A System Dynamics model to determine concession period of PPP infrastructure projects: The overarching effects of critical success factors

Fahim Ullah, MS (Corresponding Author)

1. PhD Student, Faculty of the Built Environment, University of New South Wales, Sydney, Australia.
2. Lecturer, Dept. of Construction Engineering & Management (CE&M), NIT-SCEE, National University of Sciences & Technology (NUST), Islamabad, Pakistan.

Phone: +92-51-90854165

Email address: f.ullah@student.unsw.edu.au

Postal Address: Dept. of Construction Engineering & Management (CE&M), NIT-SCEE, National University of Sciences & Technology (NUST), H-12, Islamabad, 44000 Pakistan.

Muhammad Jamaluddin Thaheem, PhD

Assistant Professor, Dept. of Construction Engineering & Management (CE&M), NIT-SCEE, National University of Sciences & Technology (NUST), Islamabad, Pakistan

Phone: +92-51-90854164

Email address: jamal.thaheem@nit.nust.edu.pk

Postal Address: Dept. of Construction Engineering & Management (CE&M), NIT-SCEE, National University of Sciences & Technology (NUST), H-12, Islamabad, 44000 Pakistan.

Samad M.E. Sepasgozar, PhD

Lecturer, Faculty of the Built Environment, University of New South Wales, Sydney, Australia

Phone: +60 (2) 9385 6528

Email address: samad.sepasgozar@gmail.com
Postal Address: Faculty of the Built Environment, University of New South Wales, Sydney, Australia.

Nuria Forcada, PhD
Associate Professor (Group of Construction Research and Innovation – GRIC),
Department of Project and Construction Engineering, Universitat Politècnica de Catalunya – UPC, Terrassa (Barcelona), Spain.
Phone: + 34 93 7398153.
Email address: nuria.forcada@upc.edu
Postal Address: C/Colón, 11 - Edifici TR5 - 08222 Terrassa (Barcelona) – Spain

Abstract

The determination of the concession period (CP) in Public-Private-Partnership (PPP) infrastructure projects has presented complexities to decision makers since various critical success factors (CSF) are involved which may be overlooked. This paper outlines a System Dynamic (SD)-based approach to provide an in-depth understanding of CSFs that determines PPP projects' CP and models them for localized use. The CSFs are obtained from published literature, duly vetted through a survey of 56 experts and are used to develop a quantitative and qualitative SD model, validated by simulating case studies of five infrastructure projects. A total of 59 concession affecting CSFs are highlighted that are reduced and compared for localized infrastructure projects. The findings, pointing to the need of CP being dynamic instead of traditional fixed and static, warrant an extension in the originally proposed concession in three cases and reduction in the remaining two. The decision-making implications of this study target the three key stakeholders: public body through reduced financial risks, private organization through increased confidence and reassessment of concession during project life, and end user through nominal tolls.

Keywords: Public-Private-Partnership; concession period; critical success factors; infrastructure projects.

Introduction

Private sector participation in infrastructure financing and management is growing around the world and this increase is taking special relevance in the case of road projects procured under public-private-partnership (PPP) (Rahmani et al., 2017). As evident from the case studies in Europe, the growing trend of private sector participation in road projects has resulted into more stringent regulations (Albalate et al., 2013). Privatization of construction projects is an emerging market in the United States of America (USA) as well. There have been significant greenfield projects such as the Dulles Greenway, and brownfield projects including Chicago Skyway, Indiana Toll Road and Pennsylvania Turnpike (MWAA, 2015). A general trend of prospects for privatization of roads in New Jersey and build-operate-transfer (BOT) concessions in Texas has surfaced. This wave of privatization is accompanied by a renewed interest in the way the public sector regulates (Cheung et al., 2010; Meng and Lu, 2017). This interest can be explained by the potential redistributive effects due to the right of exploiting a network asset such as a motorway.

PPP is evidently getting a lot of attention by governments in different parts of the world. One stated reason behind this trend is the concern over public expenditure (Cheung et al., 2010; Ullah et al., 2016). PPPs are often presented as a core part of modernizing public services, since they improve the quality and efficiency of public services (Liu and Wilkinson, 2014). However, from a more skeptical view of their value, some studies point to their complexity, short- and long-term costs and consequences for labor and those reliant on public services (Osei-Kyei and Chan, 2015). Such complexities often lead to the failure of PPP projects.

One of the most complex decisions in PPP projects is the determination of the concession period (CP) which is the time allotted to a private entity for operating a constructed facility to recover its expenditures and gain some acceptable return on investment (Ng et al., 2007b; Osei-Kyei and Chan, 2017). The project is handed over to public authority at the end of this term. CP reconciles risk-reward balance for the private party and end user: the prior in form of speedy financial recovery, and the latter in form of economic tolls and greater public welfare (Akintoye and Chinyio, 2005; Carmona, 2010; Hu and Zhu, 2014; Shi et al., 2016). Thus, if not estimated properly, CP may trigger project failure (Cheung et al., 2010; Tieva and Junnonen, 2009; Trangkanont and Charoenngam, 2014).

