Analysis and Modeling of Threatening Factors of Workforce's Health in Large-Scale Workplaces: Comparison of Four-Fitting Methods to select optimum technique

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Abstract

Introduction: Workforce is one of the pillars of development in any country. Therefore, the workforce's health is very important, and analyzing its threatening factors is one of the fundamental steps for health planning. This study was the first part of a comprehensive study aimed at comparing the fitting methods to analyze and model the factors threatening health in occupational injuries.

Methods: In this study, 980 human occupational injuries in 10 Iranian large-scale workplaces within 10 years (2005-2014) were analyzed and modeled based on the four fitting methods: linear regression, regression analysis, generalized linear model, and artificial neural networks (ANN) using IBM SPSS Modeler 14.2.

Results: Accident Severity Rate (ASR) of occupational injuries was 557.47 ± 397.87. The results showed that the mean of age and work experience of injured workers were 27.82 ± 5.23 and 4.39 ± 3.65 years, respectively. Analysis of health-threatening factors showed that some factors, including age, quality of provided H&S training, number of workers, hazard identification (HAZID), and periodic risk assessment, and periodic H&S training were important factors that affected ASR. In addition, the results of comparison of the four fitting methods showed that the correlation coefficient of ANN ($R = 0.968$) and the relative error (R.E) of ANN ($R.E = 0.063$) were the highest and lowest, respectively, among other fitting methods.

Conclusion: The findings of the present study indicated that, despite the suitability and effectiveness of all fitting methods in analyzing severity of occupational injuries, ANN is the best fitting method for modeling of the threatening factors of a workforce's health. Furthermore, all fitting methods, especially ANN, should be considered more in analyzing and modeling of occupational injuries and health-threatening factors as well as planning to provide and improve the workforce's health.

Keywords: workforce's health, occupational injury, fitting methods, accident severity rate (ASR), threatening factors

1. Introduction

Designing, implementing, and monitoring of health programs that provide, maintain, and improve workforce's health can bring more human, social, and economic benefits (1-3). Strategic planning of health requires basic and practical information about health threats and the threatening factors that affect health. One of the main threats in

large-scale workplaces is occupational injuries (3-4). The World Health Organization (WHO) knows occupational injuries as an epidemic phenomena in the field of public health (5-6). Also, the International Labor Organization (ILO) reported that approximately 268 million occupational accidents leading to injuries occur in the different workplaces, with over 2.2 million of them per year resulting in death (5, 7). The design and development of preventive and control measures in the field of health and safety in workplaces requires appropriate and practical data and information. So, as much as the findings of occupational injuries analysis become more acceptable, they can be used as a basis for planning and management of health issues in workplaces. Using the results of the studies, we may be able to determine the important and affecting factors on injuries as well as better management and control of occupational accidents and severity of injuries (8-10). One of the main threats arising from occupational accidents is severity of damages and injuries. Accident severity rate (ASR) is one of the important indices for analysis and modeling of the severity of occupational injuries (11, 12) Therefore, analysis of this index using modeling techniques can provide accurate identification of health threatening factors, as well as help managers and engineers to design and develop various health programs to prevent and reduce such injuries (8, 13). Analysis and modeling of health problems using fitting methods and statistical modeling techniques, such as linear regression, generalized linear model, regression analysis, and artificial neural networks (ANN), can lead to a better understanding and identification of the health-threatening factors in a workforce (8, 14, 15). In spite of some studies in this field, a comprehensive study on occupational injuries' severity comparing multiple regression methods to analyze and model health threatening factors in large-scale workplaces has not been observed. Therefore, this study was designed and implemented with the purpose of comparing the four fitting methods to be used in causal analysis and modeling of the factors that affect the severity of injuries as a threat to the workforces' health and in order to select the optimum technique in ASR modeling.

2. Material and Methods

This analytical and cross-sectional study was implemented in Iranian large-scale workplaces, including 10 power plant construction worksites. Selection of construction sites for this study was due to the fact that the rate of severe accidents and sometimes fatal accidents in construction is higher than that observed in other workplaces (16, 17). In the present study, 980 occupational injuries within 10 years (2005-2014) were analyzed and modeled.

