Compensation Cost Estimation Model for Construction Noise Claims Using Case-Based Reasoning

Nahyun Kwon, S.M.ASCE[1]; Jongwoo Cho, S.M.ASCE[2]; Hyun-Soo Lee, A.M.ASCE[3]; Inseok Yoon, S.M.ASCE[4]; and Moonseo Park, A.M.ASCE[5]

Abstract: Noise due to construction is recognized as a crucial source of harm to the surroundings of a site. A number of noise-related problems can cause significant risk to an ongoing project. As a first step toward coping with noise, this paper presents a model developed for estimating the noise-related compensation cost through case-based reasoning (CBR). An experiment was performed with 20 randomly selected test cases. The compensation costs were estimated based on damage days and excessive noise level of similar cases. A Monte Carlo simulation (MCS) was adopted to deal with limited and uncertain data. The results showed that the cases had a similarity of 91.8% on average, and the mean absolute error ratio (MAER) of the estimated cost based on data revised by MCS was approximately 11.8%. This indicates that the estimated and actual costs were similar, which validates the applicability of the model. This research contributes to the field of construction noise management by providing environmental managers with a systematic approach for estimating noise-related compensation during the preconstruction phase. **DOI: 10.1061/(ASCE)CO.1943-7862.0001675.** *© 2019 American Society of Civil Engineers.*

Author keywords: Noise management; Compensation estimation; Noise-related problems; Case-based reasoning; Preconstruction phase.

Introduction

In recent decades, environmental concerns have increased significantly and become social and global issues (Cheuk 2000; Diekmann and Nelson 1985; Kwon et al. 2018). This is because environmental problems have a harmful impact on society and individuals (Christini et al. 2004; Kwon et al. 2017; Jakovljevic et al. 2009). In particular, construction noise in urban areas frequently has an adverse impact on residents adjacent to the site and the surrounding environment (Çelik et al. 2017; NECRC 2017). The adverse impacts can include mental damage, as well as damage to livestock, crops, aquatic products, and even buildings. In general, noise or pressure waves are generated by the vibration of a structure and the vibration is accompanied by noise. Thus, buildings may be affected when equipment is in operation. Most people primarily suffer from mental damage, which accounts for up to 60% of all damage (NECRC 2017). Furthermore, those problems are not merely limited to mental, physical, and psychological damage to people and damage to the surrounding environment, but also pertain to economic damage and risk to construction firms (Çelik et al. 2017; Kwon et al. 2018; Matthews et al. 2015). The National Environmental Conflicts Resolution Commission in Korea (NECRC 2017) reported that noise arising from construction caused more than 88% (1,164 cases) of all noise-related disputes (1,319 cases) from 2010 to 2017. This is because many complex and large-scale projects are carried out as cities are developed. In particular, projects carried out in urban areas can cause serious damage because equipment emitting noise exceeding 80 dBA is frequently used in densely populated residential areas (Gilchrist et al. 2003; Kwon et al. 2016; Neitzel et al. 1999).

Construction firms primarily try to manage construction noise by installing soundproof walls along the boundary of the site (Elliott and Nelson 1993; Kwon et al. 2017). However, noise-related complaints in urban areas may be inevitable (Kumaraswamy 1998) because of the short distances to surrounding areas. Soundproofing all places where noise occurs can be very expensive (Hong et al. 2014). On the other hand, if adequate soundproofing measures are not taken, more claims may occur. Failure to deal with filed complaints can lead to excessive spending due to project delays, cost overruns, and compensation (Gebken and Gibson 2006; Hong et al. 2014). Construction may even be interrupted, which induces serious risks to the project (Fernández et al. 2009; Kwon et al. 2017; MOE 2006). Thus, it is necessary to prevent complaints from turning into more serious problems. To do so, noise countermeasures need to be prepared and installed before construction starts. As a first step for establishing countermeasures, the noise compensation cost needs to be estimated. However, the noise compensation cost is often ignored or not considered by environmental and project managers (Gilchrist and Allouche 2005; Matthews et al. 2015; Xueqing et al. 2008) because it is particularly difficult to estimate the cost during the preconstruction phase. Although methods exist for estimating costs, they are inadequate for estimating compensation because noise-related data and standard methodologies have not been systematically established (Gilchrist and Allouche 2005; Matthews et al. 2015; Xueqing et al. 2008). Data generated from the previous projects can be usefully employed for estimating the

[1]Ph.D. Student, Dept. of Architecture and Architectural Engineering, Seoul National Univ., #39-425, Gwanak-ro 1, Gwanak-gu, Seoul 08826, Korea. Email: nhkwon@snu.ac.kr

[2]Ph.D. Student, Dept. of Architecture and Architectural Engineering, Seoul National Univ., #39-425, Gwanak-ro 1, Gwanak-gu, Seoul 08826, Korea. Email: leone1118@snu.ac.kr

[3]Professor, Dept. of Architecture and Architectural Engineering, Seoul National Univ., #39-425, Gwanak-ro 1, Gwanak-gu, Seoul 08826, Korea. Email: hyunslee@snu.ac.kr

[4]Ph.D. Student, Dept. of Architecture and Architectural Engineering, Seoul National Univ., #39-425, Gwanak-ro 1, Gwanak-gu, Seoul 08826, Korea. Email: yoon92411@snu.ac.kr

[5]Professor, Dept. of Architecture and Architectural Engineering, Seoul National Univ., #39-425, Gwanak-ro 1, Gwanak-gu, Seoul 08826, Korea (corresponding author). Email: mspark@snu.ac.kr

Note. This manuscript was submitted on August 22, 2018; approved on January 3, 2019; published online on June 14, 2019. Discussion period open until November 14, 2019; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Construction Engineering and Management***, © ASCE, ISSN 0733-9364.

cost (Kwon et al. 2017). However, even if a large amount of raw data is available from previous projects, their usefulness for deriving meaningful outcomes may be limited unless the data are well-organized. In this context, this research establishes a case base from data of past projects that can be used for estimating the compensation cost.

In this research, a compensation cost estimation model is developed based on previous similar cases. The compensation cost is defined as an unexpected expenditure related to problems that are incurred by construction noise. The research scope is to estimate the compensation cost due to equipment noise, which is a primary cause of noise-related complaints in the preconstruction phase. Data or knowledge about noise-related problems for projects are insufficient during this phase. The research was carried out as follows. First, previous research on compensation costs of construction projects was examined through a literature review and interviews with experts. Based on surveys, the current status and limitations of compensation estimation were then identified. Based on the limitations identified in existing practice and the literature, a model was developed to estimate the noise-related compensation cost through case-based reasoning (CBR) and the fuzzy-analytic hierarchy process (f-AHP) methodology. The model has five submodules: (1) database organization, (2) attribute selection, (3) attribute weighting, (4) retrieval of similar cases from the database, and (5) estimation of the compensation cost. More specifically, the model was then validated as follows. First, a database for noise-related compensation costs was constructed from previous cases. Second, multicollinearity between attributes was considered with the variance inflation factor (VIF). Third, attributes were weighted with fuzzy-AHP in order to determine similarities between the previous and test cases. Fourth, similar cases for 20 test cases were retrieved and prioritized according to the similarities. The retrieved cases were used to predict the noise level and damage days of the test cases. Although the cases were derived based on similarities, the predicted values may have been uncertain and limited. Thus, a Monte Carlo simulation (MCS) was adopted to revise the values of the extracted cases and improve the accuracy of the prediction for excessive noise levels and damage days. Finally, the compensation costs were estimated based on the predicted noise levels and damage days. The estimated costs were compared to the actual compensation of the test cases for validation. This approach can be used to examine a loss of the costs incurred by noise in advance; thus, environmental managers can manage noise and establish preventive countermeasures in the preconstruction phase by allocating the cost to the project budget.

Construction Noise Measures and Compensation Cost

Noise propagation is the spreading of sound induced by the expansion of sound waves. The noise is closely associated with vibration because noise or pressure waves are generally generated by vibrating structures or objects (Hopkins 2007). At construction sites, the noise from equipment is transmitted and propagated from the noise sources to surrounding areas through a medium (Halliday and Resnick 2001; Hopkins 2007), which adversely affects the neighboring people and environment. Various approaches have been used at the noise source, propagation path, and receiver node in efforts to manage noise (MOE 2006; Sailer and Hassenzahl 2010). Source control refers to managing construction noise at locations where noise occurs. This control includes the use of equipment generating low noise levels, avoiding the use of equipment generating high noise levels, adjusting the schedule of equipment usage, and adhering a flexible material to impact points during the construction phase (De Salis et al. 2002; Gilchrist et al. 2003; Kwon et al. 2017). Path control refers to installing soundproof facilities along the propagation path of the noise. Receptor control includes wearing a hearing protection device or installing acoustic facilities at the receiver node. However, this type of control is the most difficult and expensive noise mitigation technique. Noise measures are generally established to mitigate noise and avoid noise-related problems during the planning phase. However, construction noise is conventionally managed by path control with soundproof walls, silencers, curtains, and panels at the site boundary (Elliott and Nelson 1993; Kwon et al. 2017). Fixed and movable soundproof walls are generally installed onsite in the transmission path of the noise. On average, these walls attenuate the noise level by approximately 10 dBA. The cost of soundproof walls changes depending on the material and performance (Kwon et al. 2016). However, it is challenging to deal with noise-related problems by depending exclusively on conventional approaches in urban areas (Elliot and Nelson 1993; Kwon et al. 2016). This is because the conventional approach of depending on soundproof facilities has a limited mitigation effect because the noise is transmitted to areas adjacent to the site by sound refraction, reflection, diffraction, and geometric spreading. If mitigating noise complaints with existing methods is difficult, compensation may need to be considered as an additional measure to avoid complaints growing into more significant problems. Thus, this research investigated how construction companies actually determine the compensation cost. Interviews with five experts in charge of cost management at their firms indicated that approximately 0.5%–1.0% of the total construction cost is allocated to address environment-related problems. These figures are based on a few past projects rather than a systematic approach or methodology. In detail, noise-related compensation is allocated as a subitem of the dispute resolution cost, which is included in common expenses as an indirect cost. The cost associated with noise may account for more than what is commonly announced because a majority of the complaints are resolved by compensation through settlement rather than going to trial (Gebken and Gibson 2006; Stipanowich 2004). In addition, the compensation is merely about 9% of the cost requested by the applicants and is considerably lower than the cost compensated in other countries, such as the United States (60%–46,000%), Japan (292%), and Germany (32%–57%) (NECRC 2016). Under these circumstances, the Ministry of Environment (MOE) in Korea is raising the amount of noise-related compensation cost. However, the current estimation is inappropriate and inaccurate because the cost is calculated merely by considering limited factors, such as the project scale, building type, and some past projects. As such, it is insufficient for noise management. Therefore, it is desirable to improve the accuracy of estimating the current compensation cost by adopting a more scientific approach. More importantly, the compensation cost needs to be estimated based on specific data related to noise, such as the days that equipment was actually used, noise level, equipment used, distance to surrounding areas, and damage days.

