Decision Support System to Evaluate and Compare Concession Options

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Abstract: With the increased popularity of concession projects over the last three decades, there is a need for a decision support system (DSS) capable of evaluating and comparing several concession project investment (CPI) options in an effective and efficient manner. Hence, a novel DSS has been developed that takes into consideration both financial and nonfinancial aspects of the investment option, as well as the uncertainties commonly encountered during the feasibility stage of a project. The DSS is fully implemented as a standalone computer software package, ECCO (evaluate and compare concession options), in order to be of practical use. This paper outlines and validates ECCO's design and structure through the demonstration of its capabilities in the evaluation and comparison of three real-life CPI case studies.

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Background

Concession projects can be defined as privately financed infrastructure (PFI) projects or public–private partnerships (PPPs) where the government grants the private sector a licence or concession to deliver infrastructure services of a certain type for a set length of time, for example, build–operate–transfer (BOT) projects. Theoretically, these projects present a win–win–win solution for the community at large, and both private and public sector participants. However, with the opportunity for private sector companies to earn higher returns comes greater risk and although private sector participants generally look upon the concession project option favorably, they have admitted that there are problems that must be addressed to improve the process (Akintoye et al. 2003). This underperformance of concession projects has been attributed to the inability of project sponsors and promoters to predict the impact of all financial and nonfinancial (risk and opportunity) factors associated with concession project investments (CPIs) and, to negotiate contracts to allow for these factors (Halligan 1997).

Decision support systems (DSSs) are systems designed to assist in the decision making process by providing all necessary information to the analyst. There are a number of DSSs that have been developed over recent years for the evaluation of high-risk construction project investments, such as CPIs. DSSs, such as COMFAR III, CASPAR (Merna and von Storch 2000), NPV-at-Risk (Ye and Tiong 2000) and INFRISK (Dailami et al. 1999) are all fully developed computer software packages that perform both probability and sensitivity analyses on economic parameters in order to predict an expected envelope of values for selected economic performance measures of projects. However, the viability of a CPI should not be determined by financial considerations alone. Nonfinancial project aspects (e.g., social, environmental, political, etc.) need careful analysis and understanding for evaluation of CPIs in a holistic fashion. For more on the limitations of the abovementioned DSSs, the reader is referred to McCowan and Mohamed (2002).

In order to appraise CPI highway projects, Ock (1998) applied a cross impact analysis (CIA) framework for inclusion of nonfinancial aspects in the probabilistic financial analysis model. However, the main limitation of this framework is that the model variables only affect the shape of the estimated project cost, not the lower and upper bounds of the probability 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. Another limitation is that frameworks which employ a brainstorm technique (e.g., the CIA) tend to be confusing when modeling complex decision problems (Saaty 2001). To overcome these limitations, nonmonetary project aspects could be incorporated in the financial analysis model in the form of risk factors. Objective risk assessment could be achieved using techniques such as the analytic hierarchy process (Tah and Carr 2000), however, this process assumes risk factors to be independent of each other which is not the case in real-life CPI options.

Against the above background, this paper presents the development and capabilities of a DSS capable of taking into consideration both financial and nonfinancial aspects of a CPI option, as well as the uncertainties commonly encountered during the feasibility stage. Capabilities of the developed DSS, evaluate and com-

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pare concession options (ECCO), are then demonstrated via input reflecting real-life CPI case studies.

Overview of ECCO

ECCO evaluates and ranks various CPI options by incorporating both financial and nonfinancial aspects of an investment, as well as the uncertainties commonly encountered at the feasibility stage. This primary objective largely dominated the design of ECCO which is based upon a combination of: (1) a mathematical modeling technique and a financial analysis model that captures the true degree of (un)certainty surrounding the project; and (2) a decision making technique and a risk factor framework (RFF) that most closely reproduces the complexity of CPI decisions. To satisfy this requirement, the analytic network process (ANP) project rating method (Saaty 2001) was utilized to provide a holistic evaluation of the CPI option's feasibility by extending the traditional financial benefit/cost (B/C) ratio, to incorporate nonfinancial aspects via an opportunity/risk (O/R) ratio.

ECCO caters to the different perspectives of equity holders, lenders, and government parties by considering a total of 15 project performance measures, including 11 financial, three nonfinancial, and one combined (financial and nonfinancial) measure. ECCO is also capable of comparing the sensitivity of up to five projects to positive or negative changes in any single factor (financial or nonfinancial) common to all projects under assessment. Finally, ECCO is an easy-to-use dialog-based application much like a commonly used Wizard program and comprises three basic modules: Module 1: model definition; Module 2: model evaluation and ranking; and Module 3: sensitivity analysis. Module 1 performs the function of creating individual project investment models based on a combination of financial factors (e.g., construction cost, operations, and maintenance costs, revenues, and other financial parameters), and nonfinancial factors (e.g., risks and opportunities). Once the individual project investment models have been developed, Module 2 could be used to evaluate, compare, and rank up to five projects. ECCO also caters to the determination of the criticality of selected factors (nonfinancial or financial) on various project investment options via Module 3. Each of the three modules caters to the creation of tab-delimited output files that can be opened in Notepad, Microsoft Word, or Microsoft Excel for further analysis or printing.