In terms of legal aspects, PPPs and their CPs are evolving, and the methodology to calculate it has yet to be matured. This is mainly due to the length of CPs (typically 15 to 30 years or longer) making the formulation of a comprehensive contract very difficult. Furthermore, PPP projects are frequently re-negotiated or bought back, when parties attempt to amend the critical elements, such as tolls and tariffs and subsequent readjustments for financial obligations, making the formulation of a globally accepted PPP legal framework nearly impossible (Mouraviev and Kakabadse, 2017a). Therefore, it is better to look at PPP in terms of the principal features that distinguish it from other types of agreements between the government and private organizations, keeping in view its unique contractual aspects. According to Mouraviev and Kakabadse (2017b), some of the legal challenges faced by PPP CPs are, but not limited to, incomplete and inconsistent legislation surrounding partnerships, weak institutional development, virtually non-existent civil participation, underdeveloped financing institutions, unclear stance from the government regarding approaches to PPP project preparation, lack of PPP-specific governance structures and established procedures for partner interaction, tariff adjustments, dispute resolution, ambiguous government approach towards risk allocation, excessive government regulation where the government focuses on input, and a contradictory perception of a policy paradigm, where the latter serves as an instrument for massive PPP deployment, although the government commitment to partnerships quickly disappears after a PPP is launched.

Although it is crucial to precisely determine the CP due to the growing innovation and quality demands (Carbonara et al., 2015; Ullah et al., 2017b), the estimating complexities result into a lack of valid and globally applicable model. In response to this research gap, the current study aims to develop a novel model based on systems dynamics (SD) concept to estimate the CP realistically and induce more adoptability by incorporation of localized critical success factors (CSFs). The model, based on the stocks and flows, and positive and negative loops, operates in a systemized way to simulate various possible decisions, and yields the results based upon randomized iterations until a constant trend is observed where the iterations are stopped and results are compiled. This model underlines the dynamic behavior of CPs instead of static traditional approach. Therefore, CPs should be revised after some time and adjusted accordingly depending upon the set terms and conditions, and project forecasted performance.

Concession period of PPP projects

Various concession-based failure stories have been reported citing the unforeseen costs, improper risk allocation, legal ambiguities, lack of responsibilities and local public resistance as contributing factors (Carbonara et al., 2015; Domingues and Zlatkovic, 2015; Khanzadi et al., 2012). Similar to other project types, value for money (VFM) in PPP projects is carefully assessed due to the associated financial risks (Kumaraswamy et al., 2007; Love et al., 2015). Although before making a PPP procurement decision, the economic justification of VFM is assessed, some other factors including project risks, construction complexities and innovations, traffic congestion problems, lack of proper and legal government policies, and social welfare are ignored (Carmona, 2010; Hu and Zhu, 2014; Jefferies and McGeorge, 2009; Love et al., 2015). For example, the M25 widening scheme in United Kingdom (UK) is criticized for its higher than necessary costs and lack of alternative options of using the hard shoulder as an extra lane during peak hours which led to a potential extra cost of around GBP 1 billion to taxpayers (Marsden, 2005). Similarly, Lagos-Shagamu-Ibadan concession road project is a PPP failure case in which many people had to be relocated and payment of royalties emanated. Several obligations, not captured in the contract package at the pre-contract stage, escalated into serious cases of protracted litigations (Akintoye and Main, 2007; Opawole and Jagboro, 2016; Trangkanont and Charoenngam, 2014).

CP is dependent upon various dynamic factors like project income (PI), toll price, severity of involved risk (SIR) and market situation (MS) (Akintoye and Chinyio, 2005; Wang et al., 2011). Its allocation and optimization decisions have been discussed by various researchers (Karim, 2011; Ke et al., 2010). However, the effects of CSFs on concession estimation are less explored proving a research gap for exploration (Ullah and Thaheem, 2017). This effect is multiplied in case of developing countries. Literature reports a simulation model proposed by Ng et al. (2007b) for determining CP that incorporates the risk of optimum tariff and payback in tendering stage. A regulatory contractual regime has been developed by Cruz and Marques (2012) for evaluating the risk allocation in Portuguese road concessions. They suggest that government must assume risk of production and provide incentives in case of highway development. Similarly, several authors have come up with theoretical frameworks for obtaining VFM from PPP concessions using assessment techniques of public sector comparator, competitive bidding, shadow bid, cost benefits analysis, lease-purchase analysis and public interest test central guidelines (Love et al., 2015; Tieva and Junnonen, 2009). Trebilcock and Rosenstock (2015) propose that governments should anticipate and plan contingencies as well as conduct enforcement and monitoring of long-term PPP contracts. They highlight the capacity as a key determinant of PPP success and reduction of potential concession renegotiations in Latin America.

These frameworks not only address the development goals but also attempt at reducing the legal risks of such CPs. In general, there are two types of perspectives on PPPs in terms of the relations between the public and private organizations: the contractual perspective focusing on the legal aspects, and the task specific focus aimed at the project execution and delivery through various stages of its life cycle (Zhang et al., 2015). The legal aspects include, but are not limited to, proper rights, polity, administrative regulations, judiciary and bureaucracy. These aspects, if not properly catered for, may lead to project delays or subsequent failures. For example, the first Polish PPP was delayed by more than a decade due to the lack of legal implications (Albalate et al., 2015). Similarly, Gurgun and Touran (2013) compare various legal frameworks for PPPs and stress their importance. These legal systems must exist but should not be overly complicated as suggested by Edkins and Smyth (2006). The authors argue that an overly complicated legal system will not only demand hiring of and extensive payments to legal advisors but also hinder the much aimed *'partnership'*, making the relation an adversarial one instead of collaborative.

