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Research Article

Decision Making Method Based on Importance-Dangerousness Analysis for the Potential Risk Behavior of Construction Laborers

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Unsafe behavior contributes to 90% of the causes of construction accidents. To prevent construction accidents, studies on existing unsafe behaviors have been regularly conducted. However, existing studies generally tend to average the survey results and conduct analyses thereon, and such a method cannot consider the potential risk as regards people's anxiety about a certain unsafe behavior. Thus, this research suggests an Importance-Dangerousness Analysis (IDA) technique so that potential risks due to unsafe behaviors of laborers working in the construction sector could be evaluated. In order to verify the applicability of the suggested technique, an actual survey was conducted, and the results of Importance-Performance Analysis (IPA) and IDA were compared with each other. It was found that, unlike IPA, unsafe behaviors that could pose potential risks were confirmed by IDA. Further, unsafe behaviors in the construction sector that should be urgently addressed were also studied. Finally, the IDA suggested in this research could contribute to effective construction safety management on-site by supporting the decisions of the safety manager based on the unsafe behavior analysis of construction laborers.

1. Introduction

Construction industry is highly accident-prone owing to the typical job characteristics such as outdoor production, workplace height, and high dependency on manpower. According to the revisions to the 2012 Census of Fatal Occupational Injuries counts, the total number of fatal work injuries in the United States was 4,628 in 2012, up from the preliminary estimate of 4,383 reported in August 2013. As per industry classification, among the 1,823 laborers in goods producing sectors, the number of accident victims in the agriculture, forestry, fishery, and hunting sectors was 509 (27.9%); the number of accident victims in the construction sector was 806 (44.2%); and the number of accident victims in the manufacturing sector was 327 (17.9%). The statistics indicate that the construction industry has the maximum number of accident victims [1]. According to a report from Korea Occupational Safety and Health Agency (KOSHA), the total number of industrial accident victims in Korea was 92,256 in 2012, wherein the number of accident victims in the construction sector was 23,349, thus, accounting for 25.3% of the total industrial accident victims. In particular, the death toll in industrial accidents in the construction sector was 557, which accounted for 38.8% of the total death toll of 1,435 in the entire industry. This represented the highest accident fatality rate in the industry. Further, the number of accident victims in the last 5 years (2008–2012) has increased from 20,835 in 2008 to 23,349 in 2012. Hence, urgent safety measures are needed for preventing accidents in the construction industry.

Unsafe behavior is a major feature of accidents. Heinrich et al. [2] suggested that about 90% of industrial accidents involve unsafe behavior; however, this does not mean that unsafe behavior is the cause of 90% of the accidents; rather, it is one of the many contributing factors, and, very often, it is the final "trigger" event. Unsafe behavior is also a major cause of accidents in the construction sector [3]. Thus, audits and management of unsafe acts by encouraging safer behavior can be a means of accident prevention.

Recent studies on the causes of industrial accidents are moving away from the existing perception that accidents occur due to unsafe physical working conditions to the perspective of investigating the relationship between the personal characteristics (i.e., social, physical, and psychological factors, etc.) of the laborers and the causal factors of industrial accidents [4]. In the construction sector, various studies are being conducted to evaluate the background factors of unsafe behavior of construction field laborers, structural analysis of the influencing factors of safe behavior, and so forth. Generally, in existing studies, data are collected based on survey results, and analysis is then conducted using techniques such as one-way ANOVA [5], factor analysis [6], structural equation model [4, 7–9] analytic hierarchy process [10], and Importance-Performance Analysis [11]. However, like in most of the survey analysis, the average value has a significant implication in such methods, and, thus, this process is inherently inadequate in evaluating the potential risks of unsafe behavior. For example, in the case of a survey on a five-point scale, the result of 100 subjects marking three points has the same average value as the result of 50 subjects marking one point and the other 50 subjects marking five points. However, evaluation of the dangers of unsafe behavior should focus on the latter case where 50 subjects marked five points, not on how much the average value is. That is, when compared to the former case, 50 people assessed that a certain factor is dangerous in the latter case, and, thus, the factor has high potential risk. It is almost impossible to evaluate such potential risk in the existing analysis method. So, an appropriate decision making method and its application in the complicate problem are essentially needed. Thus, in this study, a method for analyzing the potential risk of unsafe behaviors of construction laborers is to be suggested. In Section 2, the existing research literature on unsafe behavior is reviewed. In Section 3, a methodology for analyzing the potential risk of unsafe behavior, that is, IDA, is suggested. And, the usefulness of the suggested methodology is verified by comparing the result obtained by using the existing IPA with the outcome achieved through the methodology suggested in this research. Lastly, in Section 4, the limitations of the study and the suggested direction of the future research are described.