To cope with these limitations, researchers have devoted much effort to understanding the effect of noise and estimating the environment-related cost in construction, as listed in Table 1. Çelik et al. (2017), Gilchrist and Allouche (2005), and Matthews et al. (2015) proposed methodologies for quantifying social costs related to construction by considering various aspects (e.g., traffic, economic activity, pollution, health, social, and ecological sources). Matthews et al. (2015) estimated the social costs of infrastructure projects by using eight relevant factors, including noise-related costs. Çelik et al. (2017) suggested a strategy for quantifying social cost based on a review of various papers on how to quantify social

Table 1. Previous approaches for resolving environment-related problems from construction literature

Main category	Subcategory	Authors	Focused range in the literatures			Underlined sources and data	Outcomes
			Noise	Environment	Society		
Environmental dispute resolution	Social cost prediction	Matthews et al. (2015)	—	—	×	Travel delay, vehicle operating cost, road surface value, lost business revenue, loss of parking revenues, dust, noise, safety	Social cost assessment
		Çelik et al. (2017)	—	—	×	Ecological, social, health, pollution, traffic, economic activities,	Social cost prediction strategy
		Gilchrist and Allouche (2005)	—	×	×	Traffic, economic activities, pollution, damage to the physical environment	Application of social cost to bid evaluation phase
	Compensation cost prediction	Hong et al. (2014)	×	—	—	Noise and vibration level of equipment, attenuation factors, threshold limit	Environmental cost prediction
		Hong (2011)	×	—	—	Noise level of equipment, noise threshold limit, exposure duration	Appropriateness of the compensation due to noise
		MOE (2007)	×	—	—	Noise level of equipment, noise threshold limit, exposure duration, soundproof walls	Suggestion of compensation standard for noise
	Environmental assessment	Bojorquez-Tapia et al. (1998)	—	×	—	Growth rate, loss of natural cover, pollution, flora and fauna extinction, groundwater, traffic, construction, deforestation, transit, highway surface	Mathematical matrix-based environment assessment
		Chen et al. (2002)	—	×	—	Hazard level of work activities, noise, dust, waste, gas, work duration, expert's judgment	Construction pollution management with schedule
		Eom and Paek (2009)	—	×	—	Regulations, expert's opinion, year of equipment, equipment used, construction methods, management plan, workers, activities, involvement of residents	Environmental risk assessment
		Gangolells et al. (2013)	—	×	—	Impact scale, occurrence probability, exposure duration, severity of consequences	Integrated environmental impact assessment

cost, and Gilchrist and Allouche (2005) developed a model for applying the social cost to the bidding phase. These studies are noteworthy because factors from diverse perspectives were applied to the estimation. However, such approaches are limited in elucidating the relationship between the estimated cost and noise level during the social cost estimation process. This is because these approaches address an extensive range of costs; thus, the quantitative data for estimation are insufficient (Gilchrist and Allouche 2005; Matthews et al. 2015). This makes it difficult to estimate the cost and demonstrate the validity of the estimated cost. Hong et al. (2014), Hong (2011), and MOE (2007) addressed the environmental cost caused by construction noise. Hong et al. (2014) estimated the environmental costs based on the predicted noise and vibration. Their work is remarkable because they suggested a more specific and practical approach for estimating the environmental cost. However, the validation was merely focused on the predicted noise and vibration level, not on the estimated cost. MOE (2007) and Hong (2011) attempted to standardize compensation costs due to construction noise and vibration. They compared the current and proposed compensation standards. However, their results showed a limited ability to demonstrate clear distinctions between the two standards because the proposed method was not validated. Research on environmental evaluations (Bojórquez-Tapia et al. 1998; Chen et al. 2002; Eom and Paek 2009; Gangolells et al. 2013) has addressed the overall environment of the construction site; the scope of the assessment was extensive, which placed limits on acquiring data. Thus, these groups typically adopted a survey-based approach to evaluate the environmental risk; this relies on the subjective judgment of the respondents, which may reduce the reliability of the results (Asmar et al. 2009; Kwon et al. 2018).

Table 1 can be summarized as follows. Most related studies have attempted to predict costs or evaluate the environment for an extensive range, such as the overall environment or from a social perspective. Research on social costs has comprehensively estimated costs based on various ranges of data, including traffic, the economy, environmental pollution, and health effects. However, the estimated costs are not specific because they were broadly determined based on an excessive number of attributes extracted from a limited attribute extraction process. Accordingly, the ability to estimate the cost incurred by specific factors, such as noise, is limited. In compensation cost-related research, the cost is generally determined by factors such as the noise level of the equipment, noise threshold limit, and exposure duration. These studies are practical in that they can present the compensation cost due to noise generated in the construction site. However, they focused on merely suggesting a method of estimating costs, with insufficient validation of the results; thus, such research has been limited to presenting the applicability of proposed methods. Furthermore, research on environmental assessments has commonly focused on presenting methods for transforming experts' subjective opinions into numerical scores. In such research, construction noise receives limited consideration as part of the overall construction environment. Thus, the assessments are limited in their ability to demonstrate the degree of the noise effect.

CBR and Fuzzy AHP

In this research, CBR was applied to estimate the noise-related compensation cost based on previous similar cases. As a computerized approach, CBR has been applied to a wide range of areas, such as hazard identification, infrastructure deterioration modeling, market selection, and dispute resolution (Arditi and Tokdemir 1999; Goh and Chua 2009; Morcous et al. 2002). In construction, CBR is commonly applied to cost estimation, safety detection, and design review (Ahn et al. 2014; Ozorhon et al. 2006). Despite its wide applicability, there is a limitation in applying CBR to estimating noise-related compensation. This is because data that are relevant to noise-related compensation have not been accumulated. Thus, a compensation-related database needed to be constructed as a first step for compensation estimation.

As illustrated in Fig. 1, the general structure of CBR has four processes: case retrieval, reuse, revision, and retention (Aamodt and Plaza 1994; Morcous et al. 2002; Kwon et al. 2017). Case retrieval involves looking for the most similar cases that match a given problem in the established case base. Among the processes of the CBR cycle, case retrieval is recognized as a critical process (Ahn et al. 2014; Pal and Shiu 2004). In order to retrieve similar cases, it is necessary to compute the similarity between a given case and the acquired cases. Based on the similarity, cases similar to the given case are extracted and then selected from the set of retrieved cases. Case reuse refers to a process that proposes the solution based on the results of the retrieved cases for treating the given problem (Ahn et al. 2014; Watson 1997; Watson and Marir 1994). If the proposed solutions are not well matched or are incorrect, it is necessary to revise the solutions proposed by the reuse process. In other words, case revision changes the outcomes generated from previous similar cases, where the initial solutions are adjusted to deal with errors and solve the current problem (Ahn et al. 2014; Kwon et al. 2017). Then, the adjusted solutions are retained as a new case in the case base. In CBR, previous similar cases are retrieved by similarity distances calculated from attribute weights. Thus, it is essential to improve the accuracy of the attribute weight (Aamodt and Plaza 1994; Doğan et al. 2008; Kwon et al. 2017).

In order to determine attribute weights, fuzzy-AHP was adopted because onsite noise is induced by interactions among a number of attributes. Thus, it is necessary to reflect the opinion of experts who are well aware of the site conditions (Kwon et al. 2017); this approach can overcome the limitations of traditional AHP with regard to uncertainty and ambiguity (Kaya and Kahraman 2010; Pan 2008). Fuzzy theory was proposed by Zadeh in 1965 to mathematically articulate a degree of uncertain quantitative information or inaccuracy and ambiguity related to the subjective judgment of experts (Kaya and Kahraman 2010; Pan 2008). A fuzzy set is a class of objects with a continuum of membership grades. Such a set is characterized by a membership function, which assigns a grade of membership ranging between zero and one to each object. A fuzzy number is a variable or figure that does not represent a single value, but is defined by many values. In a fuzzy set, fuzzy numbers are used to indicate the degree of fuzziness. Fuzzy-AHP is commonly divided into five phases: (1) pairwise comparison using fuzzy numbers, (2) calculation of the fuzzy synthetic extent value, (3) degree of possibility of the extent value, (4) weight calculation, and (5) weight normalization.

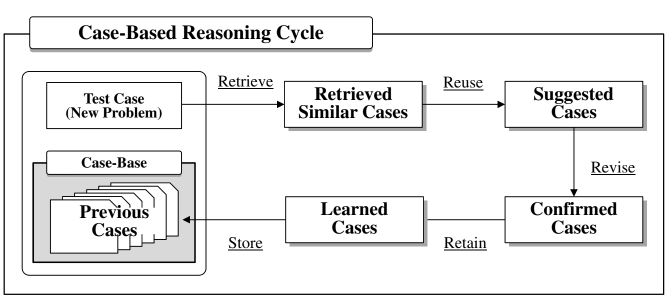

Fig. 1. General process of the CBR.

CBR-Based Compensation Cost Estimation Model

As previously discussed, this research develops a model to estimate the compensation cost based on CBR during the preconstruction phase. As described in Fig. 2, the developed model consists of five different phases: (1) database construction, (2) attribute selection, (3) attribute weighting, (4) similar case retrieval, and (5) compensation cost estimation module. In order to estimate the compensation cost based on the CBR, a database first needs to be established by collecting past noise-related dispute cases from the NECRC. The cases should be carefully reviewed because the accuracy of the predicted outcomes depends on the most similar cases (Ahn et al. 2017; Han et al. 2015). For research progress, variance inflation factors, the fuzzy-analytic hierarchy process (fuzzy-AHP), Euclidean distance measurement, and MCS are applied as component methodologies, as discussed in the following subsections. Specifically, the multicollinearity between extracted attributes needs to be considered by calculating the VIF score. The calculation aims to decrease the number of relevant attributes because improper selection of the attributes may misdirect the predicted outcomes (Aamodt and Plaza 1994; Doğan et al. 2008). To estimate the compensation cost, attribute weights should be determined based on surveys and interviews with experts, which are used to compute the similarity distance between the test case and previous cases. The case similarity is defined by the weighted Euclidean distance, which is a commonly used distance measurement method (Ahn et al. 2014; Pal and Shiu 2004). On the basis of the prioritization of the case similarity, the most similar cases are retrieved from the case base. MCS is carried out to revise the noise level and damage days of the retrieved cases because the uncertainty caused by the limited number of cases should be addressed. Subsequently, compensation costs for 20 test cases are estimated and compared with the actual costs to validate the applicability of the developed model.