Module 1: Model Definition

In order to maximize user time and resource efficiencies, the level of input data required by ECCO has been kept in line with that typically available to analysts at the feasibility stage of a project, the possibility (fuzzy) theory is used to define both financial and nonfinancial data in the program. Also, to make risk assessment easier for the analyst, a generic CPI RFF is also offered as an option when defining risk factors. This RFF contains the four most critical project risk factors at the country, market, and project levels as previously identified by Wang et al. (2002), as well as the quantified interdependencies between these risk factors, as identified by McCowan (2004). Finally, the analyst can either define input data through dialog boxes, similar to that shown in Fig. 1, or enter it directly into the project file using Microsoft Excel or Word.

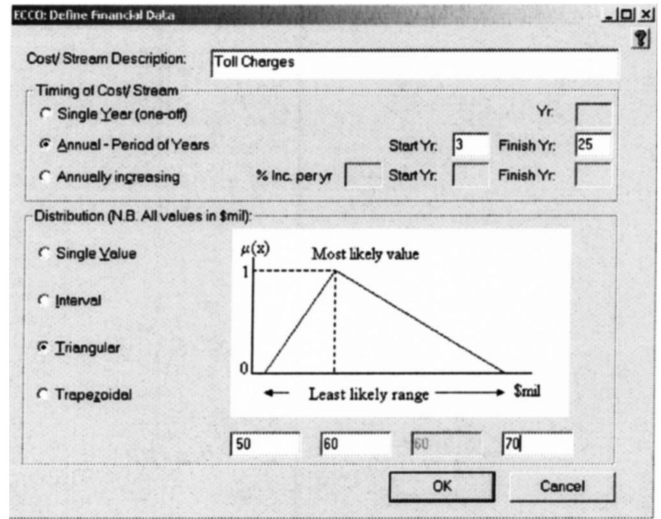

Fig. 1. ECCO's define financial data dialog box

Financial Component

The financial component of Module 1 is structured according to Bakatjan et al.'s (2003) two-phase financial analysis model. Using this model, financial cost and revenue factors are divided into two project phases: construction and operations. Analysts can define financial parameters (e.g., interest rate), costs, and revenue streams using single, interval, triangular, or trapezoidal possibility distributions in any of the following forms:

- One-off payments taking place in a certain year;
- Annual payments over a set period; or
- Annually increasing payments over a set period.

Nonfinancial Component

Using the ANP project rating method, nonfinancial factors of the project investment must be divided into two separate ANP-based frameworks for opportunities and risks. The ANP technique typically requires that all projects being rated and compared share the same risk and opportunity factor frameworks. However, since risks and opportunities faced by one project may not necessarily be the same as another project, the ANP's implementation in ECCO was slightly modified to allow flexibility for the analyst to be able to define a unique set of risk/opportunity factors for each project, as required.

A 1 (weak) to 7 (extreme) scale was employed in ECCO's design for the definition of nonfinancial factor importance, likelihood, and any interdependencies between nonfinancial factors (2, 4, and 6 can also be used as intermediate values on the scale). The nonfinancial factor's *importance* can been defined as the degree of impact on the project should a particular factor occur, *likelihood* as the possibility of a factor actually occurring/impacting upon the project, and *interdependency* as the existence of an influence of one factor on another (e.g., political instability risk may influence approval and permit risk).

The generic RFF and interdependencies can either be used in addition to other identified risk factors, or simply on their own. However, the analyst remains responsible for the quantification of each factor's importance and likelihood, as these will change from project to project. ECCO's generic RFF with interdependen-

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Table 1. ECCO's Generic Risk Influence Matrix

Direction of Influence →	C1 - Approval and Permit	C2 - Change in Law / Justice	C3 – Corruption	C4 - Political Instability	M1 - Local Partner's Creditworthiness	M2 - Corporate Fraud	M3 - Termination of Joint Venture	M4 - Inflation and Interest Rates	P1 - Cost Overrun	P2 - Improper Design	P3 - Improper Quality Control	P4 - Improper Project Management
C1 - Approval and Permit		3	7	5								
C2 - Change in Law / Justice Reinforcement			3	5								
C3 – Corruption				5								
C4 - Political Instability								3				
M1 - Local Partner's Creditworthiness			1	1		5			5			
M2 - Corporate Fraud			3	1								
M3 - Termination of Joint Venture		3	1	3	3	5			5			
M4 - Inflation and Interest Rates			3	7								
P1 - Cost Overrun	3	3		1	1	1		5		5	3	5
P2 - Improper Design		1				1					1	
P3 - Improper Quality Control		1	1			1						3
P4 - Improper Project Management		1	1			3						

cies [in the form of a risk influence matrix (RIM)] is presented as Table 1. Fig. 2 presents a summary flowchart of ECCO's Module 1: model definition.

Module 2: Model Evaluation and Ranking

The main purpose of this module is to evaluate, rank up to five CPIs at a time based on the calculation of the following 15 performance measures, and then present evaluation results in both tabular and graphical forms:

Primary Performance Measure

1. BO/CR: the product of the B/C and O/R ratios—using ANP project rating

Secondary Performance Measures

Financial

Equity holder (includes financing considerations)

2. Total project cost NPV ($);
3. Equity holder cumulative cash flows (nondiscounted) ($);
4. Equity holder payback period (year);
5. Equity holder NPV ($);
6. Equity holder benefit/cost ratio (0–1); and
7. Equity holder IRR (%).

Lender

8. Debt service coverage ratios (DSCR).

Government (overall project) (not including financing considerations)

9. Project cumulative cash flows (nondiscounted) ($);
10. Project payback period (year);
11. Overall project NPV ($); and
12. Overall project benefit/cost ratio (0–1).