2. Literature Review

The relationship between unsafe behavior and construction accidents has been verified through a number of existing studies. Dester and Blockley [3] suggest that poor safety culture is a significant factor in the unsatisfactory safety record of the construction industry and that unsafe behavior is a feature of this culture. The relationship between unsafe behavior and inappropriate culture was stressed conclusively. Langford et al. [6] tried to identify the important factors affecting the safe behavior of construction laborers. The research model of connecting the three themes, implementation strategies for safety management, attitudes of laborers about safety, and behavioral factors displayed by construction laborers, was used. Data was collected through survey, and five important factors were derived through factor analysis. In order to study the relationship between safety climate and laborers' safe behavior in the construction sector, Mohamed [7] established a structural equation model that has 10 independent variables, including commitment, safety rules and procedure, and laborers' involvement. According to the analysis result, safety climate and laborers' safe behavior showed a significant justice relationship. Safety climate plays the role of a mediator between the independent variables and laborers' safe behavior. Oliver et al. [4] examined the relationships between an individual's psychological state, work environment, organizational variables, and occupational accidents, using structural equation modeling. It was clearly established that the organizational involvement positively affects laborers' safe behavior. Choudhry and Fang [12] conducted interviews to analyze the reason for the construction laborers' unsafe behavior. As a result, the reason for the laborers' seven unsafe behavioral conducts, including ignorance and lack of safety knowledge, was identified. The research also identified 11 factors that affected the safe behavior of laborers.

Several studies on unsafe behavior have been actively conducted in Korea, where frequent construction accidents occur. Choi and Kim [8] tried to identify the relationship between the major safety climate factors and laborers' safe behavior in the Korean construction industry. With this objective, the researchers applied the structural equation model of Mohamed [7] to the Korean construction industry and drew the conclusion that "personal risk recognition" and "laborers' safety competence" were the major factors and that the safety climate positively affects laborers' safe behavior. Ryu and Her [10] recognized that safety accidents frequently occur in conditions where unsafe behavior and unsafe status were combined, and they suggested an AHP model as a systematic technique of analyzing the background of the cause of unsafe behavior. Consequently, a checklist that enabled the evaluation of unsafe behavioral factors was developed. Lee at al. [5] statistically analyzed the awareness per category regarding the accident experience of the construction laborers and, based thereon, tried to find a method to improve the safety management activities by improving the awareness levels. They conducted a survey on 36 items followed by an analysis using one-way ANOVA. Subsequently, factors including the major cause of accident occurrence and awareness of the construction laborers about the actual safety conditions in the construction sites were summarized. Shin and Lee [9] tried to reveal the causal relation among the variables affecting safe behavior. The safety climate and laborers' safe behavior were investigated, and the result was analyzed by using structural equation modeling. According to the result, the safe behavior of the construction laborers was directly affected by communication and educational training. Further, safe behavior is not confined merely to personal aspects but is also linked to the organizational climate regarding safety. Han et al. [11] attempted to identify the characteristics of unsafe behaviors of Korean and foreign laborers and prioritized the ones that required improvement by using Importance-Performance Analysis (IPA). As a result,

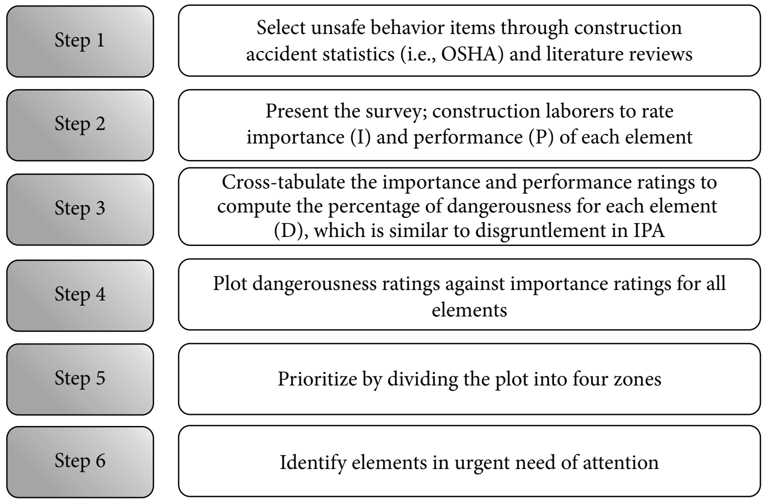

Figure 1: Six-step methodology.

among 19 items, 7 items requiring urgent improvement were derived, and the difference between unsafe behaviors of Korean and foreign laborers was identified.