Although recent studies have shifted their focus towards CP risk, new challenges are brought about by emerging risks associated with lately highlighted critical factors. New influential factors that must be incorporated into the decision models are identified (Carmona, 2010; Yu and Lam, 2013). PPP CSFs are revised from time to time to enable a better execution and management that lead to new challenges.

CSF to determine the CP

In infrastructure projects, CSF to determine the CP include financial aspects such as equity allocation, toll and service price, economic viability, operation and construction costs to the public, social welfare such as end user purchase subsidy, environmental concerns and elimination of traffic congestion (Liu and Wilkinson, 2014; Shi et al., 2016; Wibowo and Wilhelm Alfen, 2014). These factors, , affect project success and increase its complexity.

CSFs for infrastructure projects include, but are not limited to, net present value (NPV), traffic congestion and road usage, effectiveness of public bodies, population in nearby area, adequacy of project funding and annual operational revenue (Alireza et al., 2013; Zhang and AbouRizk, 2006). Since CSFs induce risk in PPP projects, they warrant effective management to achieve successful execution and subsequent closure.

Further, closure risk, which refers to a funding agency's capability to reach financial closure, poses great concern for the public entity (Domingues and Zlatkovic, 2015). However, at the feasibility and planning stages, a poor CP estimate poses even greater challenge to both public and private entities. For the public agency, an administrative and decisive scenario arises that sways the bid process. Having estimated the total project cost, the public agency may decide for the minimum possible offer to accept (Kumaraswamy et al., 2007; Wibowo and Wilhelm Alfen, 2014). It has also implications in establishing the toll rate as the public agency is responsible for not only ensuring financial recovery on part of donor agencies but also providing market compatible rates in the light of economic capacity of users (Shi et al., 2016).

For the private sector, this risk is business- and project-critical since the corporate sector needs to guarantee a profitable return on investment within a stipulated time (Carmona, 2010; Ng et al., 2007a). Any extension in this time may pose serious financial pressures demoralizing the private investors from doing further business in that market (Carbonara et al., 2015). In the case of no extensions, the financier has no other option but to escalate the revenue by increasing usage charges, transferring the financial burden to end user. Therefore, it is crucial to perform thorough risk management for concessions in the early stages of project development. To meet this demand, considerable research has gone into identifying CP duration of BOT based PPP projects (Meng and Lu, 2017; Yu and Lam, 2013).

The general trend suggests that risk allocation between the public and private sectors involved in public-purpose transport investments is an onerous and tricky matter owing to the opportunistic behavior of PPP stakeholders (Domingues and Zlatkovic, 2015; Wibowo and Wilhelm Alfen, 2014). Although the allocation of risk between public and private stakeholders varies from country to country, a major consensus is found over the assumption of entire financial risk by the private sector who undertakes the long-term maintenance and operation responsibilities (Ke et al., 2010). An exception to this risk sharing is such projects where promotion and development of some underdeveloped and deprived part of the country is the priority (Wibowo and Wilhelm Alfen, 2013). The effect of risk is further exacerbated due to the time factor as these concessions are usually very lengthy (25 – 30 years), giving rise to the stochasticity of various estimates (Tieva and Junnonen, 2009).

Owing to these challenges, concession-based projects based on their context in terms of financial, social and environmental aspects should be investigated (Hu and Zhu, 2014; Jefferies and McGeorge, 2009; Wibowo and Wilhelm Alfen, 2013). The current literature mainly covers developed countries such as USA, UK, Canada and China. The challenges of developing and underdeveloped construction industries include quality management, project success, waste management, contractual framework maturity, PPP policy, and time and cost management, to name a few (Akintoye and Main, 2007). This study focuses on a developing country because the current challenges of its construction industry are yet to be shared with the developed world.

PPP projects in Pakistan

Although there are currently 22 ongoing PPP infrastructure projects in Pakistan (NHA, 2017; Ullah et al., 2017b), there is neither a reliable estimation method for its CP nor any considerations to incorporate the localized CSFs. This, though early to say, may result in failure if not taken care of. So far only one PPP project has been completed which escalates the gravity of these concerns. The completed project was assigned a concession of 10 years which was erroneous as highlighted by post project studies. Had the concessionaire not closed the project himself as a token of good will, the government would have suffered 4 extra years of concession expenditures. This concern is particularly critical for international or foreign partners that are planning to involve in the project. As highlighted by Razzaq et al. (2016), foreign companies intending to venture in Pakistan are faced with constant fear of time and cost overruns due to lack of localized policies. It is estimated that a sum of PKR 358,594 (USD $3420.88) million has been invested in PPP based infrastructure development projects from 1991 until 2015 (NHA, 2015; Ullah et al., 2017b). Owing to such huge investments, PPP need to be thoroughly studied and its CP decision-making for local construction industry should be improved.

System Dynamics (SD) approach to determine concession periods

SD modeling is an objected-oriented methodology where cause and effect variables are arranged into a causal loop diagram (CLD) to represent the structure and interaction of principal feedback mechanisms in a system (Sterman, 2001). The main diagramming tools used are the CLD and stock and flow diagrams. CLDs consist of cause and effect variables connected by arrows denoting their causal influence. Each causal link is assigned a polarity, either positive (+) or negative (−), to indicate the relationship between the dependent and independent variables. In addition, the feedback process within the loop can be simulated to provide a delayed response; such a delay creates inertia and oscillation within the system. The SD simulation is developed in the form of stock and flow variables, where a stock variable describes the system's state (such as the existing supply of workers) and the flow variable represents the rate of system changes.

