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MODELING CONCESSION PROJECT INVESTMENTS UNDER UNCERTAINTY: A CRITICAL REVIEW

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ABSTRACT
The concession contract is becoming progressively popular as a procurement mode for large infrastructure projects worldwide. The long-term nature of these projects, coupled with the pressure of an increasingly competitive international market, exposes construction companies to greater risk than ever before. Several decision support systems (DSSs) combining economic and risk analyses have been developed for the evaluation of concession project investments (CPIs). These are structured using a wide variety of frameworks, predominantly adopting the probability theory as a mathematical modelling technique. However, there is a new school of thought that the frameworks adopted in these DSSs do not accurately reflect reality, and that the possibility theory would be more appropriate as a modelling technique. This paper discusses the key requirements of an effective yet efficient DSS, and provides a critical review of currently available systems according to two selection criteria: (1) a suitable DSS framework, and (2) an appropriate mathematical modelling technique. It then proposes that a DSS that uses an Analytical Network Process (ANP) framework in conjunction with possibility theory achieves both effectiveness and efficiency for the specific application of modelling CPIs.

KEYWORDS
Concession Project Investment, Decision Support System, Economic Analysis, Risk and Uncertainty, Possibility Theory.

1. INTRODUCTION

A largely globalised construction industry in which governments are more and more procuring vital infrastructure projects via concession contracts, has created a cut-throat environment for private sector companies today. Concession contracts by nature are long-term investments involving complex organisational structures. Over the lifespan of these projects the legislative, political, and socio-economic environment, as well as market share and demand levels could all change significantly. Thus there is high degree of risk and uncertainty surrounding these projects, and the success of a contracting company relies heavily upon its ability to select those investment options of most benefit in both the short and long term. Whether these benefits are purely monetary or a combination of monetary and non-monetary gains, investment options must be compared as objectively as possible.

Contracting organisations and developers tend to concentrate on establishing the financial viability of a project through feasibility studies. A project is deemed economically feasible, if the expected revenue meets or exceeds an acceptable pre-determined level of return on the organisation's initial investment. As this procedure involves a degree of forecasting, decisions are frequently made based on past experience, either rationally or intuitively with some degree of uncertainty, and thus are made under risk (Moselhi and Deb, 1993). If the total uncertainty is significant, as in the case of long term, concession project investments, not recognising it will often totally distort the predictions, in an unknown way, making any decisions based on these predictions highly suspect. Therefore, it is paramount for an organisation to be able to predict and compare all possible future monetary outcomes taking into account the inherent uncertainty associated with selected investment parameters including construction, operation and maintenance costs, interest rates, inflation, depreciation, tax rate, and operation life.

Traditionally, the Net Present Value (NPV), Internal-Rate-of-Return (IRR) and Pay-back Period investment appraisal techniques have formed the major component of feasibility studies. These three (3) techniques are based upon the time-cost-of-money principle and use slightly varied procedures to forecast the expected monetary returns on an investment. The reliability of their output depends upon the accuracy of the deterministic cash flow values (revenues and costs), and their timing, as estimated by the organisation. A fundamental limitation of this assumption is that the various investment parameters cannot be practically assumed with a high degree of certainty. The value of each individual parameter is affected by a myriad of risks and uncertainties which are often difficult to quantify. An element of uncertainty lies within each prediction which, alone or in combination, may have a significant impact on the outcome of the economic analysis. Uncertainty, emanating from the project itself or external factors, will always be present and needs to be accurately captured in the decision-making process (Dong and Shah, 1987).

In addition to the crucial uncertainty factor, the above techniques do not allow for the non-monetary (qualitative) factors to be considered in assessing the investment option. Non-monetary project aspects such as social, environmental, political, legal and market share factors are deemed to be important; but these would usually be considered to lie outside the normal appraisal process (Lopez and Flavell, 1998). Such aspects need careful analysis and understanding so that they can be managed (Tweedale, 1993). In extreme cases, neglect of these aspects can cause the failure of a project despite very favourable financial components (Toakley, 1997), or even the failure to go-ahead with a project that may have been of great non-monetary benefit due to its projected ordinary returns. For example, dramatic change in government policy can substantially change project revenue to the extent that a once feasible project is rendered unprofitable, or a project may open the door to many larger projects for the company in future. Therefore, it is recommended that the viability of a CPI should not be determined by monetary considerations alone.

