Feasibility Analysis Simulation Model for Managing Construction Risk Factors

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Abstract
The importance of architectural planning phase has been arisen because of the changing conditions of construction market in Korea. The existing feasibility cannot fulfill its purpose in construction development projects because they are based on intuitive approach rather than systematic approach. The purpose of this study is to make a prototype of feasibility model to be a good investment. To build the model, first, risk factors which can be occurred in project had to be selected. Second, risk factors were divided into several groups in basis of characteristic risk. Third, economical risk factors were input on financial analysis. Then, to catch the relevance and influence of all risk factors, influence diagram and decision tree was made. Finally, sensitivity analysis was activated, then what the critical factors were, and how those factors could be solved. Through these procedures, the feasibility model that was made in this study could include both quantitative and qualitative factors. This model is expected to be used as a guide of feasibility study and is to serve systematic frame in planning and feasibility stage.

Keywords: risk management; sensitivity analysis; Monte Carlo simulation; DPL (decision programming language)

Introduction
Because they are based on intuitive approach rather than systematic approach, the existing feasibility methods cannot appropriately analyze risks in construction projects. With the recent rising complexities and competitive environments in the construction projects a risk management is recognized as more important management tool than the others. However, as most risk management techniques applied to the construction projects are centered around their initial finance phases and risk management.

The purpose of this study is to propose a decision making model for construction risk management using simulation method. It is a tool for construction risk management which is called DPL and CRYSTAL BALL.

There is a lack of an accepted method of risk assessment and management among professionals in the construction industry compared with the financial and health professions (Mulholland and Christian, 1999). Trigeorgis (1996) points out some major drawbacks of traditional quantitative capital budgeting techniques such as payback period method, internal rate of return (IRR) and decision tree analysis.

The project appraisal methods should incorporate analysis of these risks. A number of capital-investment decision methods can take risks into account, but each of them focuses on different factors and has its limitations (Sudong and Robert, 2000).

The paper is organized in four main parts. The first part provides an overview of traditional approaches to making feasibility method and their difficulties. Following is an introduction of the model considering risk factors. The purpose of this study is to make a feasibility simulation model for managing risks and reducing risks of construction projects. To build the model, first, risk factors that might be involved had to be selected. Second, risk factors were classified into several groups in basis of characteristic risk. Third, economical risk factors were input on financial analysis. Then, to catch the relevance and influence of all risk factors, influence diagram and decision tree was made. As a final stage, sensitivity analysis using Monte Carlo simulation method was activated, then what the critical factors were, and how those factors could be solved. Then this model is applied to a real project. Through this procedure, the feasibility simulation model that was made in this study could include both quantitative and qualitative factors in construction projects.

Existing Approaches of Feasibility Analysis Method
The value-at-risk systems provide a decision criterion with a confidence level. However, they were first developed for dealing with market risks and extended to deal with other risks such as credit, liquidity, and cash flow (Dowd 1998).
Myers (1976) pointed out the major limitations of the NPV-at-risk method, as follows:

Note that the NPV method and most traditional evaluation tools tend to ignore the "strategic" value of a risky technology investment and help little in evaluating a complex or strategic investment. For example, if the investment can create a managerial flexibility to expand future business territory when the technology is successful and market conditions are good, the NPV method will fail to evaluate the additional value brought by the potential future growth (Ping Ho, 2003).

Traditionally, investment decisions on construction projects are based on the benefit-cost analysis and economic viability of the projects because their decisions are mainly based on the financial viability of projects. However, construction projects are characterized by high capital outlays, long lead times, and long operating periods. These characteristics make the forecasts of cash flows more difficult and expose the private sector to high levels of financial, political, and market risks. This requires the decision to incorporate risk analysis into project appraisal methods (Sudong and Robert, 2000). Probabilistic and statistical analyses lead to development of decision trees (Sudong and Robert 2000). Decision-tree analysis produces the weighted average of the possible returns, weighted by the probability of the return occurrence. This method ignores the dispersion of returns (Sudong and Robert 2000).

Development of Simulation Method

Based on shortcomings of existing tools and the complexity of the decision context, this paper describes a risk-based, analytical methodology (Han 2001) for optimized feasibility analysis in construction projects.

The risk-based, feasibility analysis is conceptualized as on that is decided primarily on a project's profit criterion. If a project fails to satisfy the profitability criterion, other potential benefits of pursuing the project are considered, as shown in Figure 1.