Such studies indicate that personal psychology and behavior are important factors for preventing accident occurrence in the construction sector. Although such relevant studies have been regularly conducted, existing findings are not capable of considering the potential risk of unsafe behavior of laborers that can cause construction accidents. Thus, this research intends to suggest an improved analysis method that considers such potential risks.

3. Methodology

3.1. Importance-Dangerousness Analysis. The method of analyzing the potential risk of unsafe behavior of construction laborers, as suggested in this research, benchmarked the 6-step methodology suggested by Stradling et al. [13]. They suggested an analysis method that is more detailed than the IPA method, which is one of the existing methods for evaluating customer dissatisfaction. Instead of conducting an analysis by simply using the average value of the response results from the existing IPA, a new measure of "disgruntlement" was derived based on the proportion of respondents marking "quite important" or "very important" on the importance of certain items or "disagree" or "strongly disagree" on the performance of those items through cross-tabulation process.

By weighing performance ratings with importance ratings in this manner, disgruntlement gives a more plausible measure than performance alone on which to base remedial actions to improve user satisfaction with service. Rather than dealing with aggregate mean scores and discrepancies between them, this method identifies "how many" and, potentially, "which" respondents believe an aspect of a service important to them is not being delivered well [13]. Regarding unsafe behavior, the aspect of "how many" and potentially "which unsafe behaviors" do the laborers consider risky would be a more significant outcome in safety management than the aspect of how risky the laborers consider the behavior to be, on an average. The methodology suggested in this research, Importance-Dangerousness Analysis (hereafter IDA), is as shown in Figure 1.

3.2. Steps 1–3. Items related to unsafe behavior were selected in step 1. In that selection process, we referred to the items related to unsafe behavior in the "accident occurrence statistics" [14] of KOSHA and selected 19 items. Subsequently, through interviews with two safety managers who have over 10 years of experience in construction safety management, the appropriateness of the selected items was assessed. Finally, the questionnaire items were prepared, as shown in "Table 1."

Regarding the response method, importance (I) and performance (P) were adjusted to importance (I) and performance of management (P), and the respondents replied as per Likert's five-point scale (from 1 = "strongly disagree" to 5 = "strongly agree").

In step 2, a survey was conducted on construction laborers across five construction companies from March 15, 2014, to April 20, 2014 (for about a month). A total of 358 laborers participated and 279 questionnaire responses, except for 45 that were deemed to be invalid, were analyzed. The details of the respondents are shown in "Table 2."

To confirm the consistency of the survey results, a reliability analysis was conducted using Cronbach's alpha coefficient through SPSS 19.0 program. In general, if Cronbach's alpha value is over 0.6, the survey result is deemed to be reliable [15]. Cronbach's alpha for the survey results of this research was over 0.6 for every item, as shown in "Table 3," and, thus, the statistical value indicated acceptable level in this result.

Tables 4 and 5 show the ranking of the proportion of people who answered "agree" or "strongly agree" regarding the performance and importance of the 19 items of unsafe behavior.

In step 3, dangerousness per item was assessed. Dangerousness assessment is conducted by using cross-tabulation in accordance with the importance assessment per item. For example, Table 6 is the result of cross-tabulation of item

Table 1: Factors in construction cost estimation.

Number	Main item	Number	Subitem
A	Inadequate use of equipment, machineries, and materials	A-1	Inadequate use of protection management
		A-2	Inadequate use of vehicle
		A-3	Cleaning and repairing of working machines
		A-4	Inadequate handling of toxic substance
B	Neglect of dangerous structure	B-1	Neglect of dangerous structures
		B-2	Obstacles left alone on the ground
		B-3	Use of defective tools and materials
		B-4	Bad state of load
		B-5	Incognizance of obstacles at bottom
C	Careless working and breaking the procedure	C-1	Inappropriate method and procedure
		C-2	Inadequate supervision and management
D	Unsafe working posture	D-1	Unsafe working posture
E	Mistakes at working	E-1	Equipment malfunction
		E-2	Wrong handling of hand tools
		E-3	Miss of footing on the stairs
F	The reckless and unnecessary acts	F-1	Reckless acts
		F-2	Unnecessary acts
		F-3	Approach hazardous locations
G	Inadequate use of protective equipment	G-1	Inadequate use of protective equipment

Table 2: Summary of the questionnaire survey.