A proper feasibility study should also provide the organisation with the opportunity to include factors related to the economic environment (boom or recession), project complexity, technical innovation, market share, competition, national significance and other strategic aspects. To provide for the effects of these qualitative aspects, the majority of organisations resort to estimating the necessary money contingencies or risk premiums, without an appropriate quantification of the combined effects of monetary and non-monetary factors.

With the increasing popularity of privately financed, concession projects in recent years, a systematic evaluation of investment options is needed, especially if these options are competing for the same capital resource. In a perfect world, an analyst contemplating an economic decision would have access to precise deterministic values. Unfortunately, this ideal state does not exist when investing in a project where there is uncertainty about nearly every estimate that is entered into an economic model (Choobineh and Behrens, 1992). Thus, analysts require a DSS or decision making tool capable of effectively and efficiently modelling the combined effect of monetary and non-monetary factors for various project investment options, as well as ranking these options according to set criteria.

This paper discusses the key requirements of an efficient, effective DSS, and provides a critical review of currently available systems according to the two selection criteria of: (1) a suitable DSS framework and (2) an appropriate mathematical modelling technique. It then proposes that a DSS using the Analytical Network Process framework in conjunction with possibility theory achieves both efficiency and effectiveness for the specific application of a holistic CPI DSS.

2. KEY REQUIREMENTS OF AN EFFECTIVE YET EFFICIENT DSS

As depicted in the flowchart of Figure 1, a DSS should comprise four basic modules: input definition, CPI model development, CPI model analysis, and ranking of several CPI investment options. The CPI model is developed and structured according to the interrelationship between the input monetary and non-monetary factors. The DSS then analyses the model developed and ranks the various CPI options according to their overall scores.

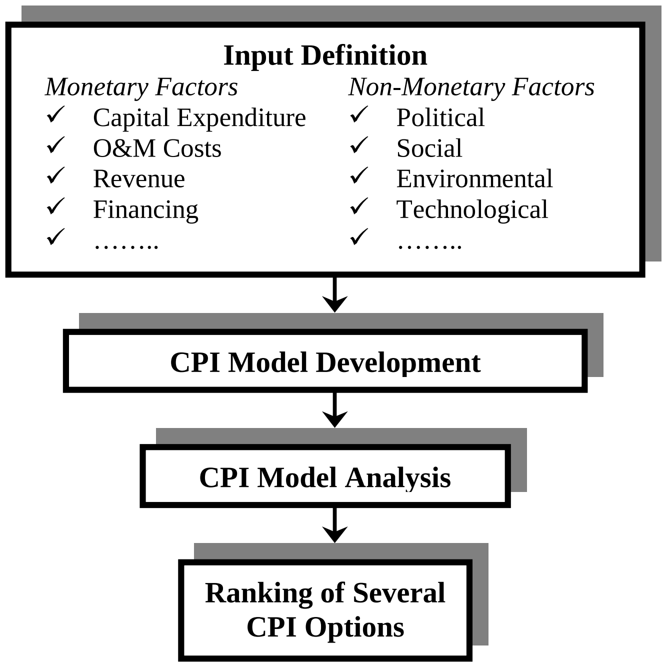

Figure 1: Flowchart of CPI DSS

According to Abdel-Aziz (2000), a DSS should be capable of modelling the following generalised aspects of concession project investments:

- various industries and evaluation methods;
- multiple project phases/sub-phases;
- cash flow characteristics;
- time dependent project variables;
- varied performance measures (eg. Benefit-cost ratio, NPV, IRR);
- uncertainty;
- comparison of several project alternatives/scenarios (incl. Sensitivity Analysis);
- both detailed and generalised aspects of projects.