SD allows to easily simulate the structure's behavior over time (Morecroft, 2015). Given its inherent capabilities, SD has been widely applied to a number of problems (Khanzadi et al., 2012). Ding et al. (2016) used SD for environmental performance assessment of construction waste management and concluded that 53.77% landfill reduction can be achieved. Khan et al. (2016) used it for handling the information complexity in construction project. Rashedi and Hegazy (2016) used it for examining budget policies for new and existing facilities, and concluded long-term strategic plan as a key factor for budget optimization. Similarly, Xu et al. (2012) used SD for concession price model in highway projects. They concluded that a rational price model will create a win-win scenario for both public and private entities. Hu et al. (2015) used it for conceptualizing a web-based tool for contracting. They argue that such tool offers the possibility to track the decisions made by private sector suppliers during the progress of a simulated project that can help government agencies to manage project schedule, bringing benefits to both parties.

Methodology

Keeping these useful research in view, the current study uses SD to incorporate the effects of PPP concession CSFs in CP estimation. These CSFs are simulated into an SD model for estimating the improved CP for reconciling the heightening contractual and use-based relationships between public and private entities, and the service users.

To identify the CSFs for CP estimation the pertinent literature published during 2005-2016 in reputed international journals is analyzed. Then, the selected CSFs are ranked using combined scores from academic and industrial experts to obtain mutually significant factors to be incorporated in the model.

Finally, five infrastructure case studies are are used to validate the model. Theoretical and practical implications of proposed model are discussed, and future research directions are deliberated.

SD is an increasingly adopted technique for handling complex decision-making scenarios (Khan et al., 2016; Ullah et al., 2017a). CP estimation comes with intrinsic risks and complexities, making SD a good candidate for thorough assessment (Khanzadi et al., 2012). SD bases its foundation on causal frameworks and gives results in the form of trend graphs. But, it is merely graphs unless validated and iterated through case studies for results to be comparable to real life projects. Thus, in addition to formulating SD based framework, case study based validation needs to be performed on the formulated model, which is at the core of current study.

Thus, a comprehensive SD model duly incorporating the identified CSFs is formulated and validated through five infrastructure case studies. The lack of availability of data and burden of its collection constrained the number to five. Four of the five case projects are in initial stages of execution or planning whereas one is completed. Due to the nascence of PPP in the country, only one completed project exists which is iterated in the current study. The case studies are based in Pakistan and data is collected from associated experts having an experience of at least 10 years or two PPP projects. Thus, the entire data collection process involved 66 experts out of which, 30 belong to academia, 26 to industry and 10 belong to the case projects (two from each project). Carried out into for steps, this study moves through CSFs identification and shortlisting, to subsequent development of a quantitative model given in the form of an equation and SD model iteration as shown in Fig. 1 and explained in the pertinent steps.

[Insert Fig. 1 here]

Step 1: Identification of factors affecting CP

Firstly, concession CSFs were identified from the pertinent literature published in reputed international journals. For searching the related literature, Science Direct, American Society of Civil

Engineers (ASCE), Google Scholar, Scopus, Taylor and Francis, and Emerald databases were used. A total of 121 research publications were consulted to highlight 59 CSFs of PPP concession.

Then, a two-stage pilot survey was conducted to identify the top 10 factors from those identified by the literature review to be incorporated in further analysis. Both academic and industrial experts were engaged to gather their opinions in 1st and 2nd stages of the survey, respectively. A questionnaire was developed to ask whether a factor affects the CP of PPP projects or not? The questionnaire was very basic, and respondents were asked to respond in either Yes or No. If their answer was yes, they were further requested to assign a score on the scale of 1 to 10 depending upon the impact of the factor on CP length.

The final Global Weight (GW) was obtained by taking a product of Academic Score (AW) and Industry Score (IW) means, as mathematically given in Equation 1.

$$\mathbf{GW = AW \times IW} \qquad \textbf{(Equation 1)}$$

The 1st stage of survey included authors and other academic experts having published at least 3 research papers on PPPs. These experts were contacted through online means. In total, 48 experts were contacted and 34 responses were received. A total of 30 responses were regarded as complete while the remaining were discarded. Thus, the accurate response rate was 62.5% (30/48). In this way, a ranking was obtained based on the opinion of academic experts.

Further, to complete the cycle of systematic review, 48 industrial experts were engaged in the 2nd stage mainly through online means. Out of total, 29 responses were received including 26 complete and 3 incomplete responses. Thus, the accurate response rate for this stage was 54.16% (26/48). The experts were mainly the personnel belonging to upper managerial positions of their respective organizations and having an experience of direct involvement in at least two PPP projects or a minimum of 10-years relevant experience.

Step 2: Development of a quantitative model

In this step, a quantitative model is developed for which a functional grouping is performed to reduce the input variables in the equation. So, based on expert opinion, factors such as *income in year*, *return on investment* and *operation revenue in year* are represented by a single variable *PI*. In addition, the factors *construction cost* and *traffic count* are intrinsically included into *NPV*.