Nonfinancial

13. Opportunity rating (0–1);
14. Risk rating (0–1); and
15. Opportunity/risk ratio (O/R).

Financial Evaluation

The financial calculations performed in this module are structured according to Bakatjan et al.'s (2003) two-phase financial analysis model and are therefore divided into construction and operation periods. All construction cost distributions are first read from a CPI project data file created in Module 1, into annual cash flow distributions (A_j) for each year (j) of the construction period (c). From these distributions, nondiscounted, cumulative cash flow distributions from the perspective of the equity holders (EQUITYFLOWyr) and the overall project (PROJECTFLOWyr) are calculated using Eqs. (1) and (2) (adapted from Bakatjan et al. 2003). The total project cost (TPC) including financing considerations is then calculated as per Eq. (3) (adapted from Bakatjan et al. 2003), along with its net present value (TPCNPV) using Eq. (4). The NPV of costs incurred by equity holders (ECOSTNPV) and the overall project (PCOSTNPV) are also calculated using

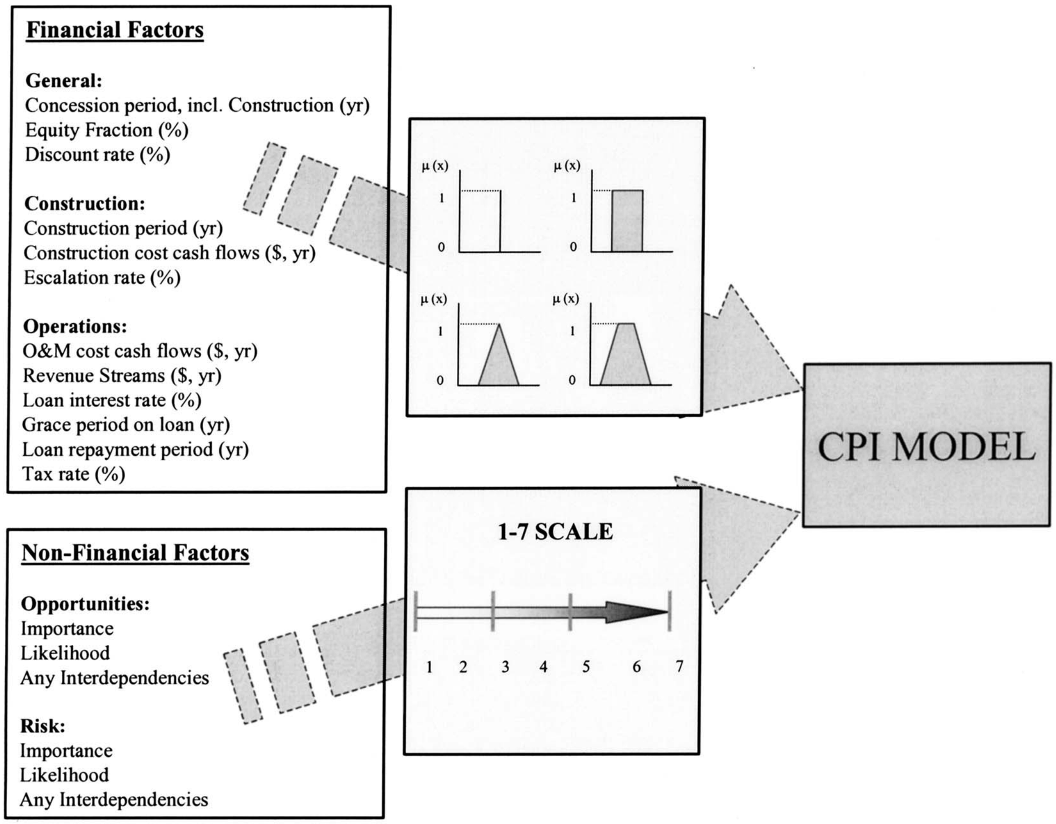

Fig. 2. ECCO's module one flowchart

Eq. (5) (adapted from Bakatjan et al. 2003), and Eq. (6), respectively for further use in NPV, B/C ratio, and IRR calculations. It should be noted that since it is assumed that the grace period (G) will be at least equal to or greater than the construction period, the financial analysis of loans is not required throughout this period

$$\text{EQUITYFLOWyr} = -e\sum_{j=1}^{\text{yr}}\left[e\cdot A_j\prod_{k=0}^{j}(1+\theta k)^{j-1} + (1-e)A_j(1+r)^{G-j+1}\prod_{k=0}^{j}(1+\theta k)^{j-1}\right] \quad (1)$$

$$\text{PROJECTFLOWyr} = -\sum_{j=1}^{\text{yr}}\left[A_j\prod_{k=0}^{j}(1+\theta k)^{j-1}\right] \quad (2)$$

$$\text{TPC} = \frac{-\text{EQUITYFLOWC}}{e} \quad (3)$$

$$\text{TPCNPV} = \sum_{j=1}^{c}\frac{\left[e\cdot A_j\prod_{k=0}^{j}(1+\theta k)^{j-1} + (1-e)\cdot A_j\cdot(1+r)^{G-j+1}\prod_{k=0}^{j}(1+\theta k)^{j-1}\right]}{(1+d)^j} \quad (4)$$

$$\text{ECOSTNPV} = e\cdot\text{TPCNPV} \quad (5)$$

$$\text{PCOSTNPV} = \sum_{j=1}^{c}\frac{A_j\prod_{k=0}^{j}(1+\theta k)^{j-1}}{(1+\text{WACC})^j} \quad (6)$$

$$\text{WACC} = d\cdot e + (1-e)\cdot r\cdot(1-t) \quad (7)$$

where WACC=weighted average cost of capital; e=equity fraction as a decimal; d=discount rate as a decimal; c=construction period in years; yr=year of construction; θ=escalation rate as a decimal; r=interest rate as a decimal; and t=tax rate as a decimal.

