RISK ANALYSIS FOR INDUSTRIAL PROJECT IN CONSTRUCTION PHASE: A MONTE-CARLO SIMULATION APPROACH

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Abstract

This paper presents a study on risk analysis in terms of contractor's costs in construction phase in which Crystal ball (software of Decisioneering, UK) has been utilized as a main tool. To realize it, a questionnaire survey has been carried out to identify the dominant factors that strongly influence contractor costs in Vietnam. Based on results of questionnaire investigation, the survey identified three factors which were duration of each construction task, costs of reinforcing steel, and cement. Then a spreadsheet model was created in order to analyze risks. The study also indicates that the cost of reinforcing steel and cement are the cause of risks for contractors. According to the suggested model, contractors may foresee the probability of completion within the approved budget, and the possibility of earning in accordance with owner's payment conditions.

Keywords: Monte-Carlo simulation, Risk analysis, financial management, Vietnam.

Symbols

IRR	Internal Rate of Return
BOT	Build-Operate-Transfer
HCMC	Ho Chi Minh City
O&M	Operation and Maintenance
PDF	Probability Distribution Function
NPV	Net Present Value

1. Introduction

Nowadays, construction industry plays a vital role in economy of developing countries. And consequently, day by day, more and more big buildings are rising up with new materials as well as new structure.

Many people define risk as uncertainty about a situation, which is the possibility of loss, damage, or any undesirable events. Risk is an unavoidable part of all phases of building projects. Financial limitation and lack of technique are major reasons that made Vietnamese contractors not perform risk analysis. Building projects in Vietnam are highly concentrated on the construction phase. In additional, the method of risk analysis is not suitably selected, thus the allocated budget for risk analysis program is also limited. Unfortunately, many contractors had to suffer their own risks. As a result of above statements, the analysis of contractor's financial risks in the construction phase has emerged as a distinct need.

The objectives of the study were:

- To identify risk factors (risk variables) effecting contractor costs in construction phase.
- To develop a financial-spreadsheet model effecting contractor costs.
- To implement the Monte-Carlo simulation in order to find influencing risk variables to contractor finance.

Based on Monte-Carlo simulation technique, this research will focus on risk analysis for contractors in construction phase. Risk management in this research is applied for medium and small size industrial building projects. All the projects are located in Ho Chi Minh City (HCMC) and Ba Ria – Vung Tau province. The duration of projects is from 2000 to 2004.

2. Literature Background

Risk, in general meaning, is the uncertainty associated with any outcome [1]. Uncertainty can be in form of probability of the possible event or consequence of the possible event. Normally, risk management is often preceded in term of cost or monetary assessment. Researches have been continuously undertaken to develop various methods for risk analysis.

Vaughan [2] classified risk management process into six steps: determining objectives, identifying risks, evaluating the risks, considering alternatives and selecting the risk treatment device, implementing the decision, and evaluation and reviewing. Pipattanapiwong [3] developed a diagram to present the development of risk management process from many researchers (Figure 1).

Many authors used Monte-Carlo simulation for risk analysis of various construction projects. Chee and Yeo [4] conducted the Monte-Carlo simulation to evaluate risk of a BOT power generation project. No risk to the creditor is presented in this research. Seneviratne and Ranashinghe [5] used the Monte-Carlo simulation for risk analysis of a road project. The researchers focused on standard deviation of the project's internal rate of return (IRR). Javid and Seneviratne [6] proposed the use of Monte Carlo simulation technique for risk evaluation of an airport project in order to apply the present value analysis and define risk as the probability of the project's NPV being lower than the target value. Dung [7] conducted the traditional Monte Carlo simulation for risk analysis of three

building projects in Vietnam. The simulation outputs include NPV and IRR. Most authors proposed O&M cost, construction cost, project cost, consumer price index, interest rate, total investment, and cost escalation rates as risk variables.