Further, the quantitative model development warrants a relationship between the input and output variables. Owing to the non-linearity, some variables are directly and some are inversely proportional to CP. *Revenue stream* (RS) is inversely proportional to CP (Karim, 2011). The smoother and increased RS ultimately helps in quick recovery of the invested money and hence the CP is reduced proportional to the increase in RS as shown in Equation 2.

$$\mathbf{CP} \propto \frac{\mathbf{1}}{\mathbf{RS}} \qquad \textbf{(2)}$$

$$\mathbf{CP} \propto \frac{\mathbf{1}}{\mathbf{PI}} \qquad \textbf{(3)}$$

$$\mathbf{CP} \propto \frac{\mathbf{1}}{\mathbf{MS}} \qquad \textbf{(4)}$$

$$\mathbf{CP} \propto \frac{\mathbf{1}}{\mathbf{NPV}} \qquad \textbf{(5)}$$

Similarly, PI is also inversely proportional to CP. A project offering more income will intrinsically call for a lesser CP due to a quicker recovery of investment as shown in Equation 3. Likewise, better market conditions reduce the CP as a quick recovery of investment is ensured due to an increased market demand and a stable return on investment (Wang, 2015). Therefore, MS is inversely proportional to CP as expressed in Equation 4. The trend of inverse proportionality continues in the combined factor *NPV* as a greater NPV means a lesser CP (Zhang and AbouRizk, 2006), as shown in Equation 5. Though this is highly debatable due to the dynamic nature of factors constituting NPV, from decision-making perspective, the minimum concession is the point at which NPV=0 whereas an increase in NPV depends upon the acceptable level of internal rate of return (IRR).

On the contrary, *SIR* is directly proportional to CP (Albalate et al., 2013), as shown in Equation 6, since it demands for an added time to concession length in order to cope with unexpected surprises (Alireza et al., 2013). Similarly, the recovery of larger investments calls for a longer CP (De Marco et al., 2012), giving a direct proportionality between the *investment size* (IS) and CP, as shown in Equation 7.

$$\mathbf{CP \propto SIR} \tag{6}$$

$$\mathbf{CP \propto IS} \tag{7}$$

Based on these relationships and the originally sought concession period (CP_0), a quantitative model shown in Equation 8 is developed to attain the modified concession period (MCP). The highlight of this model is the multiplication factor (K) that updates the CP accordingly. Thus, it ensures the dynamism in CP as K can warrant both an increase or a decrease in the original CP_0.

$$\mathbf{MCP = K \times CP_0} \tag{8}$$

$$\mathbf{K = \alpha \times NPV + \sum(\omega)i \times (CF)i} \tag{9}$$

In Equation 9, ωi represents the coefficients (a, b, c, d, …) of the top critical factors (CF) and α is the weight given to NPV. It is imperative to mention that traditional CP estimation relies upon NPV. Since this research attempts to incorporate the additional concerns in the concession decision-making, the proposed model can include necessary additional factors to determine CP.

In this case $\mathbf{CF = RS + PI + MS + SIR + IS}$

$$\mathbf{K} = (\alpha)\mathbf{NPV} + (\mathbf{a})\mathbf{RS} + (\mathbf{b})\mathbf{PI} + (\mathbf{c})\mathbf{MS} + (\mathbf{d})\mathbf{SIR} + (\mathbf{e})\mathbf{IS} \tag{10}$$

The coefficients (α, a, b, c, d, e) are obtained through interviews and online questionnaire survey involving 30 professionals with an experience of at least three PPP projects or minimum 10 years of direct involvement in PPP projects in senior management capacity. The CSFs weights obtained in the previous steps were sought along with comments over using NPV for CP estimation. Projects not using NPV were not considered for this study. The 40% of surveyed experts were from Pakistan while others were from Middle East, USA, UK, Europe, Africa, Australia, China, India and Malaysia.

Step 3: Development of a qualitative SD model

Based on the CSFs and the quantitative model, a generic qualitative SD model was developed. The complexity of the model suggested developing a reduced SD model including the most significant variables (CSFs), combining variables (clusters) including sub systems (NPV and estimation process) and the main system (CP). The model moves forward starting from the very basic factors to their constituent cluster factor which in turn adds into the two mentioned sub systems finally giving the value of K to be multiplied with the main system. The SD models are developed using Vensim PLE ®, a dedicated software designed for modelling one or more quantities that change over time.

Step 4: Model validation

A total of 5 PPP infrastructure projects were used to validate the developed models. For the sake of overarching effect, the case projects encompass completed, in execution and under planning projects. This allows examining holistic pros and cons of the proposed models.

The basic details of the case projects such as starting dates, type, length, location, key parties involved, original concession and project costs are presented in Table 1. It can be observed that all case studies are mainly headed by National Highway Authority (NHA) and Frontier works organization (FWO), the prior being the public body and latter being a major concessionaire. Four of the projects are in Punjab province whereas one is in Sindh province. The minimum inclusion criteria for the projects is set at having a CP of at least 10 years to study it thoroughly.

[Insert Table 1 here]

To evaluate the weights of the CSFs for each case study, an updated version of the previously used questionnaire survey was utilized with the additional option of an increase or decrease in the value of a CSF over project life cycle. This was done to incorporate the dynamic values of CSFs. Project managers and upper managerial executives were asked to rank and determine the increase or decrease of CSFs for each case study. In case of difference in values, multiple rounds of discussions were performed to reach a consensus and avoid any potential conflict.

Results

Factors affecting CP

From the literature review, a total of 70 factors were identified, some of which were merged. For example, the factor *constructability* was named as “construction ease”, “buildability” and “erecting” in various papers which were merged. Similarly, *traffic congestion* was named as “increase in traffic”, “more traffic movement” and “escalated traffic”. Thus, 59 factors were used in the questionnaire survey as shown in Table 2.

