Loss Prediction Model for Building Construction Projects Using Insurance Claim Payout

Hanguk Ryu[1], Kiyoung Son[2] and Ji-Myong Kim*[3]

[1] Associate Professor, Department of Architectural Engineering, Changwon National University, Korea
[2] Assistant Professor, School of Architectural Engineering, University of Ulsan, Korea
[3] Construction Science Department, Texas A&M University, College Station, Texas, USA

Abstract

The amount of risk and the occurrence of damage in construction projects have increased as construction projects are becoming larger and more complex, increasing the demands for an effective risk assessment model. Therefore, quantitative risk analysis is needed to develop a financial risk assessment model using the risk indicators for construction projects. To address this need, authors analyzed the damage records of actual construction sites in South Korea, in order to identify the critical risk factors of damage and investigate the relationships among the risk indicators to develop a loss prediction model. Authors used claim payout records from an insurance company to reflect real financial loss as the dependent variable. As independent variables, authors adopted four risk categories based on our literature review and data analysis: natural hazards, geographic information, construction method and ability, and construction information. Our loss prediction model for construction projects, along with our findings, offers fundamental guidelines for construction companies, construction project owners, and insurance companies hoping to model and predict financial loss for building construction projects.

Keywords: building construction; damage cause analysis; loss ratio; claim payouts; loss prediction model

1. Introduction

1.1 Background and Objective

The amount of risk and the occurrence of damage in construction projects have increased as construction projects are becoming larger and more complex. Insurance Statistics Information Services (INSIS) reported an average loss of 86.3 billion KRW and a total loss of 949.2 billion KRW for construction insurance in South Korea during the years 2004 to 2013. The Korea Occupational Safety & Health Agency (KOSHA) reported that the average rate of accident occurrence in the field was 0.8 during these same years.

Therefore, the risk management for current construction projects requires more than reliance on the intuition and experience of the contractor or construction manager, as has been sufficient in the past. Construction risk management methods can be classified as 1) risk reserves, 2) risk avoidance, 3) risk reduction, 4) risk transfer, and 5) risk sharing (Vaughan 1995). The Korean construction industry is aware of the importance of managing these risks, and it has focused on risk reduction using risk indicators. The identification and prediction of risks allow risk reduction. However, in some cases, the costs of damage prevention and safety management for risk reduction are greater than potential disaster recovery costs (Park 1997).

In this study, authors analyze accidents that occurred at actual construction sites and define the interrelationships among the risk indicators in order to develop a loss prediction model for building construction projects in South Korea.

To reflect real financial losses, we collected the construction site's claim payout records from an insurance company and analyzed these data to determine the risk factors of major damage, authors conducted multiple regression analysis to identify the risk indicators and to create a metric for the loss prediction model.

The developed loss prediction model for a building construction project can aid construction companies, construction project owners, and insurance companies seeking to predict financial losses for such projects.

1.2 Research Scope and Methodology

To identify the critical risk management factors and the interrelationships among the risk indicators and the dependent variable and loss ratio, authors first investigated previous studies of risk management plans

*Contact Author: Ji-Myong Kim,
Texas A&M University, TAMU Langford A128,
College Station, Texas, 77843, USA
Tel: +82-2-758-4655 Fax: +82-2-758-4542
E-mail: ando_jm@hotmail.com
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for theoretical consideration. Second, authors collected the claim payout records regarding material damages during the years 2001 to 2012 in order to represent the dependent variable. Third, authors analyzed the records with respect to cause of damage, accumulated process rate, season, and total amount of construction in order to identify the major risk factors of damage. Fourth, authors categorized the risk indicators as natural disasters, geographic information, construction methods and skills, and project size. Fifth, authors employed multiple regression analysis to explore the relationships among these four factors and the dependent variable.

2. Construction Risk Assessment Method

Some advanced insurance companies have developed their own standard risk assessment models to predict losses due to serious damages during construction. For instance, the Swiss Reinsurance Company created the Project Underwriting Management Application (PUMA), and the Munich Reinsurance Company developed the Munich Re-Engineering Expert Tool (MRET). These standard models help engineering underwriters quantify construction risks. However, use of the models is limited to insurance matters because the models were designed for market practice in the insurance business. Furthermore, although the models were created for worldwide coverage, they do not directly apply to projects in South Korea because of the great dissimilarity in severity and magnitude of natural disasters and domestic construction vulnerabilities in South Korea compared to other areas. Additionally, the models are very user friendly and easy to access, but they each consist of a solid black box, so the users cannot determine the algorithms and risk indicators and are not able to modify the models to include risk preferences, capital, and project features.