Database Construction

A qualified database should be established to obtain reliable results. In this research, a database was constructed based on actual dispute cases of the NECRC from past construction projects in Korea. The NECRC is recognized as a qualified committee that handles and mediates environment-related issues, including noise (Kwon et al. 2017). Thus, cases from the NECRC are more reliable and objective than ordinary cases at sites. In addition, the cases are suitable to be used to estimate compensation because they include noise-related information on work activities performed by various construction companies.

To construct the database, cases related to disputes on construction noise were reviewed. The cases include various data, such as the area in which the dispute occurred, applicant information, cause of the dispute, type of damage, evaluation results, expert opinions, and arbitration results, in addition to general project information, such as the site location, area, distance to adjacent areas, noise level, and equipment used (Kwon et al. 2017). In this research, 145 cases among past cases were selected by excluding erroneous

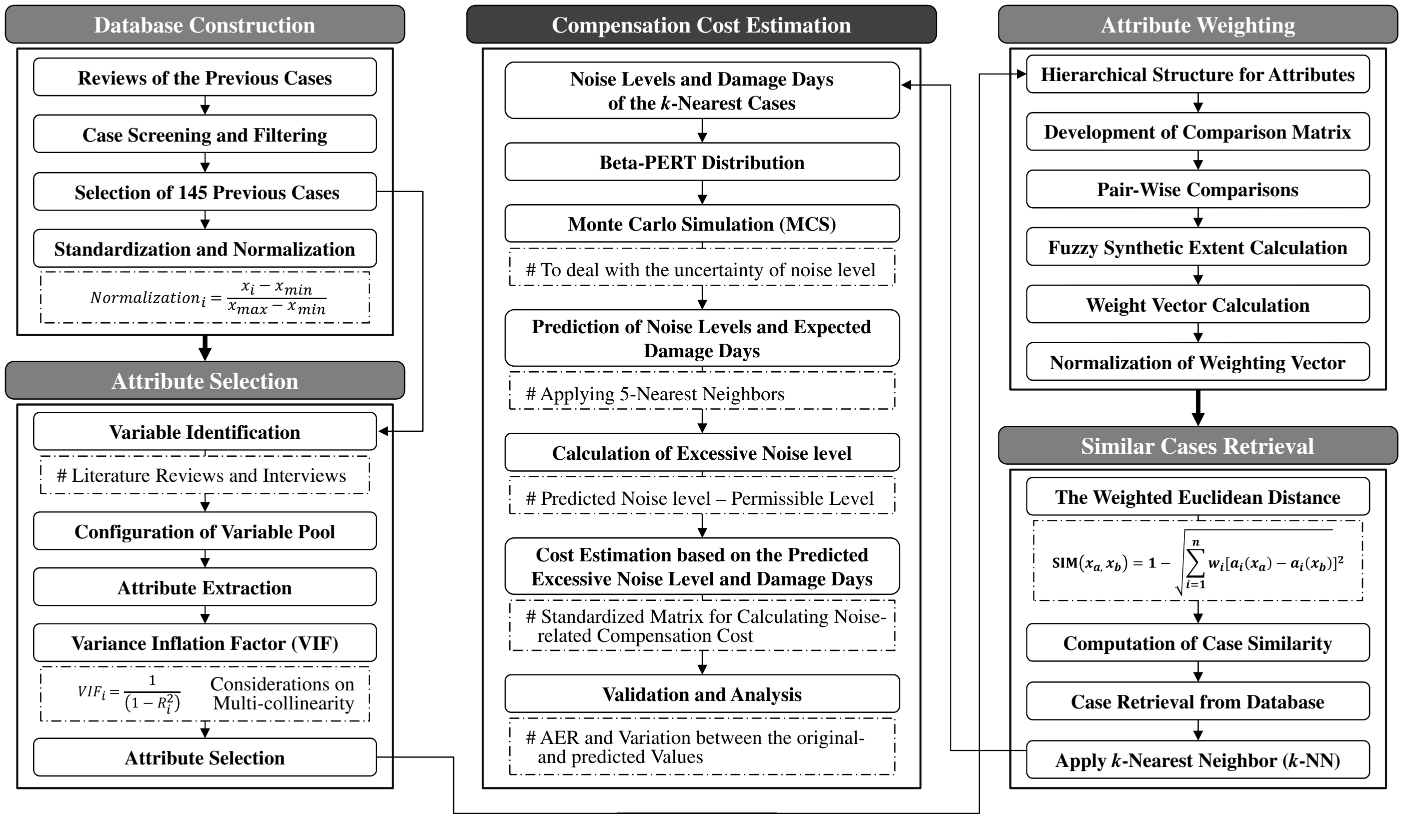

Fig. 2. CBR-based compensation estimation model.

and missing data. Erroneous cases can decrease the accuracy of the similarity between the test and the extracted previous cases (Han et al. 2015; Kwon et al. 2017). Thus, such cases were ruled out in the database. Data in the selected 145 cases were standardized and normalized because they are represented with different scales and units. The data were standardized by ratio so that the original distances among attributes could be preserved, even when the original values are transformed (Ahn et al. 2014; Kwon et al. 2017). In addition, the data were normalized with the NORMDIST function in Microsoft Excel version 2016. Normalized data are used to search for past relevant cases. During the retrieval process, accumulating more cases increases the similarity between cases and ensures reliable outcomes (Matthew et al. 2015). Thus, more previous cases need to be continuously accumulated.

Attribute Selection

This section describes the process for selecting the relative importance of attributes composing the database. This research uses variables derived from Kwon et al. (2017) for weighting attributes because they considered various factors that can be useful for retrieving similar cases. These attributes can be reliably used to search for similar cases because attributes essential to construction projects (e.g., equipment used, type of the equipment, days that equipment was actually used, barriers, and distance to surrounding areas) were extracted from the literature and interviews with experts with ample experience in the construction industry. This research first extracted 14 input attributes to calculate the attribute weights. The attributes were classified into noise-related data and general project data (Kwon et al. 2017). Here, the equipment used during the construction and days of the equipment usage need to be considered because many noise-related problems are typically caused by noise emitted from equipment. In addition, soundproof walls, which are commonly installed as noise preventive measures, are considered as input because they play an important role in preventing noise from propagating. Project-related general information, such as the site area, gross floor area, number of floors, and distance to surrounding areas, are needed to retrieve similar cases because this research is focused on estimating the cost in the preconstruction phase, during which general contractors are only aware of schematic information without detailed planning or noise-related information. Furthermore, there is a high probability of covariance between the attributes making up the case base (Ahn et al. 2017). Because the accuracy of outcomes determined from CBR depends on the collected previous cases, selecting inappropriate attributes may lead the predicted results awry. Therefore, it is necessary to consider covariance among attributes when selecting them and thereby decrease the undesirable effect of the covariance on the results (Ahn et al. 2017; Du and Bormann 2014). In order to confirm multicollinearity among the attributes in the case base including correlated attributes, the VIF is used because it is an effective method for assessing multicollinearity (Vu et al. 2015). The VIF is calculated as follows:

$$\mathrm{VIF}_i = \frac{1}{(1 - R_i^2)} \tag{1}$$

where R_i^2 = coefficient of determination for the regression of all other independent variables in the data set. The VIF values of PE_1, PE_2, PE_3, PE_4, PE_5, PE_6, and PE_7 were 3.1710, 4.3559, 4.9450, 2.0786, 2.2298, 1.2130, and 1.2290, respectively. The values PE_2 (site area) and PE_3 (gross area) were observed to have a high correlation compared to the other attributes. This seems to be because the values of both attributes are represented by area. A VIF value of 5 indicates significant multicollinearity (Rogerson 2001; Vu et al. 2015). Thus, PE_3 was excluded from the attributes in

Table 2. Profile of the 41 expert respondents

Affiliation	Main responsibility in the project	Position in their companies						Sum	Average years of experience
		ST	AM	DM	GM	Dir	SD		
Construction team	Project and construction management	4	5	1	2	8	1	21	15.4
HSE team	Hazard, safety, and environment management	1	0	2	4	1	0	8	10.4
Design team	Design management	0	0	0	1	1	0	2	27
Cost team	Cost management	1	0	1	1	2	0	5	20
Others	Electronic, mechanical	1	0	0	0	4	0	5	23.4

Note: ST = staff; AM = assistant manager; DM = deputy manager; GM = general manager; Dir = director; and SD = senior director; numbers in the table present a number of experts belonging to the related position.

order to eliminate the effect of covariance on calculating the attribute weights and retrieving similar cases. The VIFs of the attributes excluding PE_3 were 3.1169, 1.5490, 2.0771, 2.1750, 1.2129, and 1.2250, respectively, which demonstrates that the VIF was reduced. Thus, the final input attributes were selected as follows: the project duration, site area, number of floors, days that equipment was actually used, height of soundproof walls, distance to surroundings, excavator, dump truck, auger, pump car, concrete mixer, breaker, and crusher. In addition, the noise level and damage days are set as output attributes because these are used to determine the compensation cost in Korea.

Attribute Weighting

In order to evaluate the attribute weight, a questionnaire was constructed. Surveys and interviews with experts were conducted to determine the attribute weights. Attribute weights are essential for extracting similar cases from the case base. Evaluation done by more experts may improve the accuracy of their weights. In this regard, the number of experts involved in the evaluation may have been insufficient. In order to compute the weights of the attributes, experts with work experience in various areas of the construction industry, such as cost management; design management; safety, environment, and health management; and project and construction management were invited. The invited experts had an average of 19.24 years of experience in the construction field; most were responsible for managing the environment, safety, cost, and construction projects. Thus, the experts were considered suitable to evaluate the attribute weights because they were aware of the noise-related problems that occur at sites. This is summarized in Table 2. In addition, the received surveys were reviewed to prevent misunderstandings and errors in the evaluation. Out of a total of 70 questionnaires that were distributed, 41 were returned, for a response ratio of about 58%.

As previously discussed, this research adopted fuzzy-AHP to deal with the limitations of traditional AHP. Fuzzy-AHP based on triangular fuzzy numbers with a 9-point scale, which was employed by Kaya and Kahraman (2010), was applied to derive the weights, as presented in Table 3.

The received surveys were checked for consistency, and 27 passed the consistency test (CR < 0.1). Based on the surveys, weights among the attributes were determined. Tables 4 and 5 indicate that factors such as the distance between neighboring areas (0.1261), days that equipment was actually used (0.1108), height of the soundproof walls (0.0970), and usage of breakers (0.0948) need to be considered as important attributes. This seems to be because attributes such as the distance, days that equipment was actually used, soundproof walls, and equipment are closely associated with noise in the propagation process comprising the source, path, and receiver. In contrast, attributes such as the duration, areas, and number of floors are weighted lower. This can be inferred because of their marginal degree of influence on noise-related problems, although they are needed to extract similar cases.