[Insert Table 2 here]

From the questionnaire survey, the top 10 factors affecting CPs and their weights were determined as shown in Table 3. The factors are arranged based on the global (overall) weights. *RS* is top ranked factor because PPPs involve huge investments that add to serious financial complications, attracting academic research. Industry is also concerned about its finances and assigns high value to this factor. Similarly, risk in PPP arise from many sources including complex relationships, legal aspects, huge stakes and stakeholder satisfaction, making it a significant factor (Osei-Kyei and Chan, 2017). Further, the scores from both AW and IW were harmonized and converted to the same scale (out of 10). Thus, the value 7.438 for *RS* means that it has a score of 74.38% in AW. The IW score was obtained directly on a scale out of 10 so no conversion was required.

[Insert Table 3 here]

The top 10 factors were reduced to six factors as shown in Table 3 in which the percent effect shows the normalized influence of a factor on the concession decision and formulates the weight given to the factor in the developed model. For normalizing the factors scores, overall score was calculated by adding all values and then finding their percent contribution out of 1 so that the overall factors values will sum up to 1 in the absence of any external factor. The merging is carried out based on the functional similarities and discussion with the experts. This was done to reduce the number of factors and eliminate the confusion of certain factors pointing to the same thing.

Table 4 indicates that NPV receives the highest effect. This means that the experts are inclined towards using NPV based assessment of concession which is in line with the existing literature. Keeping this in view, NPV value is fixed in all case projects and remaining are sought while collecting data. Also, changing NPV will mean challenging existing published frameworks which is not the aim of this study, rather it incorporates additional CSFs. Further, the aim is to induce dynamism in CP estimation.

[Insert Table 4 here]

By substituting the values of percent effect in corresponding variables given in Equation 10, the following equation is obtained.

$$\mathbf{K = 0.29NPV + 0.29PI + 0.14RS + 0.14\ SIR + 0.08MS + 0.07SI}$$

SD model

Based on the previously described methodology, the proposed SD model to estimate modified CP is developed (see Fig 2). The positive or negative influences of each factor are defined with the "+" or "-" signs. For example, the *traffic count* positively effects the *NPV* of a project and is marked with a positive sign. Similarly, *construction costs* negatively affect the *NPV* as evident from the corresponding sign. Thus, all the factors have been marked accordingly to represent their positive or negative influence on CP. These influences result into reinforcing and balancing loops whose combination keeps the system in a natural balance.

[Insert Fig.2 here]

Adopting the FIDIC price adjustment formula (PEC, 2009), the value of K comprises of fixed as well as adjustable portions. The formula fixes 35% cost items and allows for a variable portion of 65%. Since the formula caters for the factors in the same way as intended by the developed model, its logic can be borrowed for the current study. For example, in the formula, 35% items are fixed in any case and should not be disturbed. Following the same lines, the developed model fixes 29% influence of decision for NPV based on the survey responses. The remaining 71% can be varied based on the identified CSFs and their localized percent effect. Thus, the value for K will be between 0.29 to 1.71 with 1, as the normal value in expected circumstances, 0.29 meaning a 100% decrease and 1.71 meaning 100% increase in the value of CP_0.

Furthermore, the values for the factors should always be used in portion of 1 and added to or subtracted from 1 depending upon the relations shown in equations. For example, in case of a project being 20% riskier than normal, the CP value will be factored in at 1.2. This value will be multiplied with the corresponding coefficient to get the value of K. Similarly, in case of the expected PI being 20% more, the CP value will be factored in at 0.8. Thus, the range is fixed and cannot be altered due to both mathematical and simulation limitations. Other ranges can be explored in future studies.

Based upon these logical constraints and the quantitative model, the SD model is developed. For the synthesis and validation of the proposed model, various iterative simulations are run under best, worst and normal values. Based on the triangular distribution, corresponding input values are provided to achieve graphical results. The input values are in the range of 0 – 2 with 1 being the normal value. In all cases, a test concession of 20 years is simulated. The resulting graphs display the number of years on vertical axis where ranges are shown on left side and exact year on right. Start and end years of concession are shown on the horizontal axis. The dark lines refer to the trend for concession whereas lighter lines show the randomized values at any point in the project life cycle. It must be noted that the system was not restricted to a particular value but a range of three-point random values was used as an input, giving a random pattern. To make sense of graphs, focus must be on the trend lines which is the actual CP pattern. Fig. 3 shows that the maximum allowable extension for an original period of 20 years is 34.2, which is quite logical since the system allows for 71% extension in the light of proposed model. In addition, the maximum reducible length of this concession is 5.8 years due to 29% fixed portion. Thus, the system is working in accordance with the developed equation with maximum allowable extension between 0.29 and 1.71.

[Insert Fig. 3 here]

To make it further understandable, the maximum extendable and reducible lengths of CPs were checked separately. This was achieved with two-point iterations with values 0 for obtaining maximum reduction and 2 for maximum extension. The resulting graphs are shown in Fig. 3. The maximum allowable extension is graphically represented using values of 1 for the 20-year project and 2 for the factors to show the extension. The red trend line and corresponding pattern refers to the 20-year concession whereas the blue trend line and corresponding pattern refers to the allowable extension.