2.1. Study implementation

This study was carried out in four stages as follows:

2.1.1. First Stage: Occupational injuries description

Description of occupational injuries was done according to accident investigation forms, interviews with injured workforce, witnesses, supervisors, managers, and other personnel. All registered documents of occupational injuries that were collected over a period of 10 years (2005-2014) were peer assessed and reviewed. Occupational injuries with incomplete data were excluded from the study. Finally, a total of 980 accidents that resulted in injuries to the workforce were selected for the study. Accident severity rate (ASR) as a health threat to workforces was analyzed in this study. ASR is an index for quantitative analysis and modeling of occupational injuries. ASR was applied to measuring health performance of large workplaces and identifying problems (12). According to the Occupational Safety and Health Administration (OSHA), ASR was calculated as follows (18): ASR = (total number of lost work days due to accidents and injures × 200000/total number of worked hours of workforces).

2.1.2. Second stage: Data collection of IF, OF, TF & RMF

Data of individual and organization factors (IF & OF) in addition to documents of health and safety (H&S) training system (TF) and H&S risk management (RMF), which were established and implemented in the studied large-scale workplaces, were collected by using designed checklists and results of data collection in the occupational injuries description stage. Individual factors (IF) included average age, work experience, educational level, and marital status. Organization factors (OF) or characteristics of the workplace management and structure included job title, activity types during occupational injuries, the number of workers, existing time pressure, and types of employment (formal or contractor). H&S Training Factors (TF) included pre-employment training, periodical training, past injury training, personal protective equipment (PPE) training, housekeeping training, and quantity and quality of training. H&S risk management factors (RMF) were hazard identification (HAZID), periodic risk assessment, accident investigation, risk control measures such as PPE, implementing tool box meeting (TBM) and housekeeping, applying H&S checklists, establishment of incident report, and H&S audit.

2.1.3. Third Stage: Analyzing and modeling of ASR by four fitting methods

Analysis and modeling of ASR were performed using the four fitting methods including linear regression, regression analysis, generalized linear model, and artificial neural networks (ANN) by IBM SPSS Modeler 14.2. Linear regression is a common statistical technique for classifying records based on the values of numeric input fields.

Linear regression fits a straight line or surface that minimizes the discrepancies between predicted and actual output values (19). Regression analysis is a statistical tool for the investigation of relationships between factors. Usually, the investigator seeks to ascertain the causal effect of one factor on another. The investigator also typically assesses the "statistical significance" of the estimated relationships, that is, the degree of confidence that the true relationship is close to the estimated value (14, 20). Dissimilar to the general linear model, in the generalized linear model, the dependent variable is related linearly to the factors using a specified link function. Moreover, the model allows the dependent factors to have an abnormal distribution (21). Finally, artificial neural network (ANN) is a simplified model that shows the way the human brain processes information. It works by simulating a large number of interconnected processing units that resemble abstract versions of neurons (20, 22).

2.1.4. Fourth Stage: Comparison of the Fitting Methods

Comparison of the fitting regression methods in order to select the optimum technique for approximation function of ASR and determining factors affecting ASR were done on the basis of correlation coefficient (R), relative error indices, and using most powerful data mining software, IBM SPSS Modeler 14.2.

3. Results

Accident severity rate (ASR) of the occupational injuries was obtained as 557.47 ± 397.87 (Range: 136.0 to 2250.0). Table 1 shows the descriptive results.

Table 1. Descriptive findings of the study

Studied Factors		Descriptive Values
Age (years) (M ± SD)		27.82 ± 5.23
Work Experience (M ± SD)		4.39 ± 3.65
Education	Sub Diploma	325 (33.2%)
	Diploma	398 (40.6%)
	Upper diploma	190 (19.4%)
	≥B.S	67 (6.8%)
Marital Status	Single	481 (49.1%)
	Married	499 (50.9%)
Job Title	Simple Workers	719 (73.4%)
	Technicians	237 (24.2%)
	Supervisor	24 (2.4%)
Activity Type	Normal Work	641 (65.4%)
	Installation	84 (8.6%)
	Maintenance	172 (17.6%)
	Material Handling	83 (8.5%)
Time Pressure		721 (73.6%)
Contractor		724 (73.9%)
H&S Training Factors (TF)	Pre-employment training	225 (23.0%)
	Periodic Training	381 (38.9%)
	Past Injury Training	135 (13.8%)
	PPE Training	253 (25.8%)
	Housekeeping Training	141 (14.4%)
	Quantity of Training	258 (26.3%)
	Quality of Training	245 (25.0%)
H&S Risk Management Factors (RMF)	HAZID	182 (18.6%)
	Periodic risk assessment	466 (47.6%)
	accident investigation	167 (17.0%)
	Risk control measures; PPE	272 (27.8%)
	TBM	159 (16.2%)
	Housekeeping	231 (23.6%)
	Checklist	809 (82.6%)
	Incident Report	128 (13.1%)
	H&S Audit	197 (20.1%)