Furthermore, substantial research has been conducted on construction risks and risk assessment models, and a number of risk factors and indicators have been proposed. However, quantitative and comprehensive research using risk indicators in South Korea is lacking. Lee *et al.* (2003) examined the premium rates of Contractor's all risks insurance policy (CAR) and suggested that the amount of risk could be assessed using the workability of insured and detailed construction information (Lee *et al.* 2003). Park (2005) investigated the potential risk of construction projects based on case studies and an expert survey (Park 2005). Kim (2007) studied a methodology to assess the construction risks using experiences of natural hazards, locations of sites, workability of contractors, construction information, and so on. He developed a checklist and weighting factors grounded on an expert survey and past studies (Kim 2007). Kim (2009) defined the risk factors of all stages of a construction project, such as geographic information, business conditions, environmental issues, and natural hazards, using literature reviews and expert interviews (Kim 2009).

These studies were founded on qualitative analyses, and the risk assessment models should include the various risk factors because the risk is a mixture of exposure, hazard, and vulnerability (Crichton 1999). Quantitative risk analysis considering various risk indicators is essential for the development of an effective construction risk assessment model.

3. Dependent Variable

3.1 Contractors' All Risks Insurance

Contractors' all risks insurance is responsible for all unexpected losses for contractors over the entire period of construction work. It is intended for the construction of buildings, including new construction and additions.

The insurance covers all risks, such as any third party damage, material damages to machinery and equipment for construction, and cost of removing remnants, during the period of construction except for damages that are excluded by the disclaimer. This study is limited to claim payments for the material damage.

3.2 Claim Payout Record

Authors collected claim payout records (total 133 cases) from an insurance company during the years 2001 to 2012 for events that occurred in the field. In this study, authors used records from building construction projects regarding material damages.

The damage cases were classified into 12 causes: theft, failure of construction (any defect that occurs during construction), fires and explosions, typhoon, heavy rain, heavy snow and cold, lightning, operator inattention, flooding, electrical accidents, and other claims payouts.

Table 1. Descriptive Statistics for Damage Causes

Code	Damage Cause	Frequency	Average (Mil. KRW)	Standard Deviation (Mil. KRW)	Max. (Mil. KRW)	Min. (Mil. KRW)
4	Typhoon	27.7%	63	160	1,000	10
2	Failure of construction	17.5%	77	109	546	10
5	Heavy rain	16.8%	163	312	1,400	10
3	Fire or explosion	16.1%	165	304	1,280	10
8	Carelessness of worker	5.1%	82	77	239	11
9	Flooding	5.1%	120	102	326	22
12	Etc.	4.4%	140	196	500	11
1	Theft	2.9%	124	166	370	10
6	Heavy snow & cold	1.5%	17	4	20	14
11	Electrical accident	1.5%	23	11	30	15
7	Lightning	0.7%	450	0	450	450
10	Mechanical breakdown	0.7%	37	0	37	37

Table 1. shows the descriptive statistics for the damage causes. Typhoon, failure of construction, heavy rain, and fire or explosion were the most frequently occurring accidents, at 27.7%, 17.5%, 16.8%, and 16.1%,

respectively. Lightning, fire or explosion, heavy rain, and theft were the most significant accidents considering average costs of 450, 165, 163, and 124 million KRW.

4. Data Analysis

This section describes the data analysis of the insurance records to identify the critical risk factors of damages. As shown in Table 2., the records were categorized by damage cause, accumulated process rate, season, and total amount of construction, and the frequency and magnitude were analyzed with respect to classification.

Table 2. Classification of Critical Risk Factors

Accumulated process rate (%)	Season	Total cost of construction (Bill. KRW)
0–20	Spring (March, April, May)	100–950
20–40	Summer (June, July, August)	950–1800
40–60	Fall (September, October, November)	1,800–2,650
60–80	Winter (December, January, February)	2,650–3,500
80–100		

4.1 Damage Causes

The results of the damage cause analysis are shown in Fig.1. Authors categorized the records according to damage cause. The vertical axis shows the loss frequency, and the horizontal axis shows the average payout amount for each cause of loss.