Model validation

After obtaining the trend lines for maximum possible variations in the CP_0, the model is validated using five case studies. The case study projects were simulated using the developed model based on the increase (I) or decrease (D) in the value of a particular factor from inception to its current state, the corresponding K and the CP_0 to obtain the MCP. The increase or decrease incorporates the dynamism in values as at any particular time; there can be an increase or decrease in the value of a CSF that can be catered for in the upcoming revision of CP. Thus, CP can be revised accordingly to ensure a win-win situation for both public and private entities. Project managers and upper managerial executives ranked and determined the increase or decrease of each CSFs for each case study. In case of difference in values, multiple rounds of discussions were performed to reach a consensus. Table 5 presents the accorded factors for each project. For example, the first project observed an increase of 11% in its *RS* as reflected in corresponding RS column. The resulting K value indicates a reduction in the original concession. Similarly, the second project shows a decrease in IS and SIR and increase in RS and PI which are reflected in its MCP using obtained K value. Detailed simulation output is shown in Fig. 4.

[Insert Table 5 here]

Although an initial CP of 10 years was awarded to Project 1, the payback was achieved in almost half of that time. According to the findings of this study, the post-feasibility studies conducted in 2015 revealed an interesting pattern of recovery according to which the project concession was overestimated. Then, the CP was revised with mutual consent and handed back to NHA only in 6 years in 2015. The calculations suggest a justified CP of 6.1 years as shown in Fig. 4. The red trend line refers to CP_0 and the blue line to MCP. The calculation only strengthens what was already known in this scenario. The key factor leading to the success in this project was its substantial payback in the form of large toll volume due to existing higher traffic. Further, owing to positive socio-political conditions, the market was supportive. In addition, the smaller project size, the less complicated nature, brownfield construction and easy access approach due to non-proximity with any urban area aided to the quick financial recovery. Had a proper procedure been followed in the planning phase or a revision mechanism for CP existed, the project could have been realistically planned to award a justified concession or revise it accordingly.

[Insert Fig. 4 here]

Project 2 was an extension of an existing route with tolling as the source of major income. The CP_0 was 25 years based upon local experience. As per the findings, it seems that the project would have been justified even if a CP of 24.5 years was committed, under the existing conditions. This reduction in concession is associated with an average growth of 30% in the number of vehicles or transportation means during years 2003 – 2005. No route promotion was required to attract new traffic as the route was already well established. High tolling is possible during the years of concession. The companies involved in construction have high expertise in field of highway construction. Based on this finding, it can be recommended that if the above conditions prevail, the CP can be shortened. In the current form, the concessionaire seems to have been incentivized for committing to the project. It must be appreciated but not at the cost of opportunities for public revenue generation. This warrants dynamism in CP which is at the core of this study.

Project 3 output suggests that based upon the current situation, the CP must be increased to almost 20.5 years to incorporate the additional risks and decreasing RS. Keeping in mind that only three years have passed since the start of construction, the situation seems very alarming and demands to keep the concession in check, otherwise the project will need extension for proper financial recovery or may fuel disputes among the key stakeholders. Among other factors, PI and MS balance each other because of soon-to-be-constructed interchanges and, subsequently, more toll production. Therefore, there will be no overall change in expected motorway usage. The main reason for the increase in CP can be linked to the lack of coordination and communication between the stakeholders as quoted by the PM representatives, and the increased risks of rework due to poor quality management and schedule crashing. In a follow-up inspection, non-conformance was issued for a 6 km patch and reconstruction notice was served. This validates the findings of the model and points to early corrective actions or otherwise concession extension will be required.

Project 4 originally sought CP of 25 years. Due to risky nature of project because of lack of proper tolling, prequalification technique was used for shortlisting the potential contractors. The PI is supposed to follow the tolling stream mainly along with government subsidies since tolls are not expected to entirely meet the contractor's expenses. The total project cost was estimated at PKR 52 (USD $ 0.50) billion. An amount of PKR 18 (USD $ 0.17) billion was committed by the Ministry of Planning and Development under Viability Gap Funding (VGF) while PKR 5 (USD $ 0.048) billion will be lent by the Ministry of Finance to NHA. The accumulated sum of PKR 23 (USD $ 0.22) billion will be provided to FWO as financial assistance over the construction phase. The results indicate that the CP should be increased to 27.04 years to incorporate the additional financial risks associated with the project due to lack of tolling and required traffic. Furthermore, since it is a greenfield construction, project risk is high.

Thus, the originally determined CP is not feasible for the project and is recommended for revision based upon the findings.

Project 5 is considered as an ill-fated and highly convicted project due to previous procurement failures, serving as a bad example of project planning. Since the project could not start in last three procurements, its cost has jumped from an originally estimated value of PKR 7 (US $ 0.067) billion in 2005 to latest value of PKR 36 (US $ 0.34) billion in 2015. The main reason for unsuccessful procurement is lack of political will of prime stakeholders. The socio-political complexity in the form of land acquisition has been one of the primary issues in this project. As a result, the government awarded the project to FWO, which is a state-owned enterprise with similar success stories to its credit. The input values were obtained from project experts in accordance with the previously mentioned experience guidelines. The simulation results, shown in Fig. 4, point to an increased CP of over 28 years. This increase in concession is directly associated with increased risks, deteriorating MS and lesser revenue availability. The concessionaire confidence is also disturbed by the project history of previous failures to start as reflected by the values assigned to each factor. In case these conditions prevail, the findings advocate a concession extension up to 28.2 years for incorporating the increased risks and poor MS.