The annual, equal debt installment (DI), and annual straight-line depreciation (DEP) are then calculated from the TPC value using Eqs. (8) and (9), respectively (Bakatjan et al. 2003)

$$\text{DI} = (1-e)\cdot\text{TPC}\frac{r(1+r)^N}{(1+r)^N-1} \quad (8)$$

$$\text{DEP} = \frac{\text{TPC}}{m} \quad (9)$$

where N=debt repayment period in years; and m=operations period in years.

Throughout the operations period, Module 2 reads the operational and maintenance (OM) costs and revenue stream distributions into annual cash flow distributions, R_i and OM_i, which it then uses to calculate the nondiscounted cumulative cash flows from the perspective of the equity holder (EQUITYFLOW) and the overall project (PROJECTFLOW) according to Eqs. (10) and (11), respectively. The net revenue NPV is also calculated from

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both the equity holder's (EREVNPV) and overall project's (PREVNPV) perspective using Eqs. (12) and (13), respectively. The DSCR for the lender could be obtained using Eq. (14) whereas the overall project and equity holder B/C ratio (PROJECTBC and EQUITYBC) and overall NPV (PROJECT-NPV and EQUITYNPV) are then calculated using Eqs. (15)–(18) which were adapted from formulas reported in Bakatjan et al. (2003). When using these formulas, it is important to note that the value of DI becomes zero, once the repayment period N is completed

$$\mathrm{EQFLOW}_{\mathrm{yr}} = -\mathrm{TPC} + \sum_{i=1}^{\mathrm{yr}} (1-t)(R_i - \mathrm{OM}_i) + t\{\mathrm{DI} \times [1-(1+r)^{-(N-i+1)}] + \mathrm{DEP}\} - \mathrm{DI} \quad (10)$$

$$\mathrm{PROJECTFLOW}_{\mathrm{yr}} = -\mathrm{TPC} + \sum_{i=1}^{\mathrm{yr}} (1-t)(R_i - \mathrm{OM}_i) + t \cdot \mathrm{DEP} \quad (11)$$

$$\mathrm{EREVNPV} = \sum_{i=1}^{m} \frac{(1-t)(R_i - \mathrm{OM}_i) + t\{\mathrm{DI} \times [1-(1+r)^{-(N-i+1)}] + \mathrm{DEP}\} - \mathrm{DI}}{(1+d)^{i+c}} \quad (12)$$

$$\mathrm{PREVNPV} = \sum_{i=1}^{m} \frac{(1-t)(R_i - \mathrm{OM}_i) + t \cdot \mathrm{DEP}}{(1+\mathrm{WACC})^{i+c}} \quad (13)$$

$$\mathrm{DSCR}_i = \frac{(1-t)(R_i - \mathrm{OM}_i) + t\{\mathrm{DI} \times [1-(1+r)^{-(N-i+1)}] + \mathrm{DEP}\}}{\mathrm{DI}} \quad (14)$$

$$\mathrm{EQUITYBC} = \frac{\mathrm{EREVNPV}}{\mathrm{ECOSTNPV}} \quad (15)$$

$$\mathrm{PROJECTBC} = \frac{\mathrm{PREVNPV}}{\mathrm{PCOSTNPV}} \quad (16)$$

$$\mathrm{EQUITYNPV} = -\mathrm{ECOSTNPV} + \mathrm{EREVNPV} \quad (17)$$

$$\mathrm{PROJECTNPV} = -\mathrm{PCOSTNPV} + \mathrm{PREVNPV} \quad (18)$$

The remaining performance measures to be calculated by Module 2 are the payback periods (EQUITYPAYBACK and PROJECTPAYBACK), and equity holder's IRR (EQUITYIRR). The equity holder and overall project payback periods are calculated as the year in which the respective nondiscounted cumulative cash flows (EQUITYFLOW and PROJECTFLOW) pass from negative to positive. The equity holder's IRR is calculated by iteratively calculating the equity holder's NPV (EQUITYNPV) for varying discount rates. The IRR is equal to the discount rate at which the NPV changes from a negative to positive value.

All financial formulas incorporate uncertainty by representing associated variables, with the exception of year values (e.g., construction period, concession period, repayment period, etc.), using possibility distributions. Once calculations have been performed, all performance measures are then converted (defuzzified) into their equivalent single values in order to ensure the user friendliness of the results. This conversion is achieved using Eq. (19), which calculates the *center of gravity* of the distribution in the x direction (C_x), used to represent the equivalent single value of a distribution as shown in Fig. 3

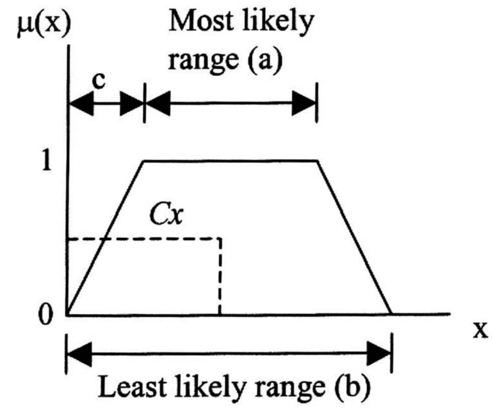

Fig. 3. Possibility distribution center of gravity

$$C_x = \frac{2ac + a^2 + cb + ab + b^2}{3(a+b)} \quad (19)$$

Nonfinancial Evaluation

A modified version of the ANP technique was used to develop the overall risk and opportunity ratings of each CPI evaluated. This involved separating the risk and opportunity factor frameworks of each project being evaluated and then introducing a dummy project into every resulting framework. Fig. 4 demonstrates the modified structure of the RFF developed by ECCO for each individual project. In this figure, the *goal* is to minimize risk by considering a list of select risk factors. The shown arrows, in the figure, represent a direction of influence, and not any specific factor interdependencies. The opportunities factor framework structure is identical to this, except that it has a goal to "maximize opportunities." Test runs were performed using the commercially