Risk Factors

Risk Definition

Risk analysis procedures are Risk Identification (checklist and intuition identification), Risk Quantification / Analysis (Decision Tree, Influence Diagram, and Monte Carlo Simulation), and Risk Response (Avoidance, Transference, Mitigation, Acceptance), and its main purpose lies in minimizing and managing the loss of risk with several techniques by stages.

Classifying the risk factors of general construction by features, it can be arranged like the below figure 2. Among them, the factors used in the existing project feasibility analysis are the ones classified mainly into financial and market aspects, and the project feasibility is judged by using the economic values these factors show. Therefore, to verify the overall feasibility of a project, the factors in the rest two aspects - the system aspect and the construction aspect - should be quantified and reflected in the feasibility analysis of the project.

This thesis analyzes risk with the risk factors perceived in Figure 2 through Influence diagram and Decision Tree approaches, and, on the basis of it, proposes the feasibility analysis approach considering all the factors able to influence the project’s feasibility as risk approach.

Risk analysis

Influence Diagram and Decision Tree

A decision maker may use both influence diagrams and decision trees as tools in the process of modeling decisions. Influence diagrams provide compact representations of decision problems while suppressing many of the details, and thus they are ideal for obtaining overviews, especially for complex problems. Influence diagrams are especially appropriate for communicating decision structure because they are easily understood by individuals with little technical background. On the other hand, decision trees display all of the minute details. Being able to see the details can be an advantage, but in complex decisions trees may be too large and "bushy" to be of much use in communicating with others. Because the two approaches have different strengths, they should
be viewed as complementary techniques rather than as competitors in the decision-modeling process.

**Simulation**

A simulation technique, e.g., Monte Carlo simulation, is then used to generate a range of possible cost and schedule values through which the project can be expected to reasonably vary (Leroy and Edward 2002). DPL is a unique program for decision analysis. At the time this is being written, it is the only program available that incorporates both decision trees and influence diagrams. Decisions can be structured in both influence-diagram and decision-tree form. In addition, DPL sports a powerful analytical engine and numerous features for analyzing decision models in a variety of ways. DPL programs do more than calculate expected values and create risk profiles.

**Approaches for Making Risk-Based Decision**

**Influence Diagram considering of Risk factors**

In DPL, data regarding the specific alternatives and outcomes are entered via the influence diagram. In the decision-tree view, the decision maker specifies the structure of the decision more fully, specifying the sequence of the decisions and chance events. This thesis, to prepare Influence Diagram and Decision Tree, divided the attributes of the risk factors perceived in Figure 2 into Decision, Risk Variables and Value Node, and drew up the Influence Diagram such as Figure 3.

![Fig.3. Influence Diagram](image)

Promises are required as follows; a decision is a rectangle, risk variables are an oval and a value node is a rounded-drawn square. A decision means the factor judging a case, risk variables mean risk factors, and value node means the outcome appearing through decision or by risk factor. Accordingly, a decision includes Investment and Construction cost, risk variables include related tax systems, interest, etc. and value node includes rent incomings.

Through Figure 3, it can be grasped what each factor influences mutually and what each factor influences to the ultimate decision.

**Decision Tree and Sensitivity Analysis**

On the basis of the Influence Diagram prepared in the above paragraph, in DPL program, Decision Tree was drawn out. To prepare Decision Tree, it should be inputted that the correlations among the factors appeared in the Influence Diagram and the probability figure able to occur in their correlations; the correlations among the factors according to the construction order were seized and established, and were established the possible probability figure according to the expert’s opinions. Also, the frequency distribution each probability could show was supposed to be a general normal distribution and analyzed.

![Fig.4. Decision Tree](image)

**Case Study**

It is verified that applying method and utility of the model by applying the project feasibility analysis model that is proposed at Figure 1 in this paper to real project.

Targeting small size rental houses, it first evaluates the financial success or failure of the selected project using traditional project feasibility analysis and then presents the result. Following that, it is perceived what the critical factors are and how those factors can be solved through project feasibility analysis considering risk factors in the latter part of Figure 1.

Finally, the feasibility model identifies its applying method and utility by decision making for project feasibility.