Discussion

The findings of simulated case projects show that considering all risk in concession estimation is a challenging task due to data demands and analytical complexities. The proposed methodology advocates revisiting the originally awarded concessions to accommodate complex emergent risk. This points to a weak PPP system in the country which is primarily due to a recent focus to this delivery mechanism. The system is infested with weak legal, contractual and methodical mechanisms. Since only one PPP project has completed its concession, the possible documented repercussions cannot be discussed with proper reference. This study highlights the upcoming problem of possible concession extension which can cause disputes. Therefore, proactive management is required to get the projects back on track by either developing contingency plans or increasing the concessions as highlighted by the findings. The inability to do so may result not only in failure of specific projects but will paint a negative picture of entire PPP procurement capability of the concerned authorities. Such negative image will discourage the investors who may otherwise be agents of running the engine of economy and uplifting the social standards by providing jobs and better infrastructure (Rahmani et al., 2017) . The proposed model can be used for verifying an estimated concession and dynamically revising it at regular pre-agreed intervals. This will help the local stakeholders in realistic concession assignment and subsequent modification. Other market segments can modify the model according to their contextual needs and priorities.

As mentioned, the revision mechanism along with incorporating the strategy offered by this study may help rationalize the concession lengths. This may result into increased investor confidence in two ways: working out holistic concession agreement that considers the locally focused CSFs and ensuring timely recovery of capital as well as interest due to realistic assessment at planning stage and reliable monitoring during project life. The elated confidence will boost the infrastructure procurement, resulting in better and economic constructed facilities.

The agencies will also benefit in the form of better estimate of total project cost during the pre-feasibility phase where the financial evaluation is performed due to country-specific factors that affect private and public stakeholders. With this knowledge, public agencies may better perform the concession negotiation and set the toll rules keeping in view not only the present economic conditions but also the financial projections (Ullah and Thaheem, 2017). End users will benefit in the shape of nominal tariff charges and improved quality of service as the probabilistic analysis, in the light of performance curves, will dictate the maintenance and rehabilitation decisions ensuring top-quality road conditions resulting in reduced travel time and improved ride quality. Thus, the models provide reliable estimation and reassessment of CP at any stage within the project life cycle.

Conclusions

This study identified 59 CSFs that affect CP. The results of the survey of 26 industrial and 30 academic experts determined that the *NPV, PI, RS, SIR, MS and IS* are the most influential aspects with a minimum of 8% influence by *MS* and *IS*, and a maximum of 29% by *NPV*. Further analysis shows that NPV received the highest value which is in accordance with the published literature, and its association with financial concerns and return, which is seemingly the top priority in PPP projects.

Additionally, a quantitative model based on the top influential factors was developed and served as an input to develop a SD model to determine the CP under the influence of CSFs. Since the existing models are not capable of meeting the increasing complexities and demands of PPP concessions and a universal model may not be the best solution, the proposed model solves this dilemma through localized CSFs. The proposed model was validated by simulating five local case studies of completed and ongoing infrastructure projects with a minimum concession of 10 years to forecast the required concession under current circumstances.

The case projects 3, 4 and 5 indicate that due to non-considerations of the identified CSFs, an extension is necessary. The reasons for this anomaly extend from quality management to risky greenfield construction, lack of promotions and interests of the public bodies in the form of local PPP policies. The projects in initial stages of execution can still be controlled if the identified CSFs are incorporated, otherwise extension will be the only way out as shown by the simulation results. Further, the conclusions are strengthened by the findings of project 1 which clearly highlights an erroneous CP assessment and had it not been the concessionaire presenting the idea of transfer, the project would have been a failure based upon post completion assessments. Project 2 is the only project demanding concession reduction pointing to its better assessment mainly due to the increased traffic and more usage of the route.

The key takeaway from this study is the introduction of dynamic CP modification model. Thus, a CP can be estimated properly if localized CSFs used in this model are incorporated that may be changed per local requirements. Even if due to some unforeseen reasons, an unrealistic CP is estimated, the model provides a dynamic recovery mechanism where the CP can be revised after a pre-agreed interval on regular basis. This will not only ensure that project is progressing well but also entail the ever-required partnership and win-win situation for both parties. If the project is progressing well and pre-agreed (NPV based) recovery can be achieved in lesser time than original CP, the CP can be reduced otherwise incase of poorly performing project (not a contractor default) but changed conditions or poor original CP estimate, the CP can be increased to ensure a no-loss to the private entity. Thus, it will increase the investor's confidence in the public authorities by ensuring a no loss situation in case of no default. This will repaint a positive image of PPPs and attract more private investment which is an asset for the developing countries.

Due to the limited results of the real-life PPP projects, the potential repercussions of unrealistic concession assignments are not known. Therefore, in the face of complex emergent scenarios, this study suggests the local practitioners to proactively manage the concession risks. The proposed models, treating the CP as a dynamic concept, contribute to a more transparent concession system by introducing the possibility of systematic modification and enhancing the chances to achieve a win-win scenario. It is the first step towards enhancing the CP revision in developing countries and further exploratory studies are required to enrich its potential by incorporating the effects of social welfare and user expectations on CP length. The proposed model is highly adaptive and flexible, allowing to incorporate additional factors. Furthermore, the management research being ontological in nature will always be subjective which may allow for disagreements as the current study is largely influenced by the experts from developing countries with limited resources and unique constraints. The study can yield different results when repeated in a different context and is thus a future direction for expansion of proposed model.

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