The above list ensures that the DSS caters for the complexity of concession project investments both financially and organisationally. CPIs involve a diversity of industries which adopt varied performance measures in evaluating investment feasibility according to their own vested interests in the project. Financially speaking, CPI cash flow characteristics are also diverse, and even variable throughout the project. The DSS should be capable of modelling such diversity and variability. Finally, Abdel-Aziz (2000) proposes that a DSS should be capable of comparing several project investment options of different types (road, rail, power, water treatment), identifying particularly sensitive factors, and catering for both highly defined and highly uncertain input data.

Two additional aspects of CPIs that should be included in the above list are:

- the interdependency of factors (both monetary and non-monetary); and
- the identification of important non-monetary factors contributing to uncertainties (both positively and negatively impacting).

In a real life project situation, the non-monetary factors are often numerous and dependent. The DSS must assist decision makers in individually identifying the more critical, non-monetary factors and their interdependencies (for example, political environment could affect environmental regulations), as the resultant uncertainty is simply too great for the human mind to evaluate due to the complexity of the decision problem. Thus, it is imperative that the DSS caters for the individual identification of non-monetary factors and the interdependency of factors to truly reflect the investment decision problem. Although several attempts have been made to cater for these two additional aspects, they have failed to incorporate all aspects listed above, in a DSS that effectively and efficiently models a CPI situation.

A DSS must be effective in modelling *all* the above aspects of a CPI, yet also be efficient in doing so. With these two design criteria in mind, it is imperative that both the selected framework structure and the mathematical modelling technique (deterministic, probabilistic, or fuzzy), are those that most closely reflect the structure of these types of investments and the true degree of certainty surrounding the project. If the wrong selection is made for either of these, results may be deceptive and the system might not be user friendly due to difficulties encountered in user input.

3. MATHEMATICAL MODELLING TECHNIQUE SELECTION - POSSIBILITY THEORY VS. PROBABILITY THEORY

According to Triantaphyllou (2000), most experts preach that the single most important step in solving any decision making problem, is to first correctly define the problem. In the construction industry today, probability theory is the most widely accepted technique for modelling risk and uncertainty (Mohamed and McCowan, 2001). This technique uses “Monte Carlo” simulation to model the combined affect of numerous risk factors according to their relative frequencies.

One of the troublesome issues associated with probability theory is the utilisation of a probability measure to evaluate uncertainty. Therefore, much effort is needed in defining and developing each contributing risk factor’s probability distribution using historical data in estimating relative frequencies. Since each construction project is affected by different risk factors, accurate knowledge of relative frequencies cannot simply be assumed from another project, as would be possible in other industries such as manufacturing where events have a repetitive nature.

Most analysts take it for granted that uncertainty is a model associated with randomness (Behrens and Choobineh, 1989). While probability theory can be a powerful tool in the appropriate circumstances, many times the type of uncertainty encountered in construction projects does not fit the axiomatic basis of probability theory. This is simply because the uncertainty in these projects is usually caused by the inherent fuzziness of the parameter estimate rather than randomness (Choobineh and Behrens, 1992). Uncertainty involved in real risk situations is often epistemic (relating to the knowledge of things) rather than alearotic (depending on chance) (Williams, 1993). The use of probability for the purpose of investment appraisal is well documented (Gregory, 1988).

Another limitation of using probability theory is that the influence of non-monetary (risk) factors on projects is often difficult to quantify. The lack of know-how in measuring strategic and intangible (qualitative) costs and benefits led current DSSs to ignore their contribution to the overall economic analysis.

One way to alleviate the above shortcomings is to use the possibility theory where the user needs only to determine a possible range, and perhaps even a most likely range for each investment parameter, without the input of each factor’s relative frequency.

The possibility theory is an appropriate vehicle as it is based on the concept that all values within a certain range are possible, with the exact value being unknown. A range of values, or an interval, is assigned subjectively, but the individual values in the interval are not assigned a relative belief value. An expert may feel that a given parameter is within a certain range and may even have an intuitive ‘feel’ for the ‘best’ value within that range. However, seldom will the analyst have an empirical foundation for the estimate based on frequency of occurrence (Choobineh and Behrens, 1992). Mak (1995) argues that normative theories in probability are not as applicable in the construction industry as some may perceive, and considers possibility theory to be superior to probability theory in analysing problems where subjective judgements dominate the risk analysis process. This viewpoint is shared and supported also by others (Andersson, 1998; Schmucker, 1984).