Authors classified the causes of damage as follows: 1) The frequency of accidents was low, but the severity was high, 2) the frequency of accidents was high, but the severity was low, 3) the frequency and severity were both low, and 4) the frequency and severity were both high. The response to the damage depended on the cause of the damage. The causes of carelessness of workers, fire or explosion, typhoon, and heavy rain had very high frequency with low severity. This means that the workers and managers in the field should be aware that these damage causes can happen at any

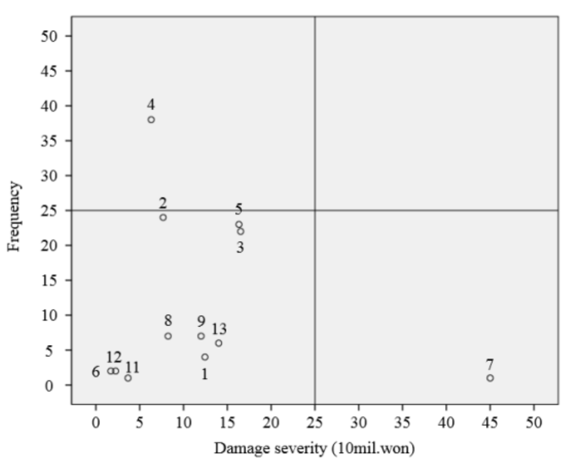

Fig.1. Frequency vs. Severity by Damage Cause

time. Lightning is a very high-severity cause with low frequency. Thus, suitable measures and efforts should be taken to minimize loss due to lightning.

4.2 Progress Rate

To analyze the change in risk amount according to progress rate, authors classified the records into five sections of progress rate and estimated the frequency and severity within each section, as shown in Fig.2. The progress rates of 20–40%, 60–80%, and 80–100% had the highest frequencies of damage, with total percentages of 25%, 29%, and 25%, respectively. Similarly, the progress rates of 20–40%, 60–80%, and 80–100% had the highest severity of damage. At low progress rates, the primary damage causes were typhoons and failure of construction. At high progress rates, heavy rain was the major damage cause for the site. The three sections of progress rates with the most frequent and severe damages are described in detail below;

1) At 20–40% progress rates, fire or explosion damage was the most frequent, accounting for 39.7% of the damage causes in this section, and the average claim payout was 2.2 billion KRW. The next most frequent damage causes were failure of construction (22.9%) and typhoons (16.6).
2) At 60–80% progress rates, heavy rains and typhoons were the primary causes, respectively accounting for 31.8% and 22% of the damage causes in this section. Failure of construction also had high occurrence but low severity.
3) At 80–100% progress rates, heavy rain and fires and explosions were the main damage causes, accounting for 47.4% and 35.2%, respectively, of the damage causes in this section. Other causes of damage were relatively unimportant in this section.

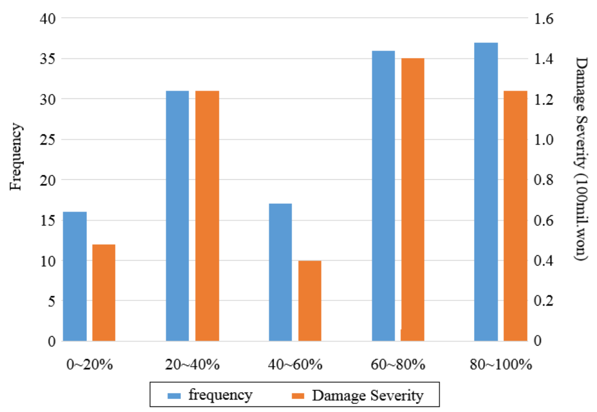

Fig.2. Frequency and Severity by Progress Rate Range

4.3 Season

Authors divided the records into four classifications to analyze them by season, defined as spring (March, April, and May), summer (June, July, and August), fall (September, October, and November), and winter (December, January, and February). As Fig.3. shows, spring had the highest severity but the lowest frequency of damage. Summer and fall had the highest frequencies of damage. The range between the smallest and largest frequency was 13.21%, while that between the smallest and largest severity was 237%.

