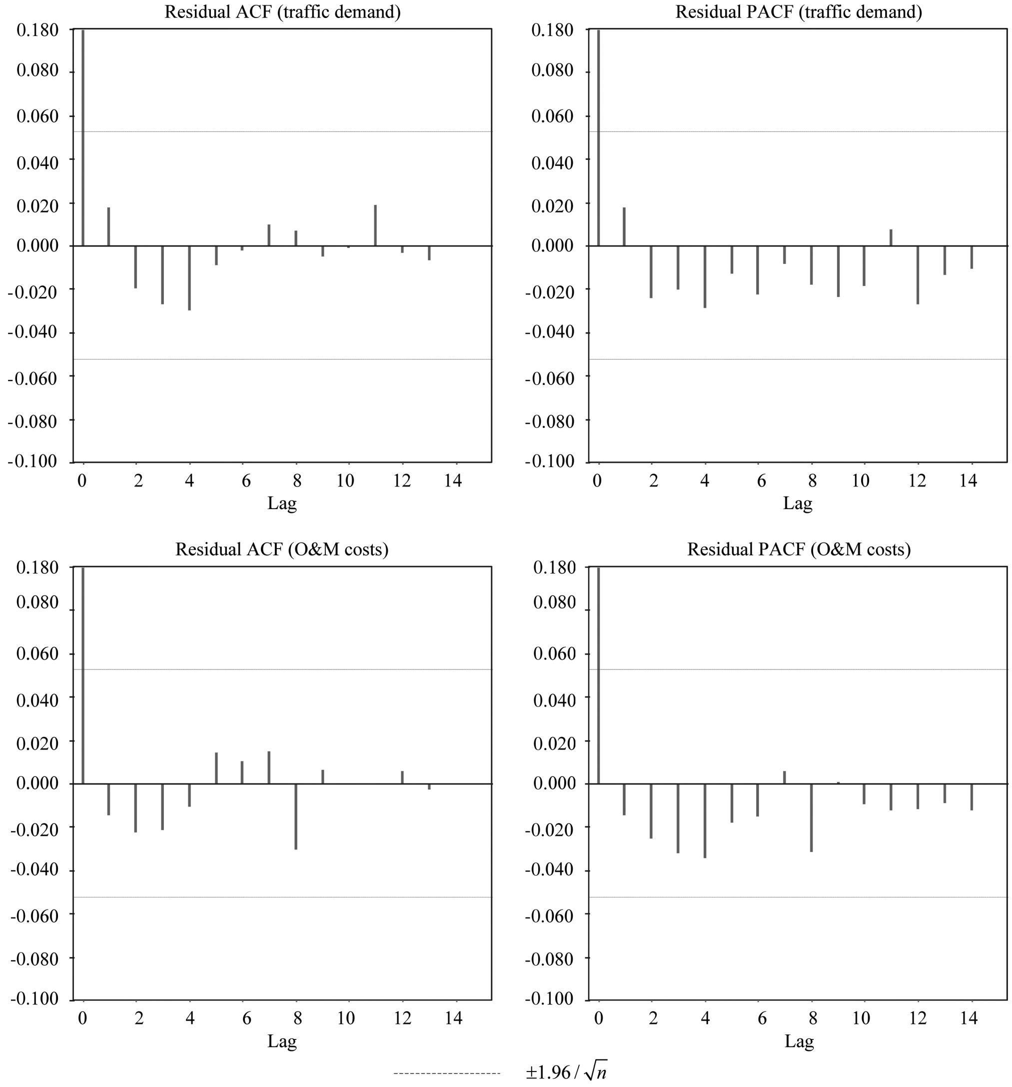

Fig. 6. ACF and PACF of the residuals of traffic-demand model and O&M cost model

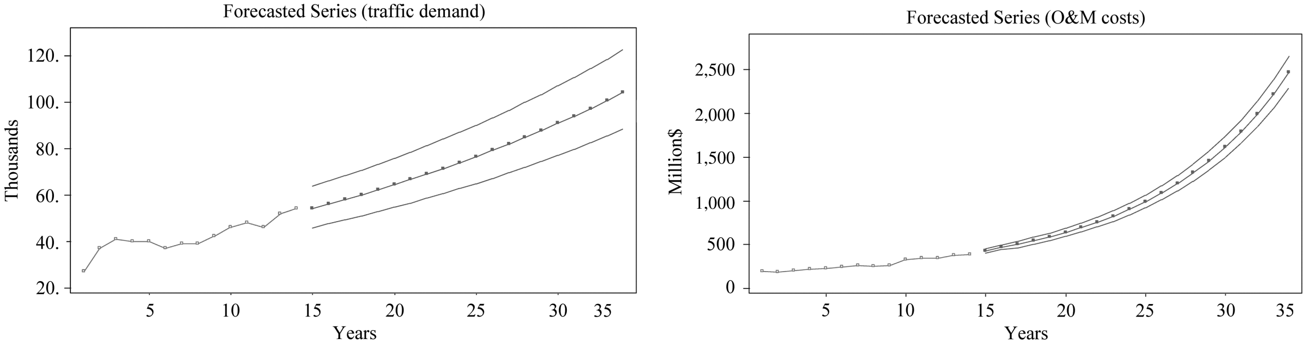

Fig. 7. Forecasted series of traffic-demand model and O&M cost model

the O&M costs of Project A show an accelerated growth over the 20 years and finally reach a value around $2.5 billion. The traffic demand increases due to the road-network development, local economic development, population increase, and so on. The O&M costs increase rapidly because of more repair and rehabilitation activities in the final years of the concession.