**Feasibility study of the rental housing project**

Because rental housing project pursues its object to earn profits by construction of rental building, the factors such as construction cost, yield and cash holding should be considered at the project feasibility analysis stage. Figure 5 shows us these factors described as a sequence of the project procedures.
Construction cost and household number/pyong are the major factors in the project planning stage, bank interest rate, cash holding and inflation are in the fund rising planning stage, rental price and period are in the rental method and formation stage, and investment payback period and yield are in the overall review stage.

**Traditional feasibility study method**

**Analysis procedure**

Generally, the project feasibility of rental house is analyzed through comparing investment to payable rent. Because the project period is long, it is common that project feasibility lays the base on the final value of present or future value converted by long-term discount index.

**Case analysis**

For the case study of small size rental housing project, one project was selected. Market study provided approximate values relating to selected site. Site standing and construction cost assessment were taken through market study. From interview with one that worked in the rental business, assuming value and rental income output were given. Outline of the selected site for this study is as Table 1.

For feasibility analysis of this case several basic assumptions were set. Because project feasibility analysis is basically the technique to forecast future at the present point of time, it needs to presume that the factors to influence feasibility analysis are closest to the forecasted future at the present time. Accordingly, with current statistical data the assumptions in this case were arranged as Table 2.

With this, Table 4 shows the ratio of net worth and borrowed capital as 75 to 25.

Based on the data of current market transactions, the cost of this project including direct cost, maintenance cost and land purchase cost were estimated as Table 4.
Table 4. Estimates of Land Purchase Cost and Construction Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Content</th>
<th>Standard</th>
<th>Unit</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand land price</td>
<td>4,500,000 Won/pyong</td>
<td></td>
<td></td>
<td>Average of appraisal Stand land price</td>
</tr>
<tr>
<td>Land purchase cost</td>
<td>To stand land price</td>
<td>1.8 times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land tax</td>
<td>To land purchase cost</td>
<td>5.60%</td>
<td>%</td>
<td>Acquisition costs, Special rural development tax, registration tax, education tax</td>
</tr>
<tr>
<td>Direct construction cost</td>
<td>Construction cost</td>
<td>2,050,000 Won/pyong</td>
<td>Construction cost Average level</td>
<td></td>
</tr>
<tr>
<td>Indirect cost</td>
<td>To direct construction cost</td>
<td>14%</td>
<td>%</td>
<td>Interview to constructor’s</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>To direct construction cost</td>
<td>4%</td>
<td>%</td>
<td>Interview to constructor’s</td>
</tr>
<tr>
<td>Management Cost</td>
<td>To management income cost</td>
<td>50%</td>
<td>%</td>
<td>Assumption</td>
</tr>
<tr>
<td>Income tax</td>
<td>To rental income</td>
<td>8%</td>
<td>%</td>
<td>Applied only to monthly rental income</td>
</tr>
</tbody>
</table>

Income details of this case were shown as Table 5 based on the initial assumption. Rental income means the income from leasehold and monthly rent.

Table 5. Output of Rental Income

<table>
<thead>
<tr>
<th>Item</th>
<th>Content</th>
<th>Basis</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent income</td>
<td>Leasehold</td>
<td>1,861,142</td>
<td>Won/pyong</td>
</tr>
<tr>
<td></td>
<td>Monthly rent</td>
<td>39,624</td>
<td>Won/pyong (Month)</td>
</tr>
<tr>
<td>Leasable area</td>
<td>Area × (1 − Vacancy rate)</td>
<td>166.6</td>
<td>pyong</td>
</tr>
<tr>
<td>Rental interest income</td>
<td>lease cost × Interest ×</td>
<td>21,700,000</td>
<td>won</td>
</tr>
<tr>
<td></td>
<td>leasable area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual rent</td>
<td>Monthly rent × 12month ×</td>
<td>79,200,000</td>
<td>won</td>
</tr>
<tr>
<td></td>
<td>leasable area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly rent multiplier</td>
<td>Yearly rate of interest × 7%</td>
<td>0.949</td>
<td>%</td>
</tr>
<tr>
<td>Monthly rent income per year</td>
<td>Yearly rent × monthly rent multiplier</td>
<td>75,191,063</td>
<td>won</td>
</tr>
<tr>
<td>Annual rental income</td>
<td>Monthly rent income per year + Rental interest income</td>
<td>96,891,063</td>
<td>won</td>
</tr>
<tr>
<td>Monthly management cost income</td>
<td>Monthly management cost income per household × the number of rental households</td>
<td>360,000</td>
<td>won</td>
</tr>
</tbody>
</table>