Factor	Category	Korean		Foreign	
		The number	Ratio (%)	The number	Ratio (%)
Sex	Male	130	97	123	95
	Female	4	3	6	5
Age	~29	3	2	3	2
	30–39	22	16	12	9
	40–49	53	40	60	47
	50~	56	42	54	42
Work	Steel-frame	20	15	40	31
	Bricklayers	7	5	2	2
	Plastering	5	4	9	7
	Heating system	2	1	1	1
	Waterproof	5	4	10	8
	Carpenter	14	10	15	12
	Metal	8	6	0	0
	Windows and doors	4	3	1	1
	Masonry	9	7	2	2
	Painting	0	0	1	1
	Insulation	4	3	3	2
	Interior finishing	2	1	3	2
	Frame	54	40	42	33
Career	~1 year	10	7	7	5
	1–5 years	28	21	60	47
	5–10 years	31	23	42	33
	10 years~	65	49	20	16

Table 3: Cronbach's alpha for Importance-Performance Analysis.

Main category	Number of questions	Cronbach's alpha			
		Korean		Foreign	
		Importance	Performance	Importance	Performance
A	4	0.777	0.749	0.888	0.771
B	5	0.812	0.672	0.876	0.798
C, D	3	0.749	0.626	0.885	0.831
E	3	0.787	0.722	0.887	0.736
F, G	4	0.775	0.816	0.907	0.856

Table 4: Performance ratings of 19 elements of unsafe behavior.

Number	Subitem	Performance (%): % strongly agree + % agree
B-2	Obstacles left alone on the ground	45
C-2	Inadequate supervision and management	50
E-2	Wrong handling of hand tools	52
A-4	Inadequate handling of toxic substance	52
B-1	Neglect of dangerous structures	52
E-1	Equipment malfunction	53
B-4	Bad state of load	54
F-2	Unnecessary acts	54
C-1	Inappropriate method and procedure	54
B-3	Use of defective tools and materials	55
A-1	Inadequate use of protection management	55
A-3	Cleaning and repairing of working machines	57
G-1	Inadequate use of protective equipment	57
F-3	Approach hazardous locations	58
E-3	Miss of footing on the stairs	58
D-1	Unsafe working posture	59
F-1	Reckless acts	62
B-5	Incognizance of obstacles at bottom	62
A-2	Inadequate use of vehicle	64

Table 5: Importance ratings of 19 elements of unsafe behavior.

Number	Subitem	Importance (%): % strongly agree + % agree
A-2	Inadequate use of vehicle	76
F-1	Reckless acts	76
E-3	Miss of footing on the stairs	75
B-3	Use of defective tools and materials	73
B-1	Neglect of dangerous structures	71
E-1	Equipment malfunction	71
A-1	Inadequate use of protection management	70
E-2	Wrong handling of hand tools	69
A-3	Cleaning and repairing of working machines	67
D-1	Unsafe working posture	67
F-3	Approach hazardous locations	67
B-5	Incognizance of obstacles at bottom	66
B-4	Bad state of load	65
C-1	Inappropriate method and procedure	64
A-4	Inadequate handling of toxic substance	63
F-2	Unsafe working posture	62
B-2	Unnecessary acts	61
C-2	Inadequate supervision and management	60
G-1	Inadequate use of protective equipment	60

"B-5." As per this result, 7% (0% + 2% + 4% + 1%) of the total respondents answered that item "B-5" presents high importance but shows low performance.

Using this process, the dangerousness of 19 unsafe behavior items is determined and is displayed in Table 7 in a descending order.

As shown in Table 4, item "B-5" presents significantly high performance. According to Table 8, however, the level of dangerousness turned out to be significantly higher, unlike the results of performance. Consequently, this item could be deemed to present high potential risk. Moreover, as shown in Table 8, items A-2, B-4, B-5, and F-3, for whom the rating of dangerousness has significantly risen when compared to that of performance, can be deemed to present high potential risk.

3.3. Steps 4–6. In steps 4–6, the priority list presenting high dangerousness and importance is identified. The result is shown in Figure 2. For easy identification of the items requiring urgent improvement, we made a classification of four zones by using the average of data as the standard as shown in Table 9.