Table 3. Fuzzy numbers used in the attribute weighting

Linguistic expressions	Score
Absolute strong (AS)	(2, 2.5, 3)
Very strong (VS)	(1.5, 2, 2.5)
Fairly strong (FS)	(1, 1.5, 2)
Slightly strong (SS)	(1, 1, 1.5)
Equal	(1, 1, 1)
Slightly weak (SW)	(0.66, 1, 1)
Fairly weak (FW)	(0.5, 0.66, 1)
Very weak (VW)	(0.4, 0.5, 0.66)
Absolutely weak (AW)	(0.33, 0.4, 0.5)

Similar Case Retrieval

The retrieval of similar cases with CBR is explained in this section. The collected cases and attribute weights calculated in the previous

Table 4. Weights for input attributes related to project and environment aspect based on the fuzzy-AHP

Attributes	Project and environment aspect (first hierarchy: 0.5423)						Second hierarchy weights	Final weights
	PE_1	PE_2	PE_3	PE_4	PE_5	PE_6		
PE_1	(1, 1, 1)	(1.08, 1.37, 1.82)	(1.06, 1.31, 1.77)	(0.47, 0.60, 0.80)	(0.42, 0.54, 0.74)	(0.54, 0.71, 0.88)	0.1407	0.0763
PE_2	(0.55, 0.73, 0.93)	(1, 1, 1)	(0.65, 0.78, 0.98)	(0.47, 0.60, 0.85)	(0.46, 0.60, 0.83)	(0.51, 0.67, 0.90)	0.1176	0.0638
PE_3	(0.57, 0.77, 0.94)	(1.02, 1.28, 1.54)	(1, 1, 1)	(0.48, 0.61, 0.81)	(0.45, 0.57, 0.77)	(0.52, 0.67, 0.88)	0.1261	0.0684
PE_4	(1.25, 1.66, 2.14)	(1.18, 1.66, 2.13)	(1.24, 1.65, 2.10)	(1, 1, 1)	(0.62, 0.79, 1.02)	(0.94, 1.22, 1.51)	0.2042	0.1108
PE_5	(1.35, 1.87, 2.37)	(1.21, 1.66, 2.15)	(1.31, 1.76, 2.24)	(0.98, 1.26, 1.62)	(1, 1, 1)	(1.06, 1.37, 1.75)	0.2325	0.1261
PE_6	(1.13, 1.42, 1.84)	(1.11, 1.48, 1.96)	(1.13, 1.49, 1.92)	(0.66, 0.82, 1.06)	(0.57, 0.73, 0.95)	(1, 1, 1)	0.1788	0.0970

Note: PE_1 = project duration; PE_2 = site area; PE_3 = number of floors; PE_4 = days that equipment was actually used; PE_5 = distance to surroundings; and PE_6 = height of soundproof walls.

Table 5. Weights for input attributes related to noise and equipment based on the fuzzy-AHP

Attributes	Noise and equipment aspect (first hierarchy: 0.4577)							Second hierarchy weights	Final weights
	NE_1	NE_2	NE_3	NE_4	NE_5	NE_6	NE_7		
NE_1	(1, 1, 1)	(0.89, 1.11, 1.44)	(0.55, 0.70, 0.95)	(0.65, 0.84, 1.11)	(0.87, 1.11, 1.43)	(0.44, 0.55, 0.75)	(0.55, 0.70, 0.92)	0.1172	0.0536
NE_2	(0.69, 0.90, 1.13)	(1, 1, 1)	(0.51, 0.66, 0.90)	(0.57, 0.71, 0.93)	(0.88, 1.01, 1.17)	(0.44, 0.56, 0.77)	(0.54, 0.69, 0.94)	0.1086	0.0497
NE_3	(1.06, 1.43, 1.80)	(1.11, 1.51, 1.96)	(1, 1, 1)	(0.87, 1.09, 1.38)	(0.99, 1.25, 1.67)	(0.53, 0.69, 0.91)	(0.64, 0.81, 1.01)	0.1493	0.0684
NE_4	(0.90, 1.19, 1.54)	(1.07, 1.40, 1.76)	(0.73, 0.92, 1.15)	(1, 1, 1)	(1.02, 1.30, 1.62)	(0.55, 0.70, 0.90)	(0.63, 0.81, 1.07)	0.1412	0.0646
NE_5	(0.70, 0.90, 1.15)	(0.86, 0.99, 1.14)	(0.60, 0.80, 1.01)	(0.62, 0.77, 0.98)	(1, 1, 1)	(0.42, 0.54, 0.73)	(0.47, 0.61, 0.82)	0.109	0.0499
NE_6	(1.33, 1.80, 2.25)	(1.30, 1.78, 2.28)	(1.10, 1.46, 1.88)	(1.11, 1.43, 1.82)	(1.37, 1.85, 2.36)	(1, 1, 1)	(1.02, 1.40, 1.78)	0.2071	0.0948
NE_7	(1.09, 1.43, 1.83)	(1.06, 1.44, 1.84)	(0.99, 1.23, 1.57)	(0.93, 1.24, 1.58)	(1.22, 1.63, 2.14)	(0.56, 0.71, 0.98)	(1, 1, 1)	0.1677	0.0767

Note: NE_1 = excavator; NE_2 = dump truck; NE_3 = auger; NE_4 = pump car; NE_5 = concrete mixer; NE_6 = breaker; and NE_7 = crusher.

phase were used to retrieve similar cases from the database. This required calculating the case similarity, which indicates the degree of similarity between the given and past cases (Ahn et al. 2014). To measure the similarity distance among cases, the weighted Euclidean distance was employed. This is one of the most general approaches to computing similarity (Ahn et al. 2014; Kwon et al. 2017; Pal and Shiu 2004). In mathematics, the similarity is determined by the distance between two points. The weighted Euclidean distance is defined as follows:

$$\mathrm{SIM}(x_i, x_j) = 1 - \mathrm{DIS}(x_i, x_j) = 1 - \sqrt{\sum_{r=1}^{n} w_r [a_r(x_i) - a_r(x_j)]^2} \tag{2}$$

where x_i and x_j = two independent cases; $\mathrm{SIM}(x_i, x_j)$ represents the degree of similarity between x_i and x_j; and $\mathrm{DIS}(x_i, x_j)$ describes the weighted distance between x_i and x_j. In addition, $a_r(x)$ indicates the value of the rth attribute of case x, and w_r denotes the weight of the case's attributes.

On the basis of Eq. (2), similarities regarding randomly selected test cases were computed. Previous cases were then retrieved according to the degree of similarity. The most similar cases to the given case were extracted from the database. In this research, the nearest-neighbor (NN) algorithm was used, which estimates values by using the most similar k-dataset among learning data. The estimated value is the average calculated from the k nearest neighbors (Kwon et al. 2017; Lee et al. 2011; Watson and Marir 1994). This research used the five nearest neighbors (5-NN) to revise outputs, such as the noise level and damage days by MCS, because an excessive number of nearest neighbors can decrease similarities of derived cases and even cause inaccurate estimation through the use of dissimilar cases. In contrast, if the number of nearest neighbors is very limited, a further search for other similar cases can be ignored (Kim 2017). Based on the revised outputs, compensation costs were estimated. Estimating the compensation cost based on previous similar cases has the following advantages: (1) testing the applicability of the developed method and collecting relevant data are feasible because of the many cases regarding noise-induced disputes, (2) a reliable outcome is ensured because actual data from sites are used, and (3) various influence factors are considered to estimate the cost. This method can provide more accurate and realistic results than existing approaches.

Compensation Cost Estimation

The estimation of the compensation cost due to construction noise is presented. The cost was determined based on the excessive noise level and damage days from the 5-NN derived in accordance with the similarity value. Here, it is challenging to predict the noise level and damage days based on limited and uncertain data because noise from construction projects has irregular characteristics depending on the project conditions, such as the schedule, equipment used, and type of work (Kwon et al. 2017; Lee et al. 2012). In particular, determining the damage days can be complicated because they vary and fluctuate depending on factors such as the distance from the site, type of equipment used, work type, year of production, duration of the actual equipment used, and soil conditions (Hong et al. 2014; Kwon et al. 2017). In the NECRC's resolution process, the public officer evaluates the noise level emitted from construction through short-term measurements, and damage days are determined by considering limited factors such as the type and noise level of equipment used, length of residence, and duration of work that has been performed (NECRC 2017); these can vary depending on the project conditions. The current cost estimation method mainly depends on the decision of the officer in charge; thus, it can be biased and is not systematic.

To deal with such limitations, this research revised the 5-NN values by adopting MCS. A 3-point estimation approach based on beta-PERT distribution was used to define the mean and standard deviation (SD) of the noise level and damage days of 5-NN, which is suitable for predicting values from insufficient data (Pawan and Lorterapong 2016; Salling 2007). The mean value and SD were obtained based on the following equation:

$$\text{Mean} = \frac{a + 4M + b}{6}, \qquad \sigma^2 = \left(\frac{b-a}{6}\right)^2 \tag{3}$$

where Mean = weighted average; a, M, and b = optimistic, most likely, and pessimistic values, respectively; and σ = variance of the distribution (Hajdu 2013; Kwon et al. 2018). The MCS is a class of computational methods that relies on repeated random sampling to acquire numerical results. It describes the uncertainty of attributes based on the probability distribution (Asmar et al. 2009; Kwon et al. 2018; Yang 2008). Thus, a random number between 0 and 1 is generated to perform MCS. In this process, the mean and SD values obtained from the three-point estimation based on the beta distribution are employed. The beta distribution, which is mathematically simple and addresses a variety of types of skewness, can provide more reliable outcomes than those of the triangular distribution (Salling 2007). The distribution can generate uniform results, a bell-shaped curve, which is called a normal distribution. In this research, 50,000 simulations were performed to predict the noise level and damage days of 5-NN based on the assumption that the two values followed a normal distribution. The mean values of the predicted noise level and damage days are presented as the final result. Table 6 presents a standard of compensation costs for noise-related damage depending on the excessive noise level and damage days provided by the MOE in Korea. The compensation cost was determined based on outputs, such as the excessive noise level and damage days, in accordance with the matrix, as presented in Table 6. Then, the costs predicted by 5-NN, 10-NN, and MCS were validated by a comparison with the actual values of the test case. In this research, the excessive noise level was set at 65 dBA, which is the permissible noise level for residential areas according to the Noise and Vibration Control Act in Korea (MOE 2016). For other countries, the compensation cost can be estimated by application of their own noise standards.

Validation

Experimental Design

Fig. 3 illustrates the process used to validate the developed model. As presented in Table 7, 20 random test cases were used to estimate the compensation cost by retrieving similar previous cases from the database. The data included in the test cases had different values for the input attributes to ensure the reliability of the estimated cost.