Table 6. Total Cost Estimate (Unit : Won)

<table>
<thead>
<tr>
<th>Annual management income</th>
<th>Monthly management income × 12months</th>
<th>4,320,000</th>
<th>Won</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual total income</td>
<td>Annual rental income + yearly management income</td>
<td>101,211,063</td>
<td>Won</td>
</tr>
<tr>
<td>Rent increasing rate</td>
<td>Annually</td>
<td>4%</td>
<td>%</td>
</tr>
</tbody>
</table>

Project feasibility study

In case of rental housing project, net worth is the main parts of project funds. Therefore, with no necessary to use corporate accounting system, IRR and NPV are driven from Income statements. The actual period of case study is from 2002 to 2011, but on account of space consideration herein describes up to 2004.

(1) Outline of the Project cost

Before examining the project feasibility, the total cost of the overall project was estimated. Total cost in this is the sum of land purchase cost, direct and indirect construction cost, management cost, and depreciation cost. It is as below.

- Land purchase cost = Land cost + Tax
- Land tax = Land cost × 5.6%
- Direct cost = total floor space × construction cost per pyong
- Indirect construction cost = Direct cost × 14%
- Depreciation cost = (Direct + Indirect construction cost)/operating period
- Management cost = management income × 0.5

(2) Financial cost repayment

According to the loan interest rate suggested at the initial assumption, financial expenses repayment were shown at Table 7 under the condition of the equal installment payment for 10 years. The result was as below.
- Loan = It estimated 25,000,000 won as the assumption.
- Repayment = Loan / repayment period
- Interest = Balance of last year × the annual rate of redemption interest

Table 7. Results of Financial Cost Repayment

<table>
<thead>
<tr>
<th>Loan repayment</th>
<th>Sum</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loan</td>
<td></td>
<td>250,000,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principal repayment method (yearly)</td>
<td></td>
<td>25,000,000</td>
<td>25,000,000</td>
<td></td>
</tr>
<tr>
<td>Interest cost</td>
<td>Interest rate(%)</td>
<td>17,500,000</td>
<td>15,750,000</td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td>250,000,000</td>
<td>225,000,000</td>
<td>200,000,000</td>
</tr>
</tbody>
</table>

Table 8. Outcomes of Income Statements (Unit: Won)

<table>
<thead>
<tr>
<th>Item</th>
<th>Sum</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rental income</td>
<td>Monthly rent</td>
<td>2,239,045,380</td>
<td>75,191,063</td>
<td>78,198,705</td>
</tr>
<tr>
<td>Lease interest income</td>
<td>Leasehold</td>
<td>7,532,184,638</td>
<td>310,000,000</td>
<td>316,200,000</td>
</tr>
<tr>
<td>Income of compound interest</td>
<td></td>
<td>553,775,008</td>
<td>21,700,000</td>
<td>23,219,000</td>
</tr>
<tr>
<td>Sum of compound interest</td>
<td></td>
<td>8,085,959,646</td>
<td>331,700,000</td>
<td>339,419,000</td>
</tr>
</tbody>
</table>

Lease interest income | Management income | Total income
| 553,775,008 | 128,641,299 | 2,921,461,687 |
| 21,700,000 | 4,320,000 | 101,211,063 |
| 23,219,000 | 4,492,800 | 105,910,505 |