The damage frequencies increased each season, from winter to spring, to summer, to fall, and the causes of damages became more diverse. The warm seasons had more accidents than the cold seasons owing to the typhoons and heavy rain. The seasonal characteristics were as follows:

1) Spring: Fires and explosions and other damages had the highest frequencies, accounting respectively for 45.4% and 26.6% of the damage causes in this season, and failure of construction (22.9%) and typhoons (16.6) were the next most frequent causes of damage. The frequency of damage overall was significantly lower in this season than in the other seasons.
2) Summer: Heavy rain was the most frequent cause of damage, accounting for 57% of the damage causes in this season, with an average claim payout of 2.2 billion KRW. Typhoons accounted for 15% of the damage in this season.
3) Fall: Fires and explosions, typhoons, and heavy rains were the major damage causes, accounting for 33.4%, 26.2%, and 11.2% of the damage in this season, respectively.

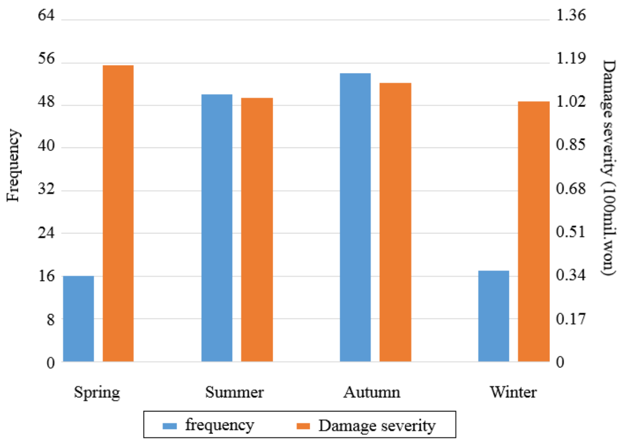

Fig.3. Frequency and Severity by Season

4.4 Total Cost of Construction Project

Authors divided the total amounts of construction projects into four categories: 100–950 billion KRW, 950–1,800 billion KRW, 1,800–2,650 billion KRW, and 2,650–3,500 billion KRW. As Fig.4. shows, the frequency decreased and the severity increased as the total cost of a construction project increased. The variety of damage causes sharply increased as the total amount of a construction project decreased. This trend suggests that small-scale projects require more diverse enhancement measures for loss prevention. The details according to the total cost of a construction project are as follows:

1) 100–950 billion KRW: Heavy rain, fires and explosions, and failure of construction had the highest frequencies, accounting for 26.4%, 24.7%, and 22.1%, respectively, of the damage causes in this amount category. Typhoons had the highest frequency at 54.5% but had relatively low severity at 8%.
2) 950–1,800 billion KRW: Heavy rains and typhoons had the highest frequencies, accounting for 42.1% and 34.3%, respectively, of the damage causes in this amount category.
3) 1,800–2,650 billion KRW: Most of the damages were caused by typhoons, accounting for 74.9% of the damage causes in this category.

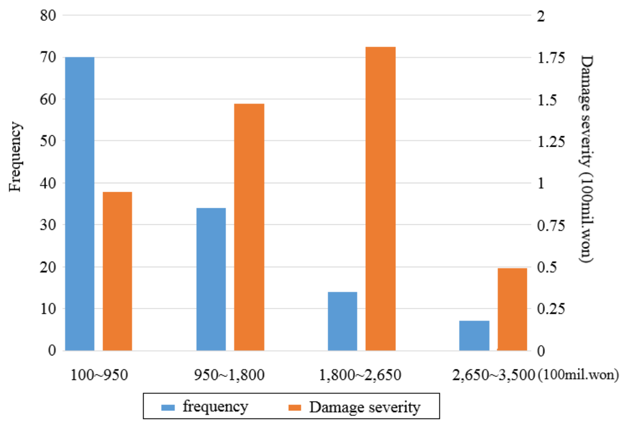

Fig.4. Frequency and Severity by Total Cost of Construction Project

5. Multiple Regression Analysis

Authors used multiple regression analysis to determine the relationships among the risk indicators and the dependent variable of loss and to develop a loss prediction model based on the claim payout records data.

5.1 Dependent Variable

The dependent variable was percentage of loss. The loss ratio was determined as the value of the claim payouts for building construction (KRW) divided by the total construction cost (KRW), as shown in Table 3.