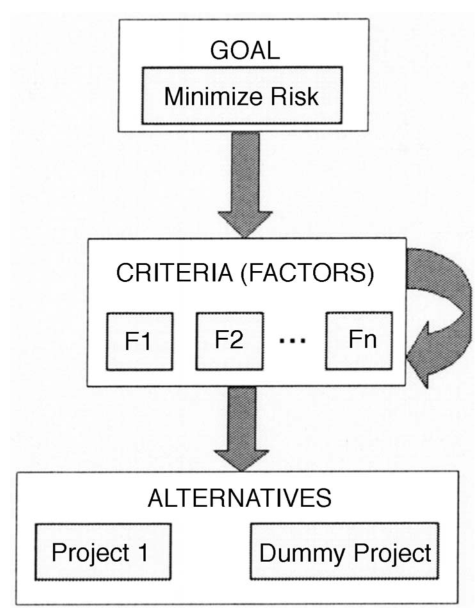

Fig. 4. Structure of risk factor framework

available SuperDecisions software (Creative Decisions Foundations 2003) to ensure that this modification of developing separate frameworks for individual CPIs using dummy projects gives the same results as the original ANP method.

Module 2 represents each ANP framework as a supermatrix of the following form:

$$W = \begin{array}{r} \\ \text{Goal } (G) \\ \text{Criteria } (C) \\ \text{Alternatives } (A) \end{array} \begin{array}{c} \begin{array}{ccc} G & C & A \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{pmatrix} \end{array}$$

where W=column stochastic matrix; W_{21}=column vector of the priorities (i.e., factor importance) of *criteria* with respect to the goal (to minimize risk or maximize opportunity); W_{32}=matrix of column eigenvectors of *alternatives* with respect to each *criterion* (i.e., factor likelihood); and W_{22}=matrix of column eigenvectors of interdependence among *criteria* (factors) (Saaty 2001). Hence, this module develops many of these supermatrices, using the importance, likelihood, and interdependencies of factors defined in Module 1: model definition. The synthesis of all interactions among the elements of W is given by the following column stochastic matrix W^{∞}:

$$W^{\infty} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ W_{32}(I-W_{22})^{-1}W_{21} & W_{32}(I-W_{22})^{-1} & I \end{pmatrix}$$

The solution of W^{∞}, or the impact of the goal on the ranking of the alternative CPIs, is given by the (3,1) entry of W^{∞}, $W_{32}(I-W_{22})^{-1}W_{21}$ (Saaty 2001).

The reason for including a dummy project in each supermatrix is that entry (3,1) of W^{∞} (the solution of the supermatrix) is, in fact, a stochastic column matrix. This means that each column of the matrix sums to 1. In other words, if only a single project is being evaluated in the framework, the project would automatically receive a maximum rating of 1. The dummy project representing the worst/best case scenario is therefore introduced and assigned a maximum likelihood value of 7 for each criterion in matrix W_{32}, for the sole purpose of providing a comparison "baseline" for the project being analyzed. Each supermatrix developed is raised to powers until the element values of the matrix change by less than 0.0001 with each iteration. The risk and opportunity ratings for the projects are then calculated by dividing its own rating by the dummy projects rating (representing worst/best case scenario) both taken from the (3,1) entry of each supermatrix. Thus, risk and opportunity ratings between 0 and 1 are obtained, where 0 and 1 represents worst/best case scenarios, respectively.

Ranking of Project Investment Options

The culmination of Module 2 is project ranking of according to their BO/CR ratings (or adapted *B*/CR ratings). The BO/CR rating is simply calculated as the product of the project's B/C ratio and the O/R ratio obtained from the evaluations of the financial and nonfinancial aspects of the project, respectively

$$\text{Project Rating} = \frac{\text{Benefit}}{\text{Cost}} \times \frac{\text{Opportunity}}{\text{Risk}} \tag{20}$$

Where either opportunities or risks are not included in a CPI model, the DSS simply ranks the projects based on adaptations of the above method. Alternatively, in the case of a purely financial comparison of projects, the project's B/C ratio is used for ranking.

Module 3: Sensitivity Analysis

The purpose of this module is to compare the sensitivity of selected projects to changes in any single factor (financial or nonfinancial) common to all projects selected. The user can select the models to be analyzed from the list of models previously evaluated by Module 2: model evaluation and ranking. The module will only analyze factors that are common to all models selected (up to five projects), and analyzes one factor at a time. The user must therefore select the following data: project(s) to be analyzed; factor (either financial or nonfinancial) to be manipulated; and range of the analysis which is defined as follows:

1. If a financial factor is to be manipulated, the range is then defined as being between a negative percentage of the original factor's value, and a positive percentage of the original factor's value; and
2. If a nonfinancial factor is to be manipulated, ECCO automatically analyzes the entire range of likelihood values (1–7) for the selected factor.