The possibility theory has been used successfully in a wide range of construction engineering fields including: project scheduling and network analysis (Chisaki et al, 1992; Lorterapong and Moselhi, 1996), contract selection and decision making (Wong and So, 1995; Wang et al, 1996) and safety performance (Tam and Fung, 1996).

In view of the above, the authors concluded that the possibility theory appears to be more appropriate, under the above circumstances, for modelling project investment decisions under risk than probability theory.

4. DSS FRAMEWORK SELECTION

The number of DSS framework variations found in literature is seemingly endless. This paper will concentrate on those that have already been applied to the CPI modelling problem, and those considered most suitable. The purpose is not to give detailed description of the frameworks mentioned, but to highlight their shortcomings which inhibit their effectiveness or efficiency as a decision making tool in the construction industry.

4.1 Economic Frameworks Incorporating Uncertainty

The following DSSs are fully developed computer software packages that perform both probability and sensitivity analysis in order to predict an expected envelope of values for selected project performance measures:

- CASPAR (Merna and Storch, 1999)
- UNIDO's COMFAR III
- @RISK
- NPV-At-Risk
- Value At Risk
- World Bank's INFRISK (Dailami et al., 1999)
- Four Moment Framework (Abdel-Aziz, 2000)

The results provided by these systems are quantitative in the form of time durations or cash flows, thus facilitating a definite "go-no go" decision. However, the limitations of the above frameworks include:

- the absence of correlation between variables;
- the failure to identify individual non-monetary risk factors that cause uncertainty distributions in forecasts;
- the input requirement of detailed probability distribution parameters or four moments;
- and in some cases, the complexity of calculations which renders the system prone to crashing when simulating realistic investment situations.

4.2 Frameworks based upon Portfolio Theory

Attempts have also been made to develop DSS's based upon the concept of Portfolio Theory (Park and Herath, 2000, Toakley, 1997). Park and Herath (2000) believe that the Real Options approach integrates traditional capital budgeting with strategic (long range) planning by capturing the flexibility to delay an investment. However, when bidding for a concession project, companies have no real option to delay. The project schedule is usually determined by public sector departments, according to community needs. Thus, Portfolio Theory does not apply to the specific application of modelling infrastructure project investment decisions.

4.3 Multi-Criteria Decision Frameworks

In essence, the decision to invest in a concession project is a multi criteria decision problem. Neural Networks (Lam et al, 2001), Multi-Criteria Analysis (Choobineh, 1990, Wirba et al, 1996, Wong, 2000), Weighted Sum Model (Mohamed and McCowan, 2000), Weighted Product Model, and Multi-Attribute Utility Analysis (Moselhi and Deb, 1993, Accorsi et al, 1999, Duarte 2001, Yeh et al, 1999) are all multi criteria decision frameworks which do not consider the interdependency of factors. Unfortunately in real life project situations, factor interdependencies can significantly affect the overall feasibility of an investment. Therefore, these frameworks would not accurately reflect the investment situation. There are several frameworks that attempt to capture the interdependency of non-monetary factors. These are briefly described below:

Cross Impact Analysis incorporating probabilistic inference is used by Han and Diekmann (2001) to model the effect of political condition, economic condition, and technological ability on the initially estimated project cost. The variables in the model only affect the shape of the initially estimated project cost, not the lower and upper bounds, of the distribution. In other words the analyst must estimate the bounds of the final project cost distribution incorporating the effects of the variables prior to defining the variables and their interactions.

The Analytical Hierarchy Process (AHP) was developed by Saaty, and has been applied by others to the assessment of construction risk (Paek et al, 1992, Tah and Carr, 2000). A fundamental assumption of the AHP is that all elements (factors) and criteria within the structure are independent of each other. For example, the relationship between the risk of a change of political direction and a change in environmental regulations can not be modelled by the AHP.