Table 3. Dependent Variable

Variable	Unit	Description
Loss ratio	%	Loss / Total amount of construction cost

5.2 Independent Variables

Based on our findings described in the previous section and our literature review, authors identified four risk factors: natural hazards, geographic information, construction method and skills, and construction information. Additionally, each risk factor was estimated according to the risk indicators, as shown in Table 4.

First, the risk of natural disasters was estimated by an indicator, i.e., flood, using the Natural Hazards Assessment Network (NATHAN) World Map of Natural Hazards of the Munich Reinsurance Company. The worldwide natural hazard map system was created to accurately assess the properties of particular places with respect to natural hazards, such as floods, windstorms, and earthquakes. This study adopted the risk of floods as a representative element of natural hazards considering the features of domestic natural hazards. The values of the natural hazards risks were collected using the location information of each construction project. Second, the geographic risk was represented by an indicator, the location of the site. The site locations were categorized as suburban, urban, and metropolitan. Third, the risk of construction method and ability was represented by an indicator, building structure type—reinforced concrete, steel, and other. Finally, the risk of construction information was represented by three indicators: number of stories, number of basements, and total construction period.

Table 4. Independent Variables

Risk Factors	Risk Indicators	Description	Units
Natural Hazards	Flood	Risk of flash floods at the site	Estimated annual occurrence (1–6) 1. Zone 1: 1 2. Zone 2: 2 3. Zone 3: 3 4. Zone 4: 4 5. Zone 5: 5 6. Zone 6: 6
Geographic Information	Site location	Location of the site	1. Suburban 2. Urban 3. Metropolitan
Construction Method & Ability	Structure type	Type of building	1. Reinforced concrete 2. Steel 3. Other
Construction Information	Floors	Number of stories	Number
	Under ground	Number of basements	Number
	Total Months	Total construction period	Months

5.3 Data Analysis

Table 5. lists the descriptive statistics of the dependent and independent variables adopted in this study. Authors employed the backward elimination method to find the best-fit regression model. Table 6. presents a summary of the regression model, which was statistically significant, P= 0.000. The R-squared value of 0.455 indicates that this relationship is explained with a 45.5% margin of variance. The dependent variable, loss ratio, was transformed into natural logarithm.

Table 7. provides the coefficients of the model. There are six significant indicators of loss ratio: (1) flood, (2) location, (3) structure type, (4) number of floors, (5) number of underground levels, and (6) total months. The other examined indicators were rejected because they lacked statistical significance, P > 0.10. The variance inflation factors (VIF) ranged from 1.221 to 1.893, indicating that these indicators had no serious multicollinearity.

Table 5. Descriptive Statistics

Variables	Minimum	Maximum	Mean	Std. Deviation
Dependent				
Loss ratio	.13	236.67	15.01	29.98
Independent				
Flood	3.00	6.00	4.74	.57
Site location	1.00	3.00	2.25	.78
Structure type	1.00	3.00	1.77	.91
Floors	1.00	72.00	17.01	11.66
Underground levels	.00	7.00	3.29	2.30
Total months	6.00	126.00	31.27	15.41

Table 6. Summary of the Model

Model	Sum of Squares	Mean Square	F	Sig.	R^2	Adj-R^2
Regression	111.593	10.145	9.249	.000	477	.455
Residual	111.880	1.097				
Total	223.474					

Table 7. Coefficients in the Model

Indicators	B	Std. Error	Beta	Sig.	VIF
Constant	2.552	2.862		.000	
Natural hazard					
Flood	.542	.217	.218	.014	1.552
Geographical information					
Location	.367	.173	.204	.036	1.893
Construction method & ability					
Structural type	.310	.120	.201	.011	1.244
Construction information					
Floors	-.022	.010	-.181	.031	1.412
Underground levels	-.150	.055	-.245	.008	1.674
Total months	-.041	.007	-.445	.000	1.221

Based on these coefficients, a multiple regression model was generated with six significant indicators to predict the transformed depending variable, as shown in Equation (1). The model explained 45.5% of the variability of the transformed dependent variable.

$$\ln(\text{Loss ratio}) = 2.552 + .542\cdot\text{Flood} + .367\cdot\text{Location} + .310\cdot\text{Structure type} + (-.022)\cdot\text{Floors} + (-.150)\cdot\text{Underground levels} + (-.041)\cdot\text{Total months} \quad (1)$$