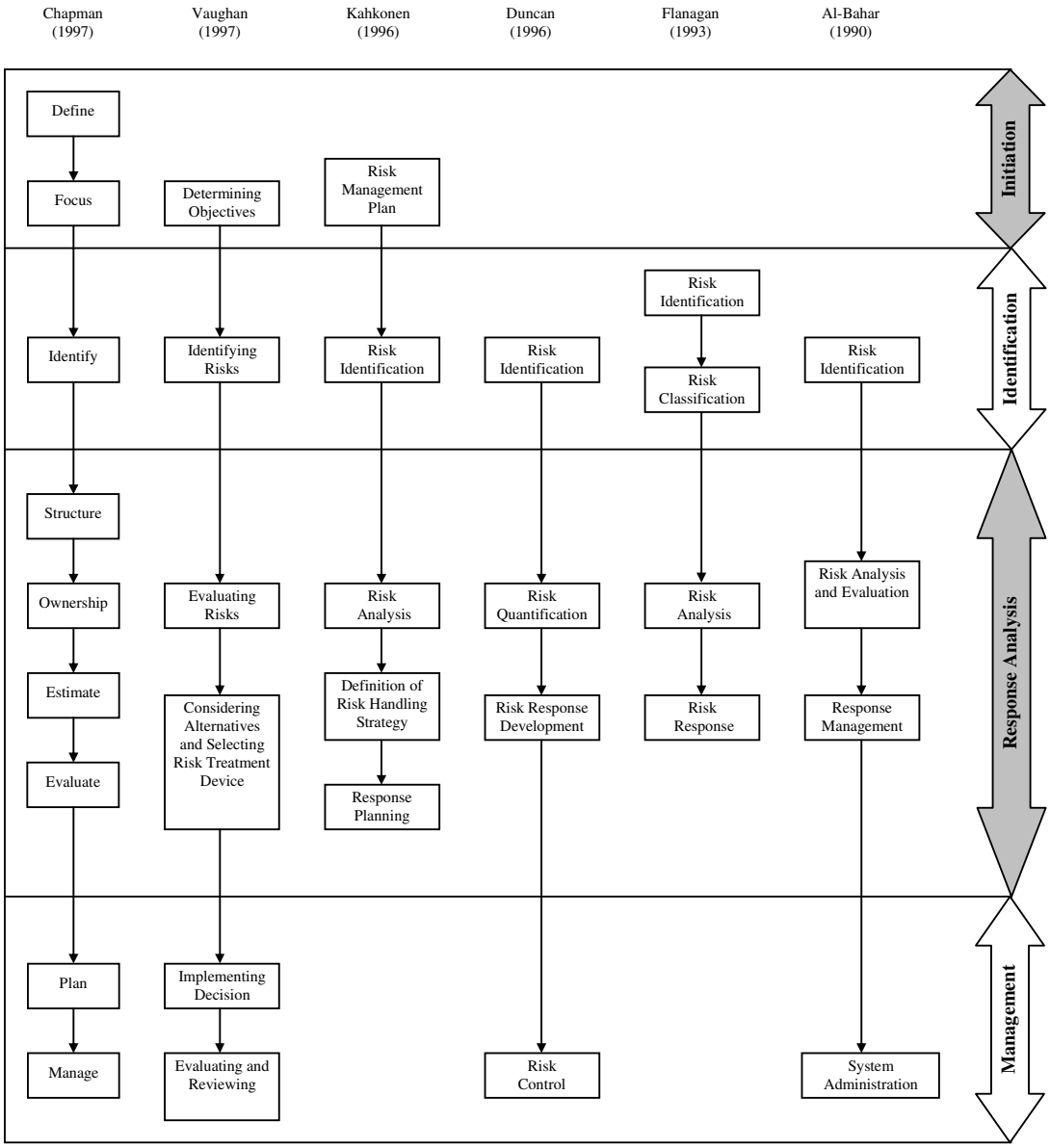

Figure 1. Summary of risk management process (Source: Pipattanapiwong [3])

The paper considers steel bar price (with diameter less than 10mm), steel bar price (with diameter greater than 10mm), shaped steel price, cement price and duration of 29 main tasks in construction phase of industrial buildings as risk variables. The simulation output is the contractor's primer cost.

3. Research Methodology

The durations of 29 construction tasks involved in the project duration were collected from twenty industrial buildings based on literature reviews and interviewing 30 relevant site engineers. 89.5% of the interviewees agreed that there is the strong correlation between the project duration and the contractor's primer cost. Moreover, most of estimators (74.77%) said that the fluctuation of material prices (steel, cement), the labor cost and equipments strongly influence the project cost.

A questionnaire survey was designed for construction personnel working at corresponding industrial buildings in order to find significant risk factors that were considered as risk variables. There were 107 replies from 310 questionnaires were sent to respondents of industrial buildings in April 2006, a response rate of 34.5%. Based on the outcome of questionnaires, the study identified two types of construction material prices influencing the contractor's primer cost are steel and cement. Then steel materials is separated into three kinds of shaped steel, steel bar with diameter greater than 10mm (bar>10) and steel bar with diameter of bar less than 10 mm (bar<=10). Cement material is Portland cement with strength of materials of 30MPa. As a result, the paper considers steel bar's price (with diameter less than 10mm), steel bar's price (with diameter greater than 10mm), shaped steel price, cement price, durations of 29 main tasks in construction phase of industrial buildings as risky variables. The simulation output is the contractor's primer cost.