Solutions for Project A

The data required for the NPV analysis of Project A are illustrated in Table 3. From 2012 to 2031, the traffic data are forecasted based on a time-series model and the toll rate is fixed at $50 because the government is likely to refuse any further toll increase. The actual revenues are then calculated, and are presented in Table 3.

Table 3. NPV Analysis of Project A for Renegotiation Models

Year	Predicted daily demand (vehicles)	Revenue (million $)	Minimum revenue (million $)	O&M cost (million $)	$\text{NPV}_a^{(1)}$ (million $)	$\text{NPV}_a^{(1)}$ (million $)	$\text{NPV}_a^{(2)}$ (million $)	$\text{NPV}_a^{(2)}$ (million $)
19	54,024	985.94	1,821.00	425.03	228.25	228.25	91.71	91.71
20	55,949	1,021.07	2,212.00	467.85	259.26	487.51	82.23	173.95
21	57,940	1,057.40	2,573.00	500.23	280.10	767.60	75.29	249.24
22	59,997	1,094.95	2,733.00	541.10	269.27	1,036.87	68.04	317.27
23	62,124	1,133.77	2,891.00	586.44	257.37	1,294.24	61.13	378.40
24	64,323	1,173.90	3,507.00	636.79	291.40	1,585.64	54.53	432.93
25	66,596	1,215.37	4,018.00	692.80	306.90	1,892.54	48.23	481.16
26	68,945	1,258.24	4,220.00	755.18	290.72	2,183.26	42.21	523.37
27	71,373	1,302.55	4,422.00	824.77	274.39	2,457.65	36.44	559.82
28	73,882	1,348.33	5,192.00	902.51	297.45	2,755.09	30.92	590.73
29	76,474	1,395.65	5,747.00	989.47	299.91	3,055.01	25.61	616.34
30	79,153	1,444.54	5,726.00	1,086.90	265.86	3,320.87	20.50	636.83
31	81,921	1,495.06	—	1,196.20	—	—	15.57	652.40
32	84,781	1,547.25	—	1,319.10	—	—	10.81	663.21
33	87,735	1,601.17	—	1,457.30	—	—	6.19	669.40
34	90,787	1,656.87	—	1,613.20	—	—	1.71	671.11
35	93,940	1,714.40	—	1,789.20	—	—	−2.66	668.45
36	97,196	1,773.84	—	1,988.10	—	—	−6.93	661.52
37	100,560	1,835.22	—	2,213.50	—	—	−11.13	650.39
38	104,030	1,898.55	—	2,469.10	—	—	−15.25	635.14

Compared with the minimum revenues specified in the agreement, the actual revenues are too low. Therefore, the concessionaire is sure to claim for toll increases in the future because it is allowed by the price-adjustment clauses. To persuade the concessionaire to give up further toll increases, the government may choose to extend the length of the concession or give direct reimbursement to compensate for the losses. Either *contract extension* or *annual subsidy or unitary payment adjustment* should allow the accumulated NPV from 19 years to the expiry of the concession to equal the minimum guaranteed accumulated NPV from 19 years to the expiry of the original concession (30 years).

As indicated in Table 3, $\text{NPV}_a^{(1)}$, which is calculated based on the minimum revenues in the remaining concession period (from 19 to 30 years), is \$3.32 billion, but $\text{NPV}_a^{(2)}$, which is estimated when no compensation measure is taken in this period, is only \$0.64 billion. If the government wants to compensate the concessionaire at the minimum revenue level in the future, the total amount of compensation is \$2.68 billion. However, the $\text{NPV}_a^{\max}$ is only \$0.67 billion, which occurs in 35 years. This means that the *contract extension* method is not capable of providing full compensation to the concessionaire and the *annual subsidy or unitary payment adjustment* method should be used together. The final solution is that the length of the concession for Project A should be extended for $T_e = 5$ years, thereby increasing $\text{NPV}_a^{(2)}$ of the concessionaire by \$34.28 million. In addition, the government also has to pay a total of \$2.65 billion (NPV) as direct reimbursement, which is equivalent to an annual payment of \$2.16 billion from 19 to 30 years.

Conclusions

Renegotiations are very common in PPP projects, and on most occasions host governments have to compensate concessionaires for their losses. This research proposes renegotiation models to compensate the concessionaire. The three most popular compensation measures are considered, namely, toll adjustment, contract extension, and annual subsidy or unitary payment adjustment. The establishment of these models is based on cash-flow analysis and the uncertainties of future cash flows are predicted by time-series models. A hypothetical example is used to illustrate the application of the proposed models.

This research leads to the conclusion that the core of the renegotiation models relies on the forecast of future traffic demand and O&M costs. The application of time-series analysis to the hypothetical example has shown that both traffic demand and O&M costs can be satisfactorily fitted to the selected time-series model. It is shown that the ARMA model is the most accurate and applicable time-series model for traffic demand, while the MA model is the most accurate and applicable time-series model for O&M costs. The results forecasted also provide a wide range of information for a long-term view of the traffic demand and O&M costs.

The quantitative renegotiation models proposed in this study enable hosting governments to compare different compensation measures and then to select the most suitable one or a combination to suit the needs of a particular PPP project in a specific hosting environment.

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