The descriptive findings of individual factors (IF) showed that the average age and work experience of injured workers were 27.82 ± 5.23 and 4.39 ± 3.65 years, respectively. The educational level of the workforce that was injured most frequently was diploma and sub-diploma level (73.8%), and half of the injured workers were married (50.9%). The results of organization factors (OF) showed that over 70% of injured workforces were simple workers and about 24.2% were technicians. Normal work had the high frequency of occupational injuries (67%); and almost one-fifth of the injuries occurred in maintenance activities (17.6%). In addition, the findings showed that time pressure was involved in 73.6% of occupational accidents and that 73.9% of occupational injuries happened to the contractor workforces. Analyzing the H&S training process indicated that approximately one-fourth of the injured workforces (23.0%) received pre-employment H&S training, 39.9% participated in periodic training, and 13.8% received H&S training after an injury occurred. Additionally, quality and quantity of trainings were estimated to be 25.0% and 26.3%, respectively. The results of H&S risk management factors showed that the proportion of main RMFs, including hazard identification (HAZID), periodic risk assessment, and accident investigation, were estimated to be 18.6%, 47.6%, and 17.0%, respectively. Furthermore, H&S control measures that were implemented, including PPE, TBM, and housekeeping, were 27.8%, 16.2%, and 23.6%, respectively. Table 2 presents the results of using the four fitting methods, including linear regression, regression analysis, generalized linear model, and artificial neural networks (ANN), to analyze and model the factors that affected ASR. As it is shown, the factors, including age, quality of provided H&S training, number of workers, HAZID, periodic risk assessment, and periodic H&S training, were important factors that affected ASR. According to results of linear regression, regression analysis, and ANN, the average age was reckoned to be an important factor that affected ASR. The results of the generalized linear model showed that average work experience and quality of H&S training were important factors that affected occupational injuries' severity.

Table 2. Analysis of health threatening factors by four fitting methods

Factors	Importance value of each factors on ASR			
	Linear Regression	Regression	Generalized Linear Model	ANN
Age	0.14	0.16	0.09	0.20
Work Experience	0.09	0.07	0.14	0.08
Education	0.02	0.04	0.02	0.03
average of workers	0.05	0.09	0.08	0.05
Activity Type	0.07	0.06	0.02	0.04
Time Pressure	0.02	0.02	0.01	0.03
Contractor	0.01	0.02	0.01	0.02
Periodic Training	0.08	0.09	0.04	0.05
Past Accident Training	0.04	0.03	0.07	0.04
PPE Training	0.03	0.02	0.01	0.02
Housekeeping Training	0.01	0.02	0.01	0.02
Duration of Training	0.03	0.04	0.08	0.06
Quality of Training	0.10	0.06	0.14	0.10
HAZID	0.09	0.10	0.09	0.07
Periodic risk assessment	0.09	0.05	0.05	0.07
accident investigation	0.08	0.04	0.06	0.06
PPE	0.02	0.03	0.01	0.02
TBM	0.01	0.02	0.02	0.01
Housekeeping	0.01	0.02	0.01	0.02
H&S Audit	0.01	0.02	0.04	0.01
sum	1.0	1.0	1.0	1.0