ECCO Demonstration

Any software can only be verified and validated in terms of its intended purpose. Each individual component of ECCO's three modules was verified to determine whether or not it fulfils their set of established requirements. This was carried out using a MATLAB program written specifically to incorporate the mathematical formulas detailed above. Results were found to replicate those calculated by ECCO for the same set of input data (McCowan 2004). The nonfinancial model included as part of ECCO was verified by comparing results from the analysis of two purely nonfinancial CPI models using ECCO, to those from the ANP based, SuperDecisions software. Both verification and validation processes are explained in more detail elsewhere (McCowan 2004). In this section, the three real-life case study projects listed below were selected to demonstrate ECCO's ability to evaluate and compare their investment options:

1. BOT hydroelectric power plant (HPP) project in Turkey, documented in Bakatjan et al. (2003);
2. BOT high speed rail (HSR) project in Taiwan, reported by Chang and Chen (2001); and
3. PPP 45-km, four-lane highway (HWY) project in eastern Canada contained in Abdel-Aziz (2000).

These HPP, HSR, and HWY projects were selected due to their varied scale, type, and concession period, and because they were hosted by a range of developing to developed countries. The following subsections provide descriptions of the CPI model developed for each project and present analysis results provided by ECCO.

Input Data—Financial Factors

All necessary information pertaining to financial factors for the HPP project were provided in the source paper. These data were transformed from deterministic (single values) into possibility distributions using descriptions given in the cited paper (Table 2). The main source of information for the HSR project is a published paper by Chang and Chen (2001). Most financial data re-

Table 2. Financial Factor Possibility Distributions ($ million)—HPP Project

Financial factor	Minimum least likely	Most likely	Maximum least likely
Equity fraction (%)	28	31.69	35
Escalation rate (%)	3.5	4.1	4.5
Interest rate (%)—Loan rate	9	10	11
Discount rate (%)—Average	9	12	12.5
Tax rate (%)	11	11	11
Construction cost—Year 1	13,843	15,206	16,571
Construction cost—Year 2	30,454	33,455	36,455
Construction cost—Year 3	33,223	36,496	39,770
Construction cost—Year 4	33,223	36,496	39,770
Revenue—Year 1 (of operations)	35,168	37,411–37,723	39,826
Revenue—Year 2 (of operations)	33,410	35,540–35,837	37,835
Revenue—Year 3 (of operations)	31,739	33,763–34,045	35,943
Revenue—Year 4 (of operations)	30,152	32,075–32,343	34,146
Revenue—Year 5 (of operations)	28,645	30,471–30,726	32,439
Revenue—Year 6 (of operations)	27,213	28,948–29,190	30,817
Revenue—Year 7 (of operations)	25,852	27,500–27,730	29,276
Revenue—Year 8 (of operations)	24,559	26,125–26,344	27,812
Revenue—Year 9 (of operations)	23,331	24,819–25,026	26,422
Revenue—Year 10 (of operations)	22,165	23,578–23,775	25,101
Annual revenue—Years 11–20 (of operations)	6,590	8,278–8,529	10,328
Annual O&M costs—Years 1–20 (of operations)	715	752–1,003	1,053

quired to develop this project's model in ECCO were specified in the paper, however additional information was also kindly provided by the authors upon request. Key financial factors are summarized below, and in Table 3

- Equity fraction=30%;
- Escalation rate=3.5%;
- Interest rate=9%;
- Discount rate=13.5% (based on 30% at return on equity rate of 24 and 70% at 9% loan interest rate); and
- Business income tax rate=25%.

No information was given pertaining to the assumptions made in estimating the above values (e.g., whether contingencies were included). Hence, to demonstrate ECCO's capabilities, values were transformed into triangular possibility distributions having a most likely value equal to its stated value (provided above), and a least likely range considered to be reasonable for that particular factor (maximum ±10%). The resulting financial factors input into the HSR model have not been included due to size limitation, but can be found elsewhere (McCowan 2004). The financial data adapted from Abdel-Aziz (2000) and used as input for the model development of the HWY project is listed below and summarized in Table 4

1. Construction period of 2 years;
2. Operations period of 30 years, thus, total project duration of 32 years;
3. Discount rate of 8.25%;
4. Equity fraction of 47.41% (value of bonds/capital cost of project);
5. Interest rate of 10.63% (weighted average of bond coupons);
6. Grace period of 9 years (weighted average of bond coupons);
7. Repayment period of 23 years;
8. Escalation rate of 2.35% (applies to all construction and operations costs);
9. Inflation of revenues in a sinusoidal pattern, starting at 2.35%

Table 3. Construction Costs ($ million)—HSR Project

Year	Cost
1995	1
1996	23
1997	126
1998	496
1999	1,347
2000	2,248
2001	2,204
2002	1,951
2003	1,042

Table 4. Annual Cost and Revenue Data—HWY Project

Financial factor	Value ($ million)
Design cost—Year 1	13
Road construction—Year 1	12.025
Road structure—Year 1	6.472
Road construction—Year 2	43.725
Road structure—Year 2	8.778
Annual operations costs	2.259
Annual maintenance costs	0.65
Major maintenance—Year 12	11.3
Major maintenance—Year 22	11.3
Major maintenance—Year 32	11.3
Annual revenues in operations	7.777158
Annual increase in revenues	0.393529/year
Government contribution—Year 3	26

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Table 5. Risk Factor Ratings—All Case Studies