5.4 Examination of the Model

Authors employ the Kolmogorov-Smirnov value to test the normality of the residuals. The value indicates that the model's residuals are normally distributed because the P-value of 0.213 is higher than 0.05, as shown in Table 8. Furthermore, the Q-Q plot and standardized residuals histogram also show that the model's residuals are ordinarily distributed, as seen in Fig.5. As shown in Fig.6., the residual plot indicates homoscedasticity. The residuals are arbitrarily spread

Table 8. Test of Model Normality

	Kolmogorov-Smirnov	
	Statistic	Sig.
Ln (Loss ratio)	.985	.213

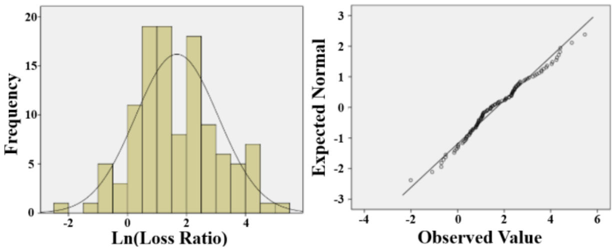

Fig.5. Model Q-Q Plot and Histogram of Residuals

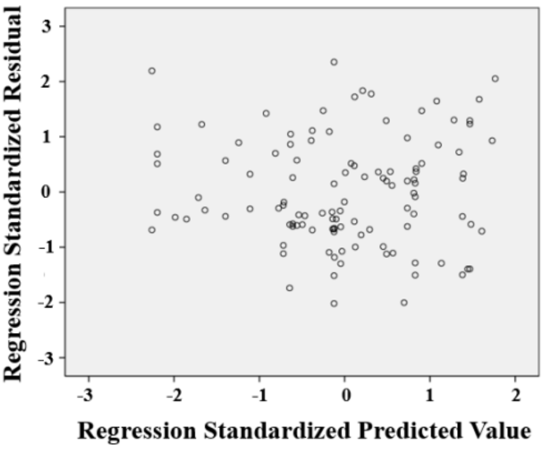

Fig.6. Residuals Plot for the Model

with no systematic patterns, demonstrating constant variance of the residuals.

5.5 Validation

Fig.7. shows a scatter plot of the actual log-transformed loss ratio versus the predicted log ratio. The model's adjusted R-squared value of 0.455 indicates that 45.5% of the variability of the transformed dependent variable can be explained by the significant independent indicators.

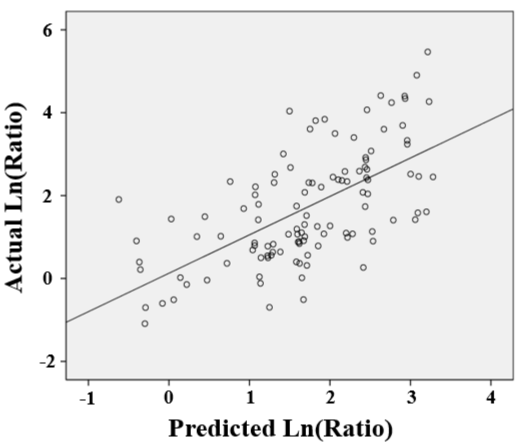

Fig.7. Actual vs. Predicted Values

6. Conclusions

The amount of risk and the occurrence of damage in construction projects have increased as construction projects are becoming larger and more complex, suggesting the strong need for an effective risk assessment model. Quantitative risk analysis is needed for the development of financial risk assessment models using the risk indicators for construction projects. To address this need, authors analyzed the damage records of actual construction sites in South Korea to identify the critical risk factors of damage, and investigated the relationships among the risk indicators to develop a loss prediction model.

We used claim payout records from an insurance company to reveal actual financial loss. We analyzed the records according to damage cause, accumulated process rate, season, and total cost of construction. The frequency and magnitude were analyzed for each of these areas as a quantitative risk analysis in order to define the critical risk factors of damage. Finally, we determined the significant risk indicators and developed a loss prediction model as a first step toward a damage estimation method for building construction projects in South Korea.

Our loss prediction model for building construction projects, along with our findings, offers fundamental guidelines for construction companies, construction project owners, and insurance companies hoping to model and predict financial loss for building construction projects in order to decrease economic damages.

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