Zone 1 is the area where both dangerousness and importance are high. The unsafe behavior belonging to this zone requires urgent improvement. Four items, including A-2, B-1, and E-1, belong to this zone. Zone 2 is the area where dangerousness is high whereas importance is low. This zone presents lower importance than Zone 1 but is deemed to present potential dangerousness and thus requires constant

Table 6: Cross-tabulation of performance and importance ratings for "B-5."

Performance (%)	Importance (%)					Row total
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
Strongly disagree	<2	<2	<0	**0**	**5**	9
Disagree	<1	6	6	**11**	**3**	27
Neutral	<0	8	17	24	13	62
Agree	<1	10	22	42	31	106
Strongly agree	0	5	9	17	28	59
Column total	4	31	54	94	80	$N = 263$

Table 7: Dangerousness measures of 19 elements of unsafe behavior.

Number	Subitem	Dangerous (%): % strongly agree + % agree
B-1	Neglect of dangerous structures	11
B-4	Bad state of load	10
E-1	Equipment malfunction	9
A-4	Inadequate handling of toxic substance	9
F-3	Approach hazardous locations	8
B-2	Obstacles left alone on the ground	8
B-5	Incognizance of obstacles at bottom	7
C-1	Inappropriate method and procedure	7
E-2	Wrong handling of hand tools	7
A-2	Inadequate use of vehicle	7
E-3	Miss of footing on the stairs	6
G-1	Inadequate use of protective equipment	6
A-3	Cleaning and repairing of working machines	6
C-2	Inadequate supervision and management	6
A-1	Inadequate use of protection management	5
B-3	Use of defective tools and materials	5
D-1	Unsafe working posture	5
F-1	Reckless acts	5
F-2	Unnecessary acts	4

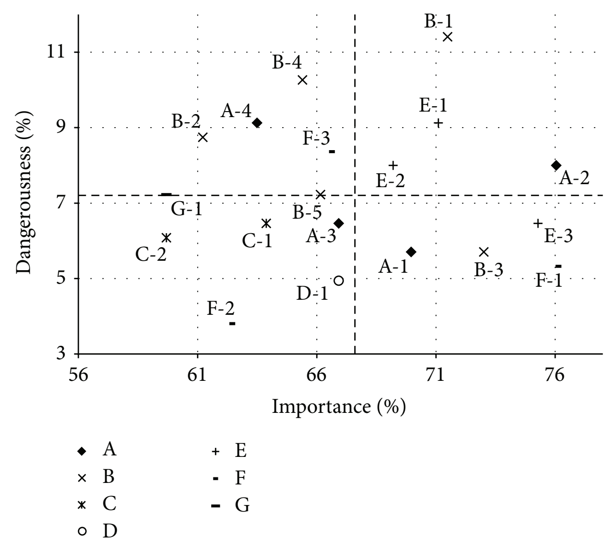

Figure 2: Scatter graph of dangerousness versus importance (IDA).

monitoring. Six items including A-4, B-2, and B-4 belong to this zone. Zone 3 is the area where both dangerousness and importance are low. For the sake of effective conduct of management tasks, it is justified to accord the lowest priority to the unsafe behavior in this zone. Four items, including A-3, C-1, and C-2, belong to this zone. Zone 4 is the area where dangerousness is low, whereas importance is high. Regarding unsafe behavior in this zone, it is deemed that the relevant items are under good management when compared to the other items, and, thus, it is necessary to maximize efforts to maintain the current condition. Four items including A-1, B-3, and E-3 belong to this zone.

3.4. Analysis of Results. In this research, an IDA that can assess the potential risk of 19 items of unsafe behaviors of construction laborers is suggested, and the applicability thereof is assessed by using the actual survey results. As it can derive the potential risk, IDA has an advantage when compared to the existing analysis methods. To elaborate, items A-2, B-4, B-5, and F-3 received relatively favorable assessments in step 2. However, according to the dangerousness assessment results in step 3, the ratings are assessed to be relatively dangerous. The items that had been considered well-managed were actually evaluated to have potential dangerousness. This outcome cannot be seen in the IPA result based on average.

This feature is also displayed during the comparison of the final results of IDA and IPA. The results of IPA are shown in Figure 3. Five items belonging to the second quadrant in IPA, which is not well-managed, are A-1, B-1, B-3, E-1, and E-2. Four items belonging to first quadrant, which is important and dangerous in IDA, are A-2, B-1, E-1, and E-2. All these items require urgent improvement or treatment. The items of IPA and IDA that belong to the zone, where high dangerous or low performance but high importance is, are shown in Table 10.