The findings of the comparison of the four fitting methods in order to select the optimum technique for approximation function of ASR are shown in Figures 1-4. The results showed that the highest correlation coefficient (R) and the lowest relative error, respectively, were for the ANN model (0.968, 0.063), generalized linear model (0.885, 0.216), linear regression (0.862, 0.257), and regression analysis (0.825, 0.319). Therefore, the comparison of these fitting methods showed that ANN is the best fitting method to analyze and model the severity of occupational injuries.
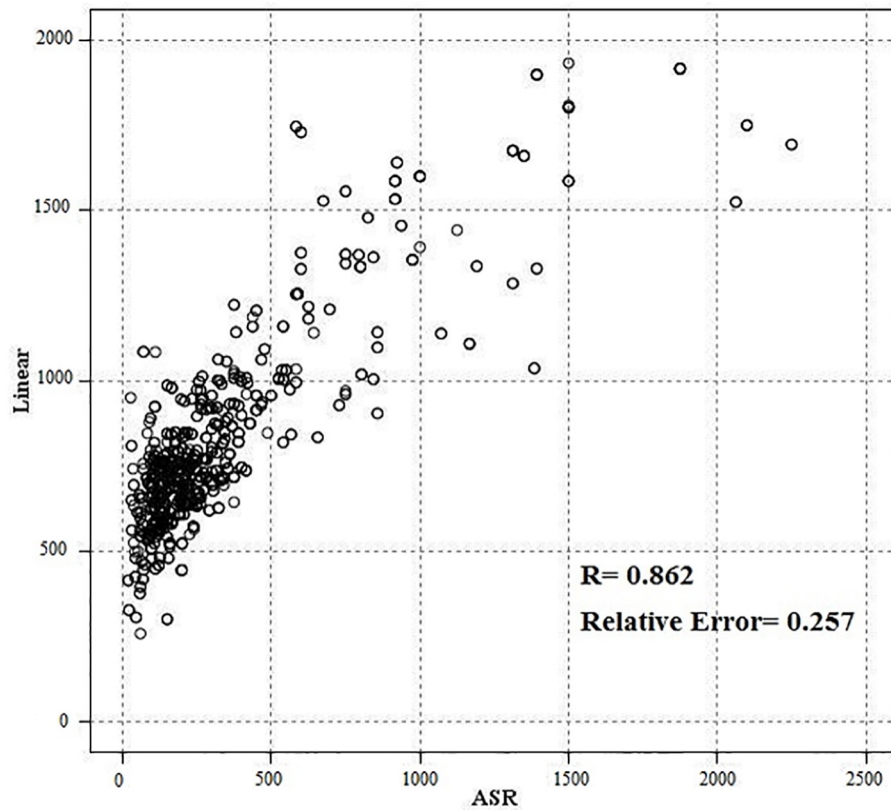
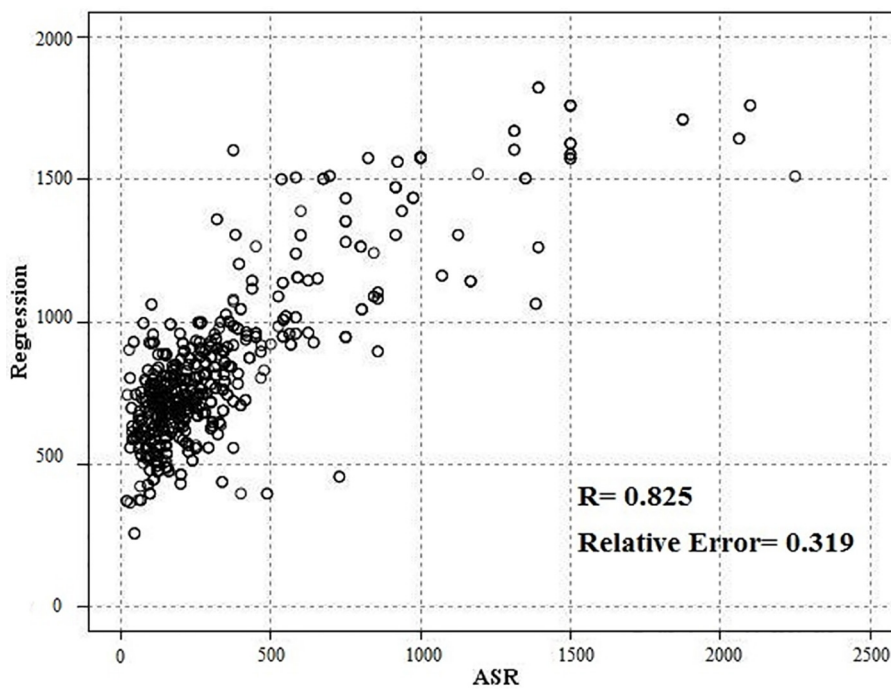**Figure 1.** Regression between actual ASR and linear regression