First, to retrieve similar previous cases from the organized database, the relative similarity distances between the given and previous cases needed to be calculated. The attribute weights were determined by fuzzy-AHP. Then, the weights were used to compute the similarity among cases by the weighted Euclidean distance. In accordance with similarity values, the five most similar cases were extracted from the database. The damage days and excessive noise levels, which are the output values of the 5-NN, were identified. Then, MCS was employed to deal with the uncertainty of the noise levels and damage days determined from the 5-NN. The predicted noise level and expected damage days were used to estimate the noise-related compensation cost. Finally, the estimated costs were compared to the actual costs for each of the 20 test cases according to the absolute error ratio (AER) and difference.

Results and Discussion

Experiments were conducted to retrieve similar cases for 20 different test cases. Table 8 presents the similarities for the retrieved five cases with the most similarity.

The average case similarities of the 5-NN ranged from 82% to 97%. The overall average similarity and standard deviation for the 20 test cases were about 91.82% and 3.02%, respectively. This confirms that cases similar to the test cases were retrieved from the database. Similarities for some test cases, such as C13, C14, and C19, were lower at 88.1%, 86.1%, and 82.4%, respectively, although the overall similarity for most cases was over 90%. In particular, the similarities of the 5-NN for C19 ranged from 0.790 to 0.869, which indicates limited similarity. This seems to be because there were only a few cases similar to C19 among the collected cases. The retrieved

Table 6. Standard for compensation cost due to construction noise in Korea (unit: dollars/person)

		Excessive noise level (dBA)					
Classification	Days of damage	Class 1 (0–5)	Class 2 (6–10)	Class 3 (11–15)	Class 4 (16–20)	Class 5 (21–25)	Class 6 (26–30)
Class 1	~7	85.01	135.46	220.48	339.13	508.22	677.32
Class 2	~15	118.65	220.48	372.76	559.60	762.33	965.99
Class 3	~1 month	135.46	287.74	508.22	728.70	982.81	1,220.10
Class 4	~2 month	203.66	423.21	677.32	949.18	1,220.10	1,474.22
Class 5	~3 month	263.45	508.22	779.15	1,067.83	1,321.94	1,626.49
Class 6	~4 month	322.31	576.42	864.16	1,135.09	1,422.83	1,711.51
Class 7	~5 month	365.28	636.21	914.61	1,203.29	1,474.22	1,761.96
Class 8	~6 month	406.39	677.32	965.99	1,253.74	1,524.66	1,812.41
Class 9	~9 month	508.22	779.15	1,067.83	1,355.57	1,626.49	1,914.24
Class 10	~1 year	576.42	864.16	1,151.91	1,422.83	1,711.51	1,999.25
Class 11	~1.5 year	677.32	965.99	1,253.74	1,524.66	1,812.41	2,101.08
Class 12	2 year	771.67	1,033.26	1,321.94	1,609.68	1,880.61	2,168.35
Class 13	2.5 year	813.71	1,101.46	1,372.38	1,660.13	1,948.80	2,219.73
Class 14	3 year	864.16	1,151.91	1,422.83	1,711.51	1,999.25	2,270.18

Note: Excessive noise level = predicted noise level – permissible noise level (65dBA); the cost is converted from South Korean won (KRW) to US dollars (USD); exchange rate: KRW/USD = 1,070.40 (prevailing rate on January 23, 2018).

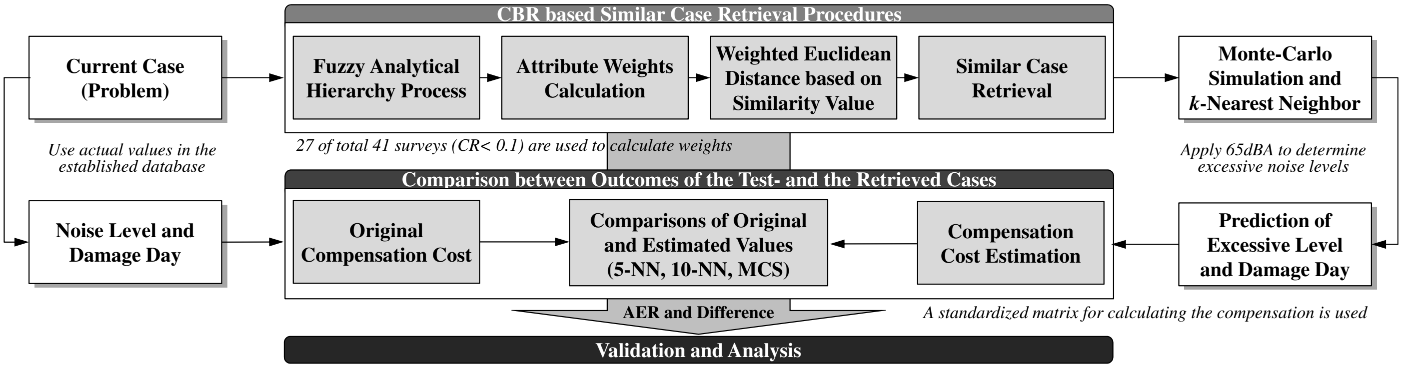

Fig. 3. Validation design.

Table 7. Profiles and input for 20 test cases

Number of test case	Building type	PE_1 (days)	PE_2 (m^2)	PE_3 (floors)	PE_4 (days)	PE_5 (m)	PE_6 (m)	NE_1	NE_2	NE_3	NE_4	NE_5	NE_6	NE_7
1	Apartment	1,035	89,813	33	630	6	50	U	U	U	U	U	U	—
2	Multifamily dwelling	175	281	4	14	0	3	U	U	—	U	U	—	U
3	Apartment	676	34,019	15	439	6	40	U	U	U	U	U	—	—
4	Multifamily dwelling	172	247	5	79	5	5	U	U	U	U	U	—	U
5	Apartment	1,019	5,557	22	168	5	23	U	U	U	U	U	—	—
6	Office	330	905	14	47	3	3	U	U	U	U	U	—	U
7	Apartment	1,005	98,094	33	566	6	53	U	U	U	U	U	—	—
8	Commercial	670	24,591	12	72	4	8	U	U	—	U	U	U	—
9	Multifamily dwelling	222	887	5	210	2	2	U	U	—	U	U	—	—
10	Multifamily dwelling	117	327	5	52	2	3	U	U	—	U	U	U	U
11	Apartment	564	20,795	15	420	2	11	U	U	U	U	U	—	—
12	Office	232	227	8	141	3	5	U	U	—	U	U	U	U
13	Apartment	1,035	78,519	21	842	6	2	U	U	—	U	U	U	—
14	Multifamily dwelling	152	263	6	24	0	5	U	U	—	U	U	U	U
15	Multifamily dwelling	103	278	6	10	0	2	U	U	—	U	U	—	U
16	Dormitory	546	1,340	15	537	6	10	U	U	U	U	U	—	—
17	Apartment	623	17,395	15	403	2	9	U	U	U	U	U	—	—
18	Religious facility	277	1,196	7	87	6	4	U	U	U	U	U	—	U
19	Apartment	1,579	73,306	41	1,459	6	26	U	U	U	U	U	—	—
20	Apartment	699	9,237	17	631	6	10	U	U	U	U	U	—	U

Note: Symbol U indicates that the equipment was mainly used during the construction.

cases were used to confirm the average noise levels and damage days for the 5-NN of each test case. Then, 50,000 simulations based on MCS were iterated.

Table 9 presents the AER and difference based on the simulation results. In most cases, the predicted noise levels based on MCS were observed to be similar to the original noise level. The mean absolute error (MAE) between the original and predicted noise levels was 2.58 dBA, which is less than 5 dBA and thus indicates reliability. On the other hand, the original and predicted damage days differed depending on the case, with an MAE of 15.43 days. In particular, the difference between the original and predicted damage days for C14 was about 117 days, which is significant compared to those of the noise level. This can be explained because extreme cases with low similarity were included in the five extracted cases, even though the overall similarity for C14 was 86%. In detail, the similarities of the third to fifth extracted cases were 0.816, 0.810, and 0.807 for C14, which demonstrates lower similarities than those of other cases (Table 8). Based on the noise levels and damage days predicted with MCS, the compensation-related cost focusing on noise was estimated. As mentioned earlier, a standardized matrix for calculating the compensation due to construction noise was used (Table 6).

Table 10 presents the estimated compensation costs of construction-induced noise for each of the 20 test cases. The costs estimated by 5-NN, 10-NN, and MCS were compared to the actual compensation cost in terms of the difference and AER. The mean absolute error ratios (MAERs) of 5-NN, 10-NN, and MCS were 17.7%, 31.7%, and 11.8%, respectively. The minimum and maximum AERs were 6.4% and 44.3%, respectively, for 5-NN; 4.0% and 98.9%, respectively, for 10-NN; and 0% and 53.3%, respectively, for MCS. In particular, the MAERs of 5-NN, 10-NN, and MCS were 9.8%, 21.9%, and 0%, respectively, for C3; 12.1%, 6.1%, and 0%, respectively, for C6; and 6.4%, 11.1%, and 0%, respectively, for C20. Overall, the predicted costs based on MCS were observed to have a lower error ratio than those of 5-NN and 10-NN. On the other hand, the error ratios based on MCS in some cases, such as C1, C8, C10, C14, and C17, were 26.1%, 53.3%, 47.1%, 22.4%, and 34.8%, respectively, which indicates low accuracy compared to the other cases. These error ratios may be because cases with low similarity were extracted from the database. However, significant errors are not necessarily caused by lower similarities of the retrieved cases because the overall similarities of C1, C8, C10, and C17 were 90.5%, 89.9%, 89.0%, and 92.6%, respectively. Especially for C17, the differences between

Table 8. Case similarities in 5 retrieved cases

Priority of similarity	Number of test cases									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	0.937	0.997	0.962	0.970	0.933	0.972	0.923	0.907	0.952	0.962
2	0.915	0.985	0.939	0.970	0.925	0.963	0.918	0.907	0.950	0.950
3	0.896	0.978	0.928	0.959	0.917	0.924	0.916	0.904	0.937	0.851
4	0.891	0.945	0.927	0.950	0.909	0.917	0.906	0.898	0.927	0.845
5	0.886	0.851	0.926	0.945	0.908	0.914	0.895	0.879	0.920	0.843
Average (%)	90.5	95.1	93.7	95.9	91.8	93.8	91.2	89.9	93.7	89.0
SD (%)	2.12	5.92	1.54	1.16	1.05	2.75	1.09	1.16	1.42	6.02

Priority of similarity	Number of test cases									
	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
1	0.991	0.962	0.930	0.950	0.987	0.963	0.991	0.986	0.869	0.976
2	0.912	0.921	0.904	0.921	0.987	0.955	0.913	0.974	0.832	0.930
3	0.911	0.880	0.888	0.816	0.985	0.941	0.911	0.970	0.827	0.919
4	0.909	0.879	0.844	0.810	0.942	0.939	0.909	0.966	0.802	0.914
5	0.906	0.879	0.838	0.807	0.852	0.923	0.906	0.957	0.790	0.905
Average (%)	92.6	90.4	88.1	86.1	95.1	94.4	92.6	97.1	82.4	92.9
SD (%)	3.66	3.70	3.91	6.90	5.85	1.56	3.66	1.06	3.06	2.78

the actual and predicted values by MCS were 3.2 days for damage days and 3.9 dBA for noise levels, which differs slightly from the original value. This research determined that a slight difference in noise level could yield a considerable difference in the estimated compensation cost because of the categorization of the matrix.