Professionals of the industry understand the probability distribution function (PDF), which can be considered as the heart of a simulation model, is an unknown dimension [8]. Therefore, it is very important to choose an appropriate PDF to use in the simulation. Choosing an appropriate PDF is an iterative process. Real activity duration data from 20 industrial buildings is a sample observation to elicit the probability distribution of activity durations. An appropriate PDF to each risk variable is determined using "Best Fit Function" of Crystal Ball. In order to ensure the validity of this study, 20-selected industrial buildings were built by only unique contractor. Thus the proposed model is also tested on a specific industrial building by that unique contractor. A sample observation of construction materials was collected from Financial Department in Ho Chi Minh City in the period of 2000-2005.

Moreover, there are many factors influencing risk variables. Consequently, it is necessary to make the following assumptions:

- There are no expected changes about environment, other nature factors that affect the contractor's schedule and cost.
- There is no expected change in current government policies related to construction industry.
- There is no zero price elasticity.
- Construction escalation rate is equivalent to domestic inflation rate
- There are no large changes from owner to project management.
- The contractor's finance is strong and it is enough to support requests from site
- Labor resource of the market is not scarce.
- For 29 construction activities: (1) they are considered as main works in construction progress based on the result of literature review and interviewing; (2) An activity duration is period of carrying out that activity from the starting time to the finishing time in accordance with design document.

A spreadsheet model was developed to determine the relation between the output and risk variables. The summary of this model shows in Figure 2