This limitation of the AHP was addressed by Hastak and Shaked (2000), in the ICRAM-1 model. The ICRAM-1 model is a variation of the AHP that allows a specific lower level sub-criterion to be directly affected by an overall upper level criterion. For example, the overall political environment could affect a sub-criterion of the future market volume. However, a specific sub-criterion of the political environment can not affect a specific sub-criterion of another criteria market potential.

The Analytical Network Process (ANP) was developed by Saaty (1996) as a variation of the original AHP in order to cater for the dependence of individual elements both within and inbetween clusters (criteria). As depicted in Figure 2, ANP looks more like a network than a hierarchy, making it an ideal DSS framework for modelling the complexity of a real-life CPI situation.

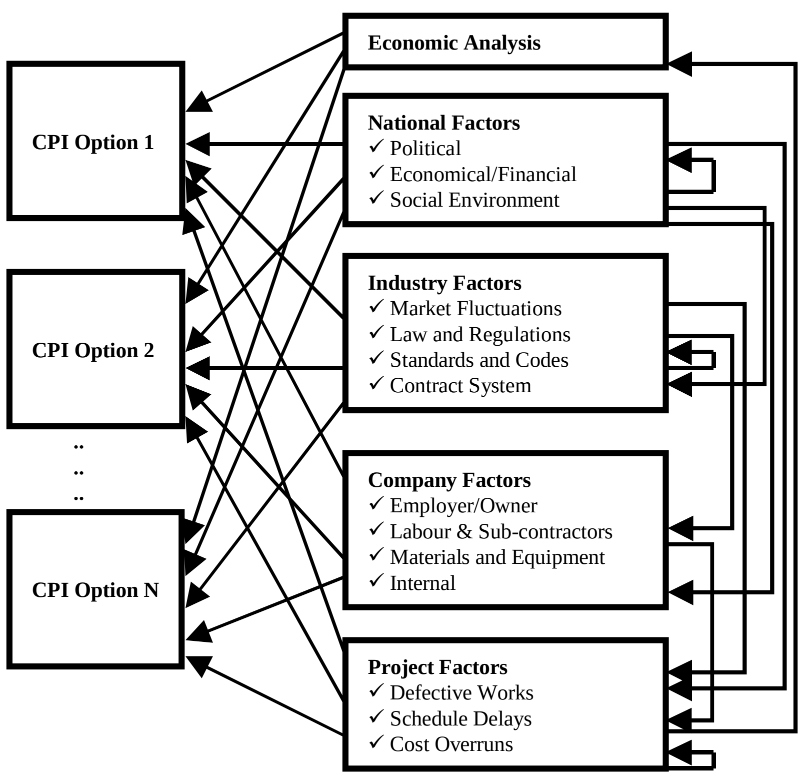

Figure 2: Typical ANP Framework Adapted From Zhi's (1995) Risk Identification Hierarchy

Saaty (1996) argues that we cannot collapse complexity artificially into a simplistic structure of two levels, criteria and alternatives, and hope to capture the outcome of interactions in the form of highly condensed judgements that correctly reflect all that goes on in the world. Although the ANP requires more effort, it is not a difficult task and can often lead to the discovery of new elements or the clarification of the decision problem (Saaty, 1996). Infact, the amount of user input could be greatly reduced by simply giving the analyst the option of assigning dependencies between elements (factors) only where required.

For the above reasons, it was concluded that the ANP appears to be the most appropriate DSS framework, under the above circumstances, for modelling CPI decisions.

5. CONCLUSION

The long-term nature of concession projects, coupled with the pressure of an increasingly competitive international market, exposes construction companies to greater risk than ever before. Several DSSs combining economic and risk analyses have been developed for the evaluation of concession project investments at the feasibility stage. This paper discusses the key requirements of an effective yet efficient DSS, and provides a critical review of current DSSs according to adopted framework and mathematical modelling technique. It identifies the shortcomings of currently available DSSs in accurately reflecting real-life CPI situations in the most efficient manner. It then proposes that a DSS using an Analytical Network Process (ANP) framework in conjunction with the possibility theory achieves both effectiveness and efficiency for the specific application of modelling and ranking concession project investment options. Future research will focus on the development of a DSS in the form of a user-friendly, computer software package, its verification through an industry survey, and validation using concession project case studies.

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