As presented in the matrix, the cost was calculated based on categorization; excessive noise level and damage days were divided into six and 14 subclasses, respectively (Table 6). For example, the actual and predicted excessive noise levels for C17 were 11.0 and 7.1 dBA, respectively (Table 9). According to the matrix, the former falls into Class 3, whereas the latter is included in Class 2. These differing ranges for the noise level and damage day caused an unexpected error ratio of over 30%, even though the differences in values between the predicted and original noise levels and damage days were insignificant. The actual and predicted damage days were 60 days (Class 4) and 81 days (Class 5) for C10 and 120 days (Class 6) and 129 days (Class 7) for C12. These differences are not large. Similarly, the actual and predicted values for the noise level and damage days in C8 were placed in different classes. Thus, it can be said that a relatively significant error in cost estimation may occur due to the categorization of excessive noise levels and damage days in the matrix, despite small variations. Although several cases showed a slightly high AER, this may be permissible for estimation during the early phases of a project, where data and information are very limited and deficient (Christensen and Dysert 2011). According to Christensen and Dysert (2011), the typical range for low variation is defined as −20% to −50%, and the accuracy range for high variation is from +30% to +100% during the preconstruction phase. Based on these defined ranges, the results of this research demonstrated that the proposed method is reliable for estimating noise-related compensation. Overall, the predicted costs by MCS were more similar to the actual values than those from the 5-NN and 10-NN, which are merely average values determined from previous cases. This seems to be because revision over a number of iterations influences improving the accuracy while managing the constraints of uncertain and limited data.

Utilization

As mentioned earlier, the compensation cost is challenging to predict during the preconstruction phase and has not been considered in depth by contractors. As an effort to solve these limitations, this research used CBR to estimate the noise-related compensation cost. The compensation costs that were estimated in this research refer to money that people can receive due to noise damage. The cost is not given to all people who live near the construction site. Applicants who file a noise-related complaint can be compensated by the construction firm if it is reasonably proven by public officers that the applicants have suffered from construction noise. Specifically, this research is focused on estimating the cost per individual resident dwelling in the adjacent area. With excessive noise level and damage days, an environmental manager can determine the total compensation cost based on the information regarding the number of residents living near the site. The average number of residents per household is provided by the National Statistical Office of each country. If C5 and C11 are taken as an example, suppose that there are 1,000 households in residential apartments adjacent to the site, and each household has an average of three residents. The similarities between the given cases (C5 and C11) and the collected cases are calculated based on the weighted Euclidean distance. Then, the 10 most similar cases are retrieved in the order of the computed similarity. Table 11 indicates various information of the similar cases retrieved from the case base (i.e., project information, similarity, noise level, damage days, and compensation cost).

Table 9. Excessive noise level and damage days

Test cases	Noise level (dBA)					Damage days (day)					Excessive level	
		MCS					MCS					MCS
	Actual	Min	Average	Max	Error	Actual	Min	Average	Max	Error	Actual	Average
C1	70	59.1	*70.0*	80.7	0.0	120	7.0	*154.9*	304.7	34.9	5	*5.0*
C2	77	66.6	*74.1*	81.9	2.9	7	6.2	*11.7*	17.1	4.7	12	*9.1*
C3	68	56.7	*69.8*	81.0	1.8	60	22.7	*43.0*	62.6	17.0	3	*4.8*
C4	76	61.3	*74.4*	87.4	1.6	30	19.5	*60.0*	99.3	30.0	11	*9.4*
C5	69	57.9	*69.4*	82.2	0.4	90	−30.5	*86.3*	194.7	3.7	4	*4.4*
C6	73	66.0	*75.6*	86.4	2.6	60	11.8	*56.0*	99.6	4.0	8	*10.6*
C7	67	58.5	*68.7*	78.5	1.7	60	−33.7	*50.0*	128.1	10.0	2	*3.7*
C8	75	50.8	*76.4*	98.3	1.4	90	14.5	*81.0*	147.5	9.0	10	*11.4*
C9	75	59.8	*72.7*	83.6	2.3	60	−13.7	*58.1*	140.8	1.9	10	*7.7*
C10	91	64.2	*78.8*	94.6	12.2	60	22.3	*81.0*	145.1	21	26	*13.8*
C11	71	57.7	*72.7*	89.0	1.7	90	−43.6	*86.4*	206.6	3.6	6	*7.7*
C12	86	63.9	*81.5*	100.2	4.5	120	−42.1	*129.9*	301.2	9.9	21	*16.5*
C13	67	55.1	*68.1*	81.2	1.1	60	−1.4	*51.5*	103.3	8.5	2	*3.1*
C14	86	63.3	*81.6*	99.6	4.4	30	−1.1	*146.8*	276.9	116.8	21	*16.6*
C15	77	70.1	*75.1*	79.8	1.9	7	9.5	*13.2*	17.1	6.2	12	*10.1*
C16	70	57.9	*69.5*	81.2	0.5	60	23.4	*43.0*	63.3	17.0	5	*4.5*
C17	76	57.0	*72.1*	87.5	3.9	90	−31.9	*86.8*	212.3	3.2	11	*7.1*
C18	72	63.5	*73.7*	84.3	1.7	60	17.7	*63.9*	102.0	3.9	7	*8.7*
C19	67	59.3	*67.1*	75.0	0.1	60	−35.4	*56.7*	138.8	3.3	2	*2.1*
C20	78	58.2	*73.1*	87.9	4.9	120	41.5	*120.0*	198.5	0.0	13	*8.1*
MAE			2.58 dBA						15.43 days			

Note: The excessive noise levels are calculated based on 65 dBA, which is regulated as the permissible noise level in Korea (excessive noise level = actual or predicted based on MCS noise level—65 dBA); term "Error" indicates an absolute difference between the actual and average value based on MCS. Italic values represent the average values of the noise level, damage days, and excessive noise level.

Table 10. Experiment results (unit: US dollars)

Test cases	Actual value	Compensation cost ($)			Difference ($)			AER (%)		
		Predicted value			Predicted value			Predicted value		
		5-NN	10-NN	MCS	5-NN	10-NN	MCS	5-NN	10-NN	MCS
C1	322.3	457.8	513.5	406.4	−135.5	−191.2	−84.1	42.0	59.3	26.1
C2	220.5	250.9	359.3	220.5	−30.5	−138.8	0.0	13.8	63.0	0.0
C3	203.7	223.7	248.3	203.7	−20.0	−44.7	0.0	9.8	21.9	0.0
C4	508.2	467.5	487.8	423.2	40.7	20.5	85.0	8.0	4.0	16.7
C5	263.5	318.6	321.9	263.5	−55.1	−58.5	0.0	20.9	22.2	0.0
C6	423.2	474.2	448.9	423.2	−51.0	−25.7	0.0	12.1	6.1	0.0
C7	203.7	230.4	242.3	203.7	−26.7	−38.7	0.0	13.1	19.0	0.0
C8	508.2	449.4	446.7	779.1	58.9	61.6	−270.9	11.6	12.1	53.3
C9	423.2	385.7	522.4	423.2	37.6	−99.2	0.0	8.9	23.4	0.0
C10	1,474.2	894.4	959.1	779.1	579.8	515.1	695.1	39.3	34.9	47.1
C11	508.2	433.7	404.1	508.2	74.6	104.1	0.0	14.7	20.5	0.0
C12	1,422.8	1,108.2	1,008.3	1,203.3	314.6	414.5	219.5	22.1	29.1	15.4
C13	203.7	228.9	405.1	203.7	−25.2	−201.4	0.0	12.4	98.9	0.0
C14	982.8	1,196.2	1,039.5	1,203.3	−213.4	−56.7	−220.5	21.7	5.8	22.4
C15	220.5	250.9	359.3	220.5	−30.5	−138.8	0.0	13.8	63.0	0.0
C16	203.7	223.7	289.7	203.7	−20.0	−86.0	0.0	9.8	42.2	0.0
C17	779.1	433.7	404.1	508.2	345.5	375.0	270.9	44.3	48.1	34.8
C18	423.2	484.5	496.3	508.2	−61.3	−73.1	−85.0	14.5	17.3	20.1
C19	203.7	174.9	268.7	203.7	28.8	−65.0	0.0	14.1	31.9	0.0
C20	576.4	613.0	640.2	576.4	−36.6	−63.8	0.0	6.4	11.1	0.0
		Mean absolute error ratio (MAER)						17.7	31.7	11.8

Note: Environmental cost and difference are converted from South Korean won (KRW) to US dollars (USD); and exchange rate: KRW/USD = 1,070.40 (prevailing rate on January 23, 2018).