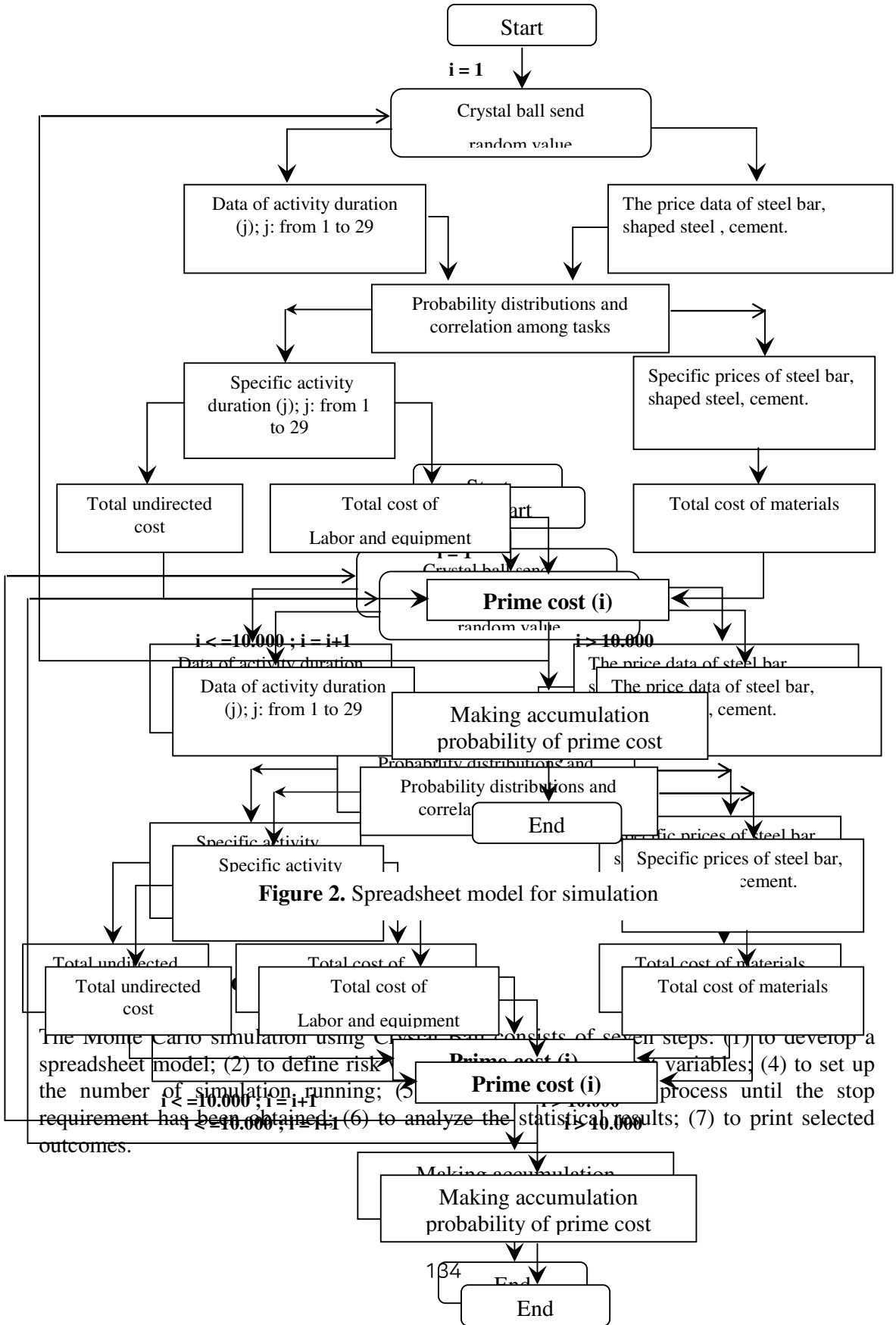

Figure 2. Spreadsheet model for simulation

The Monte Carlo simulation using Crystal Ball consists of seven steps: (1) to develop a spreadsheet model; (2) to define risk variables; (4) to set up the number of simulation running; (5) to run the process until the stop requirement has been obtained; (6) to analyze the statistical results; (7) to print selected outcomes.

4.1. The correlation between the material prices

The correlation between risk variables was also considered as blood vessel of a simulation model with the heart is PDF. The correlation coefficient between construction material prices were determined by Excel. Table 1 illustrates that there is a positive strong correlation between prices of steel bars, shaped steel and cement. This is very meaningful for the simulation process.

Table 1. Correlation matrix among of the material prices

	Steel bar ∅<=10	**Steel bar ∅>10**	**Shaped steel**	**Cement**
Steel bar ∅<=10	1.00			
Steel bar ∅>10	0.99	1.00		
Shaped steel	0.98	1.00	1.00	
Cement	0.66	0.66	0.62	1.00

(∅: a diameter of steel bar)

Table 2 describes probability distribution functions that are suitable for material prices using a "Best fit" function of Crystal Ball. Gamma PDF is the appropriateness of various steel prices while normal distribution is more appropriate for cement prices.

Table 2 Probability distribute function (PDF) of material prices

	Steel bar ∅<=10	**Steel bar ∅>10**	**Shaped steel**	**Cement**
Probability Distribute Function (PDF)	Gamma	Gamma	Gamma	Normal

(∅: a diameter of steel bar)

4.2. The correlation between the activity durations

The result shows that Beta PDF is only appropriate for the duration of 4 following activities: excavation, formwork removing for foundations, concrete for ground beams, and concrete for ground floor. The result seems to imply that Beta PDF is unsuitable for 25 remaining activities. The correlation between the durations of various activities was measured by an Excel's function based on an available sample of 20 industrial buildings. The result of correlation coefficient determines that there is strong correlation between the durations of various activities. Some of them have the positive correlation while others have negative correlation. These are very important to raise strong validity of a result variable.

4.3. Case study

A case study is taken from a real industrial building project that has been in construction progress with commenced time on September 2005. This industrial project is a medium scale having total gross floor area (GFA) of 3672 m^2. The total investment cost is estimated at VND 7.244 billion.

A Monte Carlo simulation of 10000 trials is applied. Table 3 contains listing of key output statistics. Simulation results show that the project is safe to contractor because the standard deviation is approximately VND 124,720,182 comparing with VND 3,247,683,806 of mean value of the contractor's primer cost. It is very useful for contractors to make a decision taking risks. In addition, a positively skewed primer cost is perhaps favorable to this contractor. The fluctuation of material prices (steel, cement) and the duration of construction task caused the variation of prime cost of contractor with maximum amplitude of VND 700,000,000. It tends to un-safety for this contractor in carrying out the project.