	Importance			Likelihood		
Risk factor/project	HPP	HSR	HWY	HPP	HSR	HWY
C1—Approval and permit	2	6	5	2	2	5
C2—Change in law/justice reinforcement	5	4	5	3	1	1
C3—Corruption	2	4	5	2	4	0
C4—Political instability	5	4	5	3	2	0
M1—Local partner's creditworthiness	3	5	3	1	3	1
M2—Corporate fraud	2	5	3	1	3	1
M3—Termination of joint venture	7	5	3	3	2	1
M4—Inflation and interest rates	5	5	5	5	4	3
P1—Cost overrun	5	6	5	3	4	4
P2—Improper design	5	6	5	2	3	1
P3—Improper quality control	3	6	3	3	4	3
P4—Improper project management	5	6	5	2	4	3

Note: Scale is from 1 (weak) to 7 (extreme); 0 represents no importance/likelihood.

with an annual increase of 0.05%, amplitude 0.3%, and cycle length of 10 years;

10. Inflation of all maintenance costs at 1.5% per year and 0.04% annual increase;
11. Government contributions of $19.333 million in Year 1, $9.667 million in Year 2, and $26 million in Year 3; and
12. Tax rate 0%—not specified in source, hence assumed to have been already taken into account in cost data.

The HWY model was developed using data given in the source dissertation pertaining to uncertainty in inflation rates of toll growth and maintenance costs, in major maintenance costs, and in certain construction costs. For more information on financial factors the reader is referred to McCowan (2004).

Input Data—Nonfinancial Factors

The generic RFF was adopted for all three projects due to an absence of nonfinancial data in the source papers. For similar reasons, the opportunities created by each of the case study projects were not included in the models.

Each of the source authors was requested to provide importance and likelihood ratings (on a scale of 1–7) for each of the 12 risk factors of the generic RFF. Table 5 presents the ratings given to each of the risk factors. Finally, interdependencies were represented by ECCO's generic RIM (Table 1) for the HPP and HSR projects, while the source author of Case Study Three kindly provided project specific ratings for interdependencies between risk factors for the HWY project.

It is interesting to note in the HPP project that the most likely risk factor to affect the project was "M4—inflation and interest rates" ("strong likelihood"), which was also rated as "strongly important" to the project. Several other factors were considered strongly important, but not very likely to affect the project investment.

In the HSR project, the importance ratings supplied were generally of a higher magnitude (ranging from 4 to 6), while the likelihood ratings were fairly moderated (ranging only between 1 and 4). In other words, although the risk factors were considered strongly important to the success of the project investment, they were not considered likely to affect the project. The most highly rated risk factors for this case study consisted of project level risk factors (P1–P4), closely followed by the market level factor, M4, inflation and interest rates, and the country level factor, C3, corruption.

Analysis Results

The results for the evaluation and comparison of the three projects are presented as Table 6 and Fig. 5. ECCO ranked the projects in the following order according to their B/CR rating due to the absence of opportunity ratings data: The HWY project (7.633); the HPP project (4.630); and then the HSR project (0.915).

From the equity holder's perspective, looking at the financial feasibility of the projects, the HSR project is least feasible with a negative NPV and a B/C ratio well under one. Therefore, although the HSR project is by far the largest in monetary value terms, unless measures are taken to increase revenues, decrease taxes, or reduce interest payments, this project would be infeasible for equity investors, given the data provided.

Table 6. Analysis Results from ECCO—Equivalent Single Values

Performance measure	HPP	HSR	HWY
Construction cost NPV ($ million)	114.82	4,035.37	128.439
Equity holder NPV ($ million)	22.00	−771.13	25.82
Equity holder B/C	1.714	0.373	1.435
Equity holder payback period (year)	8	31	12
Equity holder IRR (%)	19.66	9.27	12.47
Overall project NPV ($ million)	33.85	371.49	38.23
Overall project B/C	1.35	1.078	1.527
Project payback period (year)	9	26	11
Average annual DSCR	1.675	0.928	2.334
Project opportunity rating (0-1)	0	0	0
Project risk rating (0-1)	0.370	0.408	0.188
Project O/R ratio	N/A[a]	N/A[a]	N/A[a]
Project B/CR rating	4.630	0.915	7.633
Project BO/CR rating	N/A[a]	N/A[a]	N/A[a]
Project ranking	**2**	**3**	**1**

[a]N/A=not applicable.

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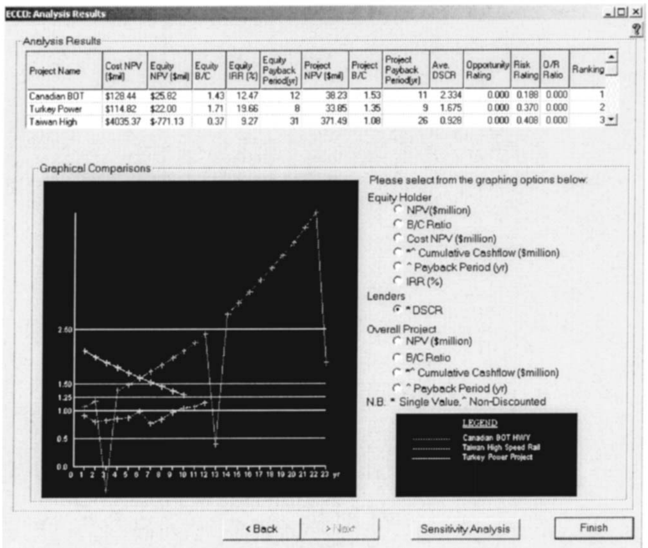