Based on the results, environmental managers can identify specific data, such as excess noise level and damage days, which can be immediately used to solve a given problem. However, the values identified in Table 11 may have been uncertain and limited. Thus, MCS was employed to revise the initial values identified from the retrieved cases in order to achieve more reliable results. Based on the results revised from MCS, the contractor or environmental manager can predict the excessive noise level and damage days; 4.4 dBA (69.4–65 dBA) and 86.3 days for C5, respectively. The excessive noise level and damage days for C11 are 7.7 dBA (72.7–65 dBA) and 86.4 days, respectively. According to the standard for compensation in Table 6, the total noise compensation

J. Constr. Eng. Manage., 2019, 145(8): 04019047

Table 11. Data included in the 10 retrieved cases for C5 and C11

Test case	Similarity of the cases	Building type	PE_1 (days)	PE_2 (m^2)	PE_3 (floors)	PE_4 (days)	PE_5 (m)	PE_6 (m)	NE_1	NE_2	NE_3	NE_4	NE_5	NE_6	NE_7	Noise level (dBA) Min	Noise level (dBA) Avg.	Noise level (dBA) Max	Damage days	Compensation (US$)
C5	0.933	Apartment	1,004	16,350	24	455	6	21	U	U	U	U	U	—	—	70	*72*	74	*30*	*287.7*
	0.925	Apartment	974	24,975	30	397	6	17	U	U	U	U	U	—	—	67	*68*	68	*15*	*118.6*
	0.917	Apartment	1,006	17,392	27	492	6	8	U	U	U	U	U	—	—	70	*74*	78	*120*	*576.4*
	0.909	Apartment	949	9,827	22	562	4	40	U	U	U	U	U	—	—	60	*67*	74	*180*	*406.4*
	0.908	Apartment	676	34,019	15	439	6	40	U	U	U	U	U	—	—	63	*68*	72	*60*	*203.7*
	0.904	Apartment	435	7,990	16	424	6	32	U	U	U	U	U	—	—	60	*68*	75	*60*	*203.7*
	0.897	Apartment	913	43,729	30	544	4	34	U	U	U	U	U	—	—	69	*73*	76	*60*	*423.2*
	0.896	Apartment	623	17,395	15	403	2	9	U	U	U	U	U	—	—	73	*75*	79	*90*	*508.2*
	0.896	Office	406	2,641	10	119	6	33	U	U	U	U	U	—	—	66	*70*	75	*60*	*203.7*
	0.896	Hotel	731	1,107	17	517	7	2	U	U	U	U	U	—	—	66	*72*	77	*30*	*287.7*
C11	0.983	Apartment	623	17,395	15	403	2	9	U	U	U	U	U	—	—	73	*75*	79	*90*	*508.2*
	0.910	Multifamily dwelling	336	1,082	4	193	2	6	U	U	U	U	U	—	—	75	*77*	78	*15*	*372.8*
	0.909	Multifamily dwelling	586	506	5	503	0	4	U	U	U	U	U	—	—	79	*80*	81	*60*	*677.3*
	0.908	Apartment	949	9,827	22	562	4	40	U	U	U	U	U	—	—	60	*67*	74	*180*	*406.4*
	0.905	Dormitory	546	1,340	15	537	6	10	U	U	U	U	U	—	—	68	*70*	71	*60*	*203.7*
	0.902	Apartment	435	7,990	16	424	6	32	U	U	U	U	U	—	—	60	*68*	75	*60*	*203.7*
	0.899	Apartment	676	34,019	15	439	6	40	U	U	U	U	U	—	—	63	*68*	72	*60*	*203.7*
	0.892	Office	180	668	6	180	0	4.3	U	U	U	U	U	—	—	72	*80*	87	*90*	*779.1*
	0.890	Apartment	1,019	5,557	22	168	5	23	U	U	U	U	U	—	—	68	*69*	70	*90*	*263.5*
	0.888	Multiplex housing	307	808	10	209	6	2	U	U	U	U	U	—	—	73	*75*	78	*60*	*423.2*

Note: Symbol U indicates that the equipment was mainly used during the construction. Italic values represent the average values of the noise level, damage days, and compensation cost.

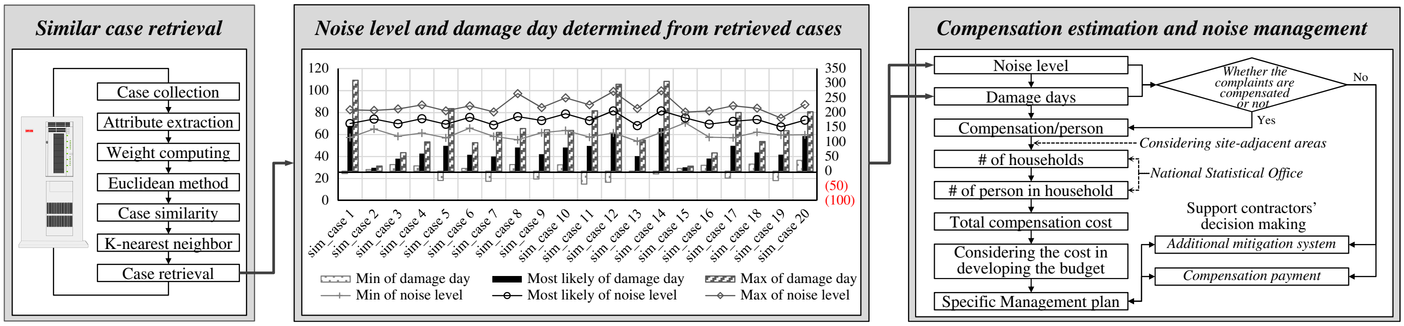

Fig. 4. Use of the developed model.

cost is therefore estimated to be US$790,350 (US$263.45/person × 3 persons × 1,000 households) for C5 and US$1,524,664 (US$508.22/person × 3 persons × 1,000 households) for C11, respectively. In the same way, the compensation costs for the new cases can be predicted. The revised outcomes are retained as a solution for a new case in the case base. Based on the predicted cost, the environmental manager can establish noise mitigation measures or plans during the preconstruction phase where relevant data are very lacking, as illustrated in Fig. 4. This approach can support contractor decision-making as to which measures (e.g., installation of mitigation systems, such as noise barriers and compensation payment) are more reasonable. This is expected to help deal with noise-related problems.

Conclusions

Recently, environment-related disputes have continued to increase, and construction noise is one of the main negative impacts on the surrounding environment, including residents and construction companies. Noise-related problems can significantly increase the cost and risk of a project, including delays, cost overruns, compensation, and even interruptions. Therefore, construction noise needs to be managed. As a first step to managing noise, the compensation due to noise needs to be estimated. However, estimating the compensation cost due to construction noise in the preconstruction phase is difficult because no standard estimation method exists, or insufficient quantitative data for such an estimation have been collected in a database. Thus, a model was developed to estimate the noise-related compensation cost based on previous cases. The developed model estimates the compensation cost based on excessive noise levels and damage days extracted from previous cases. To estimate the cost, experiments were performed on 20 test cases, and the estimated and actual costs were compared to validate the model. The results confirmed an overall similarity of about 91.8%, and the estimated costs with 5-NN, 10-NN, and MCS showed MAERs of 17.7%, 31.7%, and 11.8%, respectively. This indicates that the cost estimated by the model is similar to those of the test cases, which validates its applicability.

The benefits of the developed model can be summarized as follows. It provides a reliable estimation approach because the costs are determined from specific similar cases that actually occurred in the past. Furthermore, statistical and mathematical methods for estimating the compensation cost under uncertain and limited conditions of a project were used, which provides the environmental manager with more reliable outcomes compared to current methods. By referring to the estimated cost, it is possible to examine expected losses due to noise-related problems during the construction. This research focused on estimating the compensation cost due to noise, not just reducing noise-related disputes. Thus, it may be difficult to conclude that noise-related problems will be reduced based on the estimated cost. However, by referring to the estimated cost, it is possible to examine expected losses due to noise-related problems during construction. In addition, outcomes that include the estimated cost, noise level, and damage days are conducive for site managers to practically manage noise and allow the project to proceed according to the expected schedule. Thus, the model can be practically used to estimate the compensation cost as an alternative to existing methods and provides environmental managers with preemptive opportunities to cope with problems, either by installing additional soundproof walls or negotiating with complainants. Thus, this research contributes to the literature and knowledge on noise management by presenting a methodology for estimating the compensation cost due to construction noise.

The developed model uses a matrix for the compensation cost standard that is provided in Korea. Thus, concerns may arise regarding the usability and applicability of the developed model to other countries. However, this model can be adapted if other countries organize a similar compensation standard. The estimated cost depends on the similarity of the retrieved cases, so there may be concern over limits due to a lack of collected cases in the database and the number of experts involved in the attribute weighting. Thus, more cases need to be collected in order to make the estimated cost more accurate and reliable. Furthermore, the accuracy of the weights should be enhanced based on more surveys of experts, and other methods of computing the attribute weights needed to be considered in future research. In this research, the database values were normalized by ratio because many attributes have different scales or units. Depending on the normalization method, outcomes including the similarity may vary. Thus, other normalization methods need to be considered to achieve reliable outcomes in future research. Finally, the compensation costs were estimated based on the noise and project-related attributes included in the cases of the NECRC and some construction firms. However, the collected cases did not include specific information such as the day of the week and time of day. This seems to be because construction activities are conducted over a wide area for a long period, and noise from construction occurs irregularly and intermittently. This makes it challenging to check or measure specific data regarding the day of the week and time of day. Because of difficulties in data acquisition, this research estimated the compensation cost by depending on the slightly limited factors available from the collected cases. Further research should be conducted to achieve more reliable and accurate outcomes based on more specific factors such as the day of week and time of day. Nevertheless, this research is expected to provide meaningful results for estimating the compensation cost in the preconstruction phase, during which site managers

J. Constr. Eng. Manage., 2019, 145(8): 04019047

and general contractors are only aware of schematic information without detailed planning, and when relevant information is insufficient.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

Acknowledgments

This research was supported by the Ministry of Land, Infrastructure, and Transport of the Government of Korea under the Infrastructure and Transportation Technology Promotion Program (18RERP-B082884-05) and the National Research Foundation of Korea (NRF) grant funded by Korea Government (MSIT) (2017R1A2B2007050).

References

Aamodt, A., and E. Plaza. 1994. "Case-based reasoning: Foundational issues, methodological variations, and system approaches." *AI Commun.* 7 (1): 39–59. https://doi.org/10.3233/AIC-1994-7104.

Ahn, J., S. H. Ji, M. Park, H. S. Lee, S. Kim, and S. W. Suh. 2014. "The attribute impact concept: Applications in case-based reasoning and parametric cost estimation." *Autom. Constr.* 43 (Jul): 195–203. https://doi.org/10.1016/j.autcon.2014.03.011.

Ahn, J., M. Park, H. S. Lee, S. Ahn, S. H. Ji, K. Song, and B. S. Son. 2017. "Covariance effect analysis of similarity measurement methods for early construction cost estimation using case-based reasoning." *Autom. Constr.* 81 (Sep): 254–266. https://doi.org/10.1016/j.autcon.2017.04.009.

Arditi, D., and O. B. Tokdemir. 1999. "Comparison of case-based reasoning and artificial neural networks." *J. Comput. Civ. Eng.* 13 (3): 162–169. https://doi.org/10.1061/(ASCE)0887-3801(1999)13:3(162).

Asmar, M. E., A. S. Hanna, and C. K. Chang. 2009. "Monte Carlo simulation approach to support alliance team selection." *J. Constr. Eng. Manage.* 135 (10): 1087–1095. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000074.

Bojórquez-Tapia, L. A., E. Ezcurra, and O. Garcıa. 1998. "Appraisal of environmental impacts and mitigation measures through mathematical matrices." *J. Environ. Manage.* 53 (1): 91–99. https://doi.org/10.1006/jema.1998.0191.

Çelik, T., S. Kamali, and Y. Arayici. 2017. "Social cost in construction projects." *Environ. Impact Assess. Rev.* 64 (May): 77–86. https://doi.org/10.1016/j.eiar.2017.03.001.

Chen, Z., H. Li, C. T. Wong, and P. E. Love. 2002. "Integrating construction pollution control with construction schedule: An experimental approach." *Environ. Manag. Health* 13 (2): 142–151. https://doi.org/10.1108/09566160210424572.