Table 3. Statistic results of the contractor's prime cost

Statistics for Display Range:	**Value**
Trials	9,863
Mean	3,247,683,806
Median	3,222,396,328
Mode	---
Standard Deviation	124,720,182
Variance	2E+16
Skewness	1.01
Kurtosis	3.83
Coeff. of Variability	0.04
Range Minimum	3,000,000,000
Range Maximum	3,700,000,000
Range Width	700,000,000
Mean Std. Error	1,256,662.40

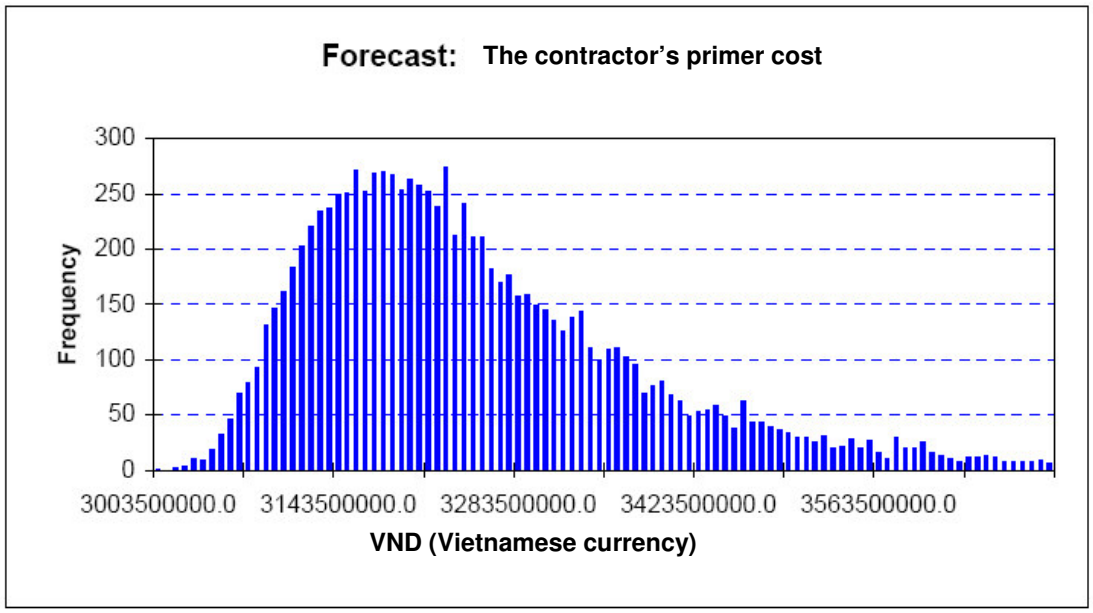

Figure 3. Frequency chart of the contractor's prime cost

As shown in figure 3 and figure 4, the probability of the contractor's primer cost having greater than VND 3.4 billion is of 10%. This seems to promote contractors taking a bid to the project.

A sensitivity analysis is performed to identify the most critical input risk factors to the outputs. Clearly, the contractor's primer cost is very sensitive to steel prices, cement prices, bricklaying activity, formwork activity and excavation, particularly a price of steel bar (with a diameter is greater than 10mm), which ranks the first in the list

Forecast: The contractor's primer cost (cont'd) **Cell: F75**

Percentiles:

Percentile	VND
0%	3,004,022,391
10%	3,111,950,702
20%	3,142,288,527
30%	3,169,253,507
40%	3,195,254,483
50%	3,222,396,328
60%	3,251,757,119
70%	3,290,603,186
80%	3,340,373,093
90%	3,423,578,331
100%	3,697,644,265

End of Forecast

Figure 4 . Cumulative probability of the contractor's primer cost

5. Conclusion

In brief, the paper presents a financial risk analysis of industrial building, making use Monte-Carlo simulation. The simulation approach is adopted because it deals with problems of complex systems. Several major risks associated with the contractor's primer cost are identified. A Monte-Carlo spreadsheet model is applied to a case study project. Conclusion may be drawn from the case study project are as follow:

- Beta PDF tends to be appropriate for the duration of 4 activities as excavation, formwork removing for foundations, concrete for ground beams, and concrete for ground floor.
- Mean of prime cost is around in VND3,247,683,806 ± VND124,720,182. It is very useful for making decision of contractors depending on taking risk level.
- The fluctuation of material prices (steel, cement) and duration of construction task caused variation of prime cost of contractor with maximum amplitude is VND 700,000,000.
- Factors strongly affect to the contractor risk in terms of the primer cost as steel prices, cement prices and the duration of bricklaying activities
- The probability of the contractor's primer cost having greater than VND 3.4 billion is of 10%. This seems to promote contractors taking a bid to the project

Although these findings should not be generalized and applied to all industrial projects in Vietnam, they present very relevant information. In this context, the steel prices in Vietnam depend on rough steel prices in the world; therefore, it is useful contractor to predict the influence of construction material prices to their interest. Moreover, in order to continue further studies, researchers should go through with other kinds of building projects such as office buildings and apartments. Data from other projects with similar scope and type should be analyzed to make more validation of the proposed model.

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