Table 9. Project Feasibility Analysis through the Traditional Methods

<table>
<thead>
<tr>
<th>Item</th>
<th>Sum</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land purchase cost</td>
<td>572,623,425</td>
<td>572,623,425</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct cost</td>
<td>348,425,455</td>
<td>348,425,455</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect construction cost</td>
<td>48,779,564</td>
<td>48,779,564</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>13,937,018</td>
<td>13,937,018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management cost</td>
<td>64,320,650</td>
<td>2,160,000</td>
<td>2,246,400</td>
<td></td>
</tr>
<tr>
<td>Depreciation cost</td>
<td>411,142,036</td>
<td>20,557,102</td>
<td>20,557,102</td>
<td></td>
</tr>
<tr>
<td>Total cost</td>
<td>1,491,295,059</td>
<td>1,015,832,373</td>
<td>22,717,102</td>
<td>22,803,502</td>
</tr>
<tr>
<td>Operating expenses</td>
<td>1,430,166,628</td>
<td>-1,015,832,373</td>
<td>78,493,961</td>
<td>83,107,004</td>
</tr>
<tr>
<td>Interest</td>
<td>96,250,000</td>
<td>17,500,000</td>
<td>15,750,000</td>
<td></td>
</tr>
<tr>
<td>Ordinary profit (without tax)</td>
<td>1,333,916,628</td>
<td>-1,015,832,373</td>
<td>60,993,961</td>
<td>67,357,004</td>
</tr>
<tr>
<td>Rental income tax</td>
<td>179,123,630</td>
<td>6,015,285</td>
<td>6,255,896</td>
<td></td>
</tr>
<tr>
<td>Current net income (with tax)</td>
<td>1,154,792,998</td>
<td>-1,015,832,373</td>
<td>54,978,676</td>
<td>61,101,107</td>
</tr>
<tr>
<td>-443,208,948</td>
<td>54,978,676</td>
<td>61,101,107</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IRR 18% On the assumption that it was the same as the initial purchase cost, land cost was estimated at the first.

NPV 248,412,442 On the assumption that it was the same as the initial purchase cost, land cost was estimated at the first.

After analyzed through traditional project feasibility analysis, it was judged that this project would produce the profit of 18% in IRR(Internal Rate of Return) and about 24,000,000 won in NPV for up to 10 years after. However, this feasibility analysis method can tell us only about the financial feasibility, not about the factors that will be able to affect the progress of the project from now on. Because analyzing only the financial aspect as stated above, it can’t suggest the alternatives reflecting other risk factors.

Project feasibility analysis considering risk factors
After analyzing the correlation among the major factors used in the traditional project feasibility analysis methods, Influence Diagram as Figure 3 was made
Influence Diagram was converted into Decision Tree in DPL program and probable values among the factors were inputted by professional opinions, and Decision Tree was completed.

The above Decision Tree was converted and sensitivity analysis was executed through a common program, Crystal Ball. Sensitivity analysis is a technique grasping the influence each risk factor makes to a total project. The below figure shows Tornado Diagram of IRR and NPV with the credibility of 95% according to the changes when each risk factor changed. Through this figure, the influence degree of the NPP and IRR can be analyzed.

![Sensitivity Chart: NPV](image)

**Risk analysis and response**

Sensitivity analysis was executed and the risk factors which should be managed in priority could be identified as seen in Figures 5 and 6.

Analyzing the Decision Tree results, it could be realized that it was better to invest in a real-estate project rather than interest incomings, and the project feasibility of this case was judged to be positive. But, to keep the feasibility of this case, as the result of the sensitivity analysis, the floor space index, the direct cost and the inflation should be managed in priority, and the different responses for these 3 risk factors are necessary. The inflation is the factor influenced by the national economy, so the response of acceptance is necessary; the floor space index and the actual cost are the ones influenced by individual judgment, so positive risk mitigations should be prepared and the risk factors should be removed.

**Conclusion**

The stage of project planning and feasibility analysis is the one influencing the most in promoting a project, in which stakeholders examine their project’s feasibility through several methods and try many verifications of their project’s direction they are promoting.

The most important factor in this stage is the project’s profitability part in which the financial analysis is mainly made. But it is difficult to see only the financial analysis as the feasibility examination result of all the problems appearing in the project’s entire process. Accordingly, this thesis provided the feasibility analysis method including both financial analysis and non-financial one by drawing the risk variables of the project’s risk factors as well as the financial factors and classifying them by features.

The factors in the financial part and the non-financial one such as the construction aspect, the system one and the market one were all drawn and analyzed through the Influence Diagram and the Decision Tree. The correlations and the influential power among the risk factors prepared like so told which risk factors influenced the most to the project through the sensitivity analysis, and risk factors could be responded with the risk response methods; acceptance, avoidance and mitigation.

The project feasibility examination is the complicated decision-making process where both the qualitative factors and the quantitative ones activate, so the model where the two kinds of factors are all mixed properly is necessary. For this, this thesis presents the systematical model to prepare the responses to the main risk factors and verify the project’s feasibility in the stage of project planning and feasibility analysis through the method perceiving both the qualitative factors and the quantitative ones the risk factors and through the management of these factors.
References
2) Diekmann & Sewester & Taher, Risk Management in Capital Projects, CII, 1988