Cheuk, F. N. 2000. "Effects of building construction noise on residents: A quasi-experiment." *J. Environ. Psychol.* 20 (4): 375–385. https://doi.org/10.1006/jevp.2000.0177.

Christensen, P., and L. R. Dysert. 2011. *Cost estimate classification system—As applied in engineering, procurement, and construction for the process industries*. AACE International Recommended Practices 18R-97. Morgantown, WV: AACE International.

Christini, G., M. Fetsko, and C. Hendrickson. 2004. "Environmental management systems and ISO 14001 certification for construction firms." *J. Constr. Eng. Manage.* 130 (3): 330–336. https://doi.org/10.1061/(ASCE)0733-9364(2004)130:3(330).

De Salis, M., D. Oldham, and S. Sharples. 2002. "Noise control strategies for naturally ventilated buildings." *Build. Environ.* 37 (5): 471–484. https://doi.org/10.1016/S0360-1323(01)00047-6.

Diekmann, J. E., and M. C. Nelson. 1985. "Construction claims: Frequency and severity." *J. Constr. Eng. Manage.* 111 (1): 74–81. https://doi.org/10.1061/(ASCE)0733-9364(1985)111:1(74).

Doğan, S. Z., D. Arditi, and H. M. Günaydin. 2008. "Using decision trees for determining attribute weights in a case-based model of early cost prediction." *J. Constr. Eng. Manage.* 134 (2): 146–152. https://doi.org/10.1061/(ASCE)0733-9364(2008)134:2(146).

Du, J., and J. Bormann. 2014. "Improved similarity measure in case-based reasoning with global sensitivity analysis: An example of construction quantity estimating." *J. Comput. Civ. Eng.* 28 (6): 04014020. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000267.

Elliott, S. J., and P. A. Nelson. 1993. *Active control of sound*. New York: Academic Press.

Eom, C. S., and J. H. Paek. 2009. "Risk index model for minimizing environmental disputes in construction." *J. Constr. Eng. Manage.* 135 (1): 34–41. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:1(34).

Fernández, M. D., S. Quintana, N. Chavarría, and J. A. Ballesteros. 2009. "Noise exposure of workers of the construction sector." *J. Appl. Acoust.* 70 (5): 753–760. https://doi.org/10.1016/j.apacoust.2008.07.014.

Gangolells, M., M. Casals, N. Forcada, A. Fuertes, and X. Roca. 2013. "Model for enhancing integrated identification, assessment, and operational control of on-site environmental impacts and health and safety risks in construction firms." *J. Constr. Eng. Manage.* 139 (2): 138–147. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000579.

Gebken, R. J., and G. E. Gibson. 2006. "Quantification of costs for dispute resolution procedures in the construction industry." *J. Prof. Issues Eng. Educ. Pract.* 132 (3): 264–271. https://doi.org/10.1061/(ASCE)1052-3928(2006)132:3(264).

Gilchrist, A., and E. N. Allouche. 2005. "Quantification of social costs associated with construction projects: State-of-the-art review." *Tunnelling Underground Space Technol.* 20 (1): 89–104. https://doi.org/10.1016/j.tust.2004.04.003.

Gilchrist, A., E. N. Allouche, and D. Cowan. 2003. "Prediction and mitigation of construction noise in an urban environment." *Can. J. Civ. Eng.* 30 (4): 659–672. https://doi.org/10.1139/l03-019.

Goh, Y. M., and D. Chua. 2009. "Case-based reasoning for construction hazard identification: Case representation and retrieval." *J. Constr. Eng. Manage.* 135 (11): 1181–1189. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000093.

Hajdu, M. 2013. "Effects of the application of activity calendars on the distribution of project duration in PERT networks." *Autom. Constr.* 35 (Nov): 397–404. https://doi.org/10.1016/j.autcon.2013.05.025.

Halliday, D., and R. Resnick. 2001. *Physics*. New York: Wiley.

Han, J., M. Kamber, and J. Pei. 2015. *Data mining: Concept and techniques*. Seoul: Acorn Publishing.

Hong, J. 2011. "A study on readjusting damage amount for the environmental arbitration-focused on mental damages caused by noise and vibration emanating from construction sites." [In Korean.] *Korean Environ. Law Assoc.* 33 (1): 3–39.

Hong, T., C. Ji, J. Park, S. Leigh, and D. Seo. 2014. "Prediction of environmental costs of construction noise and vibration at the preconstruction phase." *J. Manage. Eng.* 31 (5): 04014079. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000313.

Hopkins, C. 2007. *Sound insulation*. New York: Butterworth-Heinemann.

Jakovljevic, B., K. Paunovic, and G. Belojevic. 2009. "Road-traffic noise and factors influencing noise annoyance in an urban population." *Environ. Int.* 35 (3): 552–556. https://doi.org/10.1016/j.envint.2008.10.001.

Kaya, T., and C. Kahraman. 2010. "Multi-criteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul." *Energy* 35 (6): 2517–2527. https://doi.org/10.1016/j.energy.2010.02.051.

Kim, S. 2017. "Dual-optimization method for improving accuracy of GA-CBR cost estimation model." Ph.D. dissertation, Dept. of Architecture and Architectural Engineering, Seoul National Univ.

Kumaraswamy, M. M. 1998. "Consequences of construction conflict: A Hong Kong perspective." *J. Manage. Eng.* 14 (3): 66–74. https://doi.org/10.1061/(ASCE)0742-597X(1998)14:3(66).

Kwon, N., M. Park, H. S. Lee, J. Ahn, and S. Kim. 2017. "Construction noise prediction model based on case-based reasoning in the preconstruction phase." *J. Constr. Eng. Manage.* 143 (6): 04017008. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001291.

Kwon, N., M. Park, H. S. Lee, J. Ahn, and M. Shin. 2016. "Construction noise management using active noise control techniques." *J. Constr. Eng. Manage.* 142 (7): 04016014. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001121.

Kwon, N., K. Song, H. S. Lee, J. Kim, and M. Park. 2018. "Construction noise risk assessment model focusing on construction equipment." *J. Constr. Eng. Manage.* 144 (6): 04018034. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001480.

Lee, H. S., H. Kim, M. Park, E. A. L. Teo, and K. P. Lee. 2012. "Construction risk assessment using site influence factors." *J. Comput. Civ. Eng.* 26 (3): 319–330. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000146.

Lee, H. S., S. Kim, M. Park, S. H. Ji, K. Seong, and J. H. Pyeon. 2011. "A method of assigning weight values for qualitative attributes in CBR cost model." [In Korean.] *Korean. J. Constr. Eng. Manage.* 12 (1): 53–61.

Matthews, J. C., E. N. Allouche, and R. L. Sterling. 2015. "Social cost impact assessment of pipeline infrastructure projects." *Environ. Impact Assess. Rev.* 50 (Jan): 196–202. https://doi.org/10.1016/j.eiar.2014.10.001.

MOE (Ministry of Environment). 2006. *Guidance of noise and vibration control under construction*. Sejong City, South Korea: MOE.

MOE (Ministry of Environment). 2007. *A study on the evaluation method of environmental damage and rational adjustment of compensation standard*. Sejong City, South Korea: MOE.

MOE (Ministry of Environment). 2016. *Noise and vibration control act*. Act No. 13805. Sejong City, South Korea: MOE.

Morcous, G., H. Rivard, and A. Hanna. 2002. "Case-based reasoning system for modeling infrastructure deterioration." *J. Comput. Civ. Eng.* 16 (2): 104–114. https://doi.org/10.1061/(ASCE)0887-3801(2002)16:2(104).

NECRC (National Environmental Conflict Resolution Commission in Korea. 2017. *Environmental dispute mediation status report*. Seoul: NECRC.

NECRC (National Environmental Conflict Resolution Commission in Korea). 2016. *Press release on the raising compensation cost for psychological damage caused by construction noise*. Seoul: NECRC.

Neitzel, R., N. S. Seixas, J. Camp, and M. Yost. 1999. "An assessment of occupational noise exposures in four construction trades." *J. Am. Ind. Hyg. Assoc.* 60 (6): 807–817. https://doi.org/10.1080/00028899908984506.

Ozorhon, B., I. Dikmen, and M. Birgonul. 2006. "Case-based reasoning model for international market selection." *J. Constr. Eng. Manage.* 132 (9): 940–948. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:9(940).

Pal, S. K., and S. C. Shiu. 2004. *Foundations of soft case-based reasoning*. New York: Wiley.

Pan, N. 2008. "Fuzzy AHP approach for selecting the suitable bridge construction method." *Autom. Constr.* 17 (8): 958–965. https://doi.org/10.1016/j.autcon.2008.03.005.

Pawan, P., and P. Lorterapong. 2016. "A fuzzy-based integrated framework for assessing time contingency in construction projects." *J. Constr. Eng. Manage.* 142 (3): 04015083. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001073.

Rogerson, P. 2001. *Statistical methods for geography*. London: SAGE Publications.

Sailer, U., and M. Hassenzahl. 2010. "Assessing noise annoyance: An improvement-oriented approach." *Ergonomics* 43 (11): 1920–1938. https://doi.org/10.1080/00140130050174545.

Salling, K. B. 2007. *Risk analysis and Monte Carlo simulation within transport appraisal*. Lyngby, Denmark: Univ. of Denmark.

Stipanowich, T. J. 2004. "ADR and the 'Vanishing Trial': The growth and impact of alternative dispute resolution." *J. Empirical Legal Res.* 1 (3): 843–912. https://doi.org/10.1111/j.1740-1461.2004.00025.x.

Vu, D. H., K. M. Muttaqi, and A. P. Agalgaonkar. 2015. "A variance inflation factor and backward elimination based robust regression model for forecasting monthly electricity demand using climatic variables." *Appl. Energy* 140 (Feb): 385–394. https://doi.org/10.1016/j.apenergy.2014.12.011.

Watson, I. 1997. *Applying case-based reasoning: Techniques for enterprise system*. San Francisco: Morgan Kaufmann.

Watson, I., and F. Marir. 1994. "Case-based reasoning: A review." *Knowl. Eng. Rev.* 9 (4): 327–354. https://doi.org/10.1017/S0269888900007098.

Xueqing, W., L. Bingsheng, E. Allouche, and L. Xiaoyan. 2008. "A practical bid evaluation method considering social costs in urban infrastructure projects." In *Proc., 2008 4th IEEE Int. Conf. on Management of Innovation and Technology*, 617–622. New York: IEEE.

Yang, I. T. 2008. "Distribution-free Monte Carlo simulation: Premise and refinement." *J. Constr. Eng. Manage.* 134 (5): 352–360. https://doi.org/10.1061/(ASCE)0733-9364(2008)134:5(352).