Fig. 5. Annual DSCR values

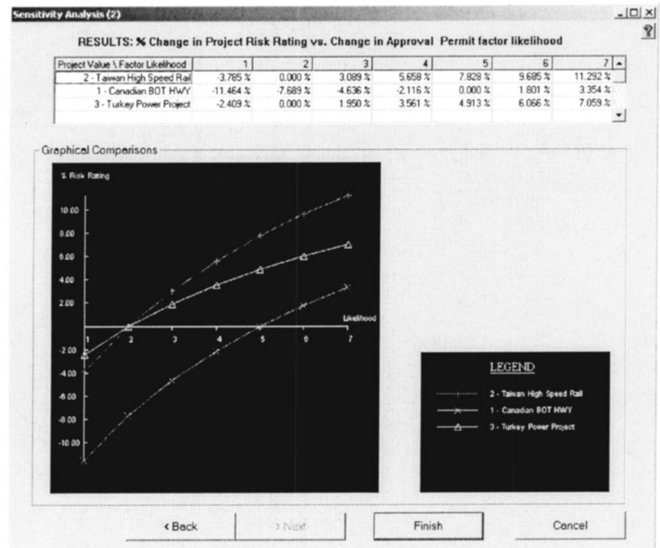

Fig. 6. Sensitivity analysis results (approval and permit risk factor)

The HPP project has a lower NPV than the HWY project ($22.00 million versus $25.82 million), yet a greater B/C ratio (1.714 versus 1.435) and IRR (19.66 versus 12.47%). In other words, a greater percentage return is likely for the least capital outlay. Hence, financially speaking, the HPP project would be considered as the better investment. However, looking now at the two projects' nonfinancial aspects, the HPP project has been evaluated as a more risky investment (project risk rating of 0.370 versus 0.188). This acts to reduce the B/CR rating so much so that the ranking of the two projects is reversed, and the HWY would be considered the better investment on the basis of considering both financial and nonfinancial aspects (7.633 versus 4.630). ECCO, therefore, provides a streamlined project rating system that takes into account the combined effect of finances, risk, and uncertainty on the overall project attractiveness.

From the debtor's perspective, the annual DSCR should be at least equal to one for the project to be considered feasible. In other words, the net revenue must be able to meet the debt installment due on loans throughout the repayment period. From Fig. 5 it is evident that lenders would consider the HWY and HPP projects feasible, while the HSR project would be considered infeasible with a DSCR less than one for most of the repayment period. The three spikes in the HWY project's DSCR graph are caused by the major maintenance required every 10 years of operations. Apart from these spikes, however, the project has a DSCR greater than one at all times, with an average value of 2.334. The HPP project is most able to service its debt consistently, having a minimum DSCR value of 1.293 and an average value of 1.675.

From an overall project perspective, according to the overall single equivalent B/C ratios, the HWY project would be ranked first (1.53), followed by the HPP project (1.35), and then the HSR project (1.08). A more careful investigation of the distributions reveals that the maximum least likely overall B/C ratio for the HPP project is, in fact, slightly greater than that of the HWY project (1.72 versus 1.69). However, the HPP project's single equivalent value is reduced by the large spread of its distribution {1.04, 1.29, 1.31, 1.72} compared to that of the HWY project {1.35, 1.55, 1.69}. Thus, greater uncertainty in the HPP project's B/C ratio has decreased its attractiveness and ranking. It can be also be seen from the results that the HSR project may possibly become feasible if its financing arrangements could be optimized, since its overall project B/C ratio (excluding financing considerations such as debt installments) is greater than one.

The nonfinancial factor, "approval and permit," was selected in order to demonstrate ECCO's ability to identify the sensitivity of various projects to changes in nonfinancial factors. Fig. 6 presents the results of this analysis from which it is evident that the HWY and HSR projects are highly sensitive to the "approval and permit" risk factor, followed closely by "compared to the HPP project." In the case where the HWY and HSR projects go forward, it is particularly important to ensure government support in the form of timely approvals and permits. For example, the government party may agree to take contractual responsibility for any consequences of delays to approvals and permits on the project. In this way, contractual negotiations between parties become streamlined. This finding, which demonstrates that analysis results could be used as a tool for improved contractual negotiations, is one of the many benefits that could be offered by ECCO. These benefits include the following:

1. Clear identification of project risk (nonfinancial) factors that may have otherwise been overlooked;
2. Streamlined project rating system, which takes into account the combined effect of finances, risk, and uncertainty on the overall project viability;
3. Economic performance measures calculated are those commonly used by the various parties involved (equity holders, debtors, and sponsor);
4. Facilitation of go/no-go decision through quantitative results;
5. Increased confidence that predictions are realistic; and
6. Identification of critical risk factors for input into the selected project's risk management plan.

Conclusion

There are a number of DSSs that have been developed over recent years for the modeling of high-risk CPI options. However, these are all limited in their capacity to incorporate both financial and nonfinancial aspects of an investment and the uncertainties commonly encountered at the feasibility stage. This paper presented the detailed structure of a DSS design developed using a combination of: (1) a mathematical modeling technique and financial analysis model that captures the true degree of certainty surrounding the project; and (2) the decision making technique and RFF that most closely reproduces the complexity of CPI decisions. The paper also demonstrated the capabilities of the DSS through the evaluation and ranking of three real-life published case studies.

Notation

The following symbols are used in this paper:

c = construction period in years;
d = discount rate as decimal;
e = equity fraction as decimal;
IRR = internal rate of return;
m = operations period in years;
NPV = net present value;
N = debt repayment period in years;
r = interest rate as decimal;
t = tax rate as decimal;
WACC = weighted average cost of capital;
yr = year of construction; and
θ = escalation rate as decimal.

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