Figure 2. Regression between actual ASR and regression analysis
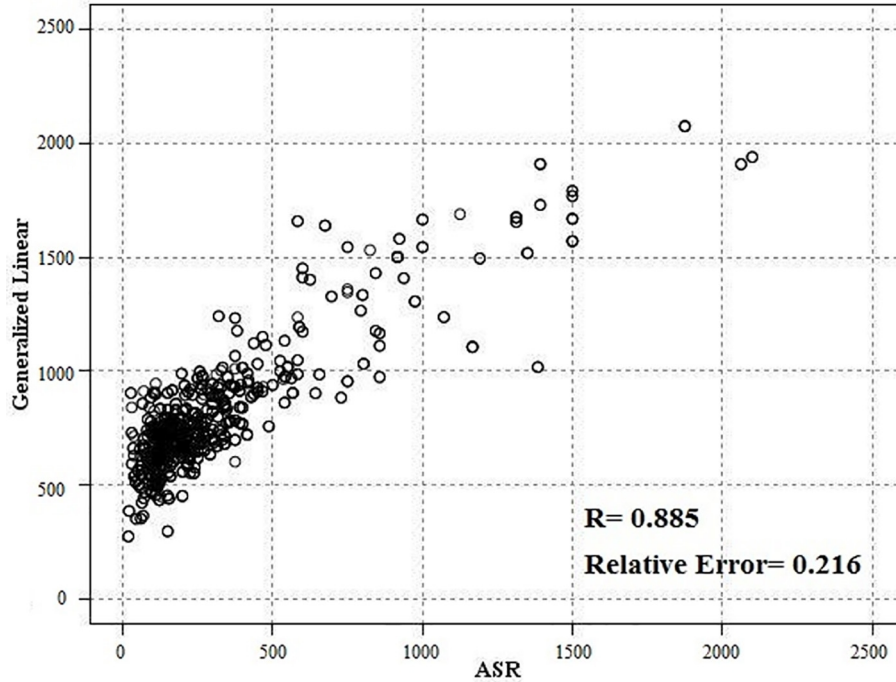
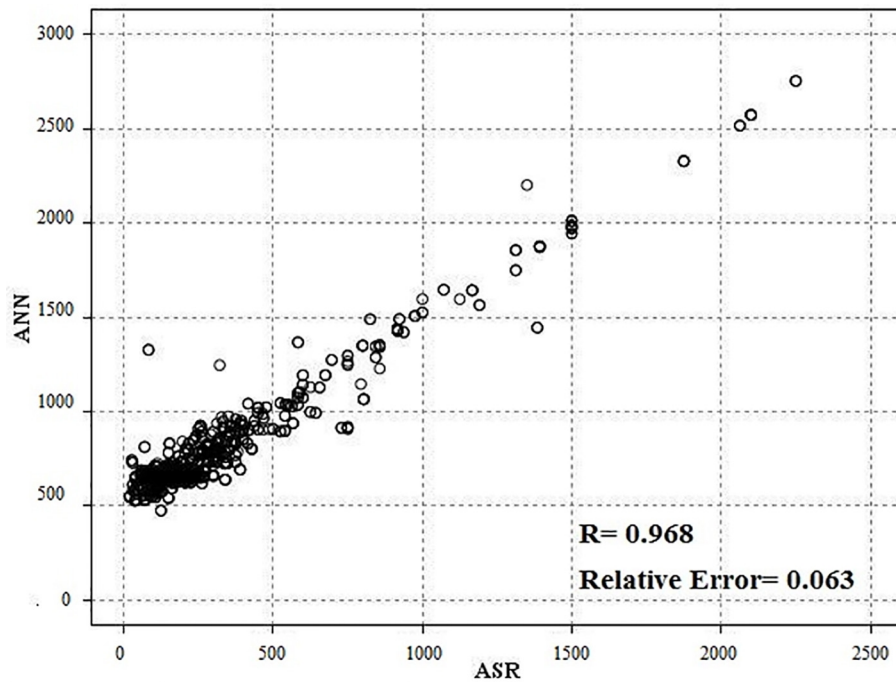**Figure 3.** Regression between actual ASR and generalized linear model

Figure 4. Regression between actual ASR and artificial neural networks (ANN)

4. Discussion

The findings of present study, which was designed and implemented based on using analytical fitting methods, indicated that occupational injuries, as one of the most important threats to workforce's health, are induced by several combinations of factors. These findings are consistent with results of other studies, and they indicated that individual factors (e.g., average age of workforce, work experience, and education level), organization factors (e.g., activity type, average number of workers in each activity, time pressure, and using contractor workforce), H&S training factors (e.g., periodic and past injury training, PPE, housekeeping training, quality and quantity of training),

H&S risk management factors (e.g., HAZID, periodic risk assessment, accident investigation, using PPE, implementing TBM and housekeeping) as risk control measures and H&S audit are the most important factors in causal analysis and modeling the severity of occupational injuries (8, 23-25). Consistent with the findings of the study, other studies have reported that individual and organizational factors can play a significant role in the incidence and severity of occupational injuries (24, 26). Haslam et al. revealed that workers play a direct role in 70% of the injuries caused by human error and unsafe acts (26). The importance of individual factors on the grounds that workers are responsible for the protection of their lives proved the effects of these factors on each type of job and activity that is involved (24, 26-28). According to the findings, organization factors are the most important factors of occupational injuries. Organizational factors have two roles and impacts on the severity of occupational injuries. Factors such as the type of activity can directly affect the severity of injuries. In addition, the number of workers and time pressure as a mediator can affect the severity of injuries (10, 26). Studies have reported that awareness and readiness to workplace hazards is one way to prevent and reduce the severity of occupational injuries, thus the H&S training factor is the most important factor of the injuries' severity (23, 25). Lack and inadequacy of training and a poor health and safety climate have been shown to be the root causes of occupational injuries that have an impact on workforces' health (27, 29). Also, the results of four fitting methods indicated that H&S training factors significantly affected ASR and defects in the design and implementation of appropriate H&S training programs, which can cause serious and sometimes tragic health effects (23, 25, 27, 29). Furthermore, consistent with other studies, the findings revealed that poor design and implementation of factors associated with H&S risk management, including the establishment of a hazard identification system (HAZID), periodic risk assessment, developing and implementing accident investigations, and risk control measures, such as PPE, implementing TBM, and housekeeping, can play a significant and determinative role in severe health threats of occupational injuries (24-25, 30).

It was observed that the fitting analysis techniques seemed practical and applicable to analyze and model the health threats and the factors affecting them. Therefore, based on the more significant and strong findings, all of the fitting analysis methods can be used in setting goals and policies and to design health programs to prevent and reduce the severity of occupational injuries in large-scale workplaces. Furthermore, the comparison of the findings of the four fitting methods revealed that, despite the suitability and applicability of all of the methods, ANN had the best correlation coefficient (R) and the lowest relative error, so this fitting method can be selected as the optimum technique for approximating the severity of occupational injuries and other health consequences in large-scale workplaces. Some studies also have suggested that ANN as a good technique to analyze and model health and safety threatening factors to workforces (15, 31, 32). For example, Carrillo-Castillo and co-workers applied ANN to model and predict accidents' severity in the manufacturing sector, and they confirmed that neural networks were useful in estimating accident's risk factors (31). Also, Moghaddam et al. used artificial neural networks to predict the severity of highway crashes and showed that the best application of ANN was in estimating the severity of injuries (32). It seems that a comprehensive study should be designed and implemented in the future with the purpose of analyzing and modeling health effects, such as occupational injuries using the ANN technique.

Finally, the limitations of this study included the high time consumption of data gathering; in addition, the geographical distribution of the studied workplaces was high. In addition, the main limitations to generalizing the results to the larger populations were providing the introduced fitting methods as a common method for analysis and modeling of occupational injuries, as well as training H&S engineers how to use these analytical techniques.

5. Conclusions
The results affirmed that all of the fitting methods were suitable and applicable in analyzing and modeling the severity of occupational injuries. Furthermore, comparison of the fitting methods revealed that ANN was the best analytical modeling approach in the analysis of occupational injuries in large-scale workplaces. Therefore, all fitting methods, especially ANN, should be considered more in analyzing and modeling of occupational injuries and health-threatening factors as well as planning to provide and improve workforce's health. Also, it seems that a comprehensive study aimed at analyzing and modeling of occupational injuries and other health and safety issues using the ANN technique should be designed and implemented in the future.

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