In particular, item A-2 was assessed to be well-managed in IPA. However, according to the results of IDA, it was derived as an item that presents high dangerousness as it belonged to

Table 8: Potential risks items (in step 3).

Rating	Performance		Dangerousness	
1	B-2	44%	B-1	11%
2	A-4	52%	**B-4**	**10%**
3	C-2	52%	A-4	9%
4	E-2	53%	E-1	9%
5	B-1	54%	B-2	8%
6	E-1	54%	**F-3**	**8%**
7	F-2	55%	**A-2**	**7%**
8	A-1	55%	**B-5**	**7%**
9	B-3	55%	E-2	7%
10	**B-4**	**55%**	G-1	7%
11	C-1	56%	E-3	6%
12	A-3	58%	A-3	6%
13	G-1	58%	C-1	6%
14	**F-3**	**59%**	C-2	6%
15	E-3	60%	A-1	5%
16	D-1	61%	B-3	5%
17	F-1	62%	F-1	5%
18	**A-2**	**64%**	D-1	5%
19	**B-5**	**64%**	F-2	4%

Table 9: Definitions of Zones 1–4.

Zone 2 High dangerousness but low importance	Zone 1 High dangerousness + high importance
Zone 3 Low dangerousness + low importance	Zone 4 High importance but low dangerousness

Table 10: Comparison of results of IPA and IDA.

Methodology	Number	Subitem
IDA	A-2	Inadequate use of vehicle
	B-1	Neglect of dangerous structures
	E-1	Equipment malfunction
	E-2	Wrong handling of hand tools
IPA	A-1	Inadequate use of protection management
	B-1	Neglect of dangerous structures
	B-3	Use of defective tools and materials
	E-1	Equipment malfunction
	E-2	Wrong handling of hand tools

Zone 1. Here, it can be deemed that item A-2 is relatively well-managed in the perspective of average value, but it also means that a relatively high number of respondents answered that it is not being well-managed.

When compared to other management tasks of construction projects (i.e., cost management, quality management, scheduling, etc.), lack of management would be critical, as it not only affects the economic aspects but also can cause

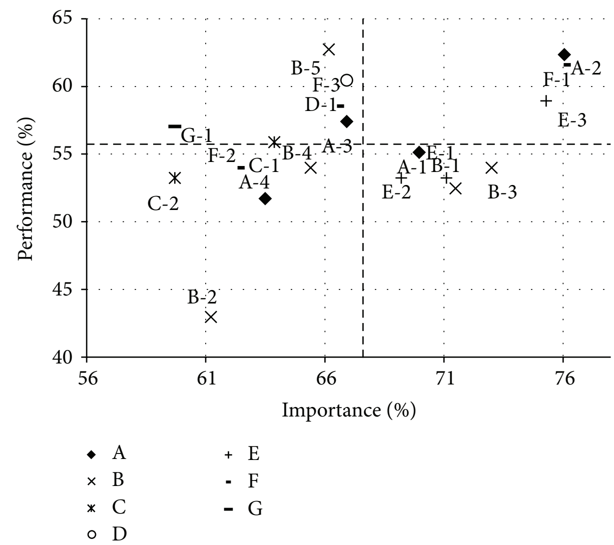

Figure 3: Scatter graph of IPA (reversion of the x-axis and y-axis).

casualties. Thus, when the factors in safety management such as unsafe behavior are considered, how many people find it dangerous may be a more adequate standard in assessing dangerousness than how dangerous it is on average. The IDA suggested in this research could conclusively help safety managers in deriving items that have potential risk. The results of IDA identify the areas that require urgent attention and support the decision making of the safety manager so that he/she could effectively conduct specific tasks within the limited resources and time. Additionally, IDA can be used in various dangerousness analyses of safety management, including assessment of unsafe behavior of construction laborers, analysis on the job stress of construction laborers, assessment of the construction equipment, and assessment of the safety management level in the construction sector.

4. Conclusion

The single most important factor among all direct causes of construction accidents is unsafe behavior. Although studies on unsafe behavior have been regularly conducted, they tend to average survey results and conduct analyses thereon. With that method, however, it is impossible to consider how many people feel anxious about certain unsafe behaviors. Thus, in this research, the IDA technique is suggested in order to assess the potential risks regarding unsafe behaviors of laborers in the construction sector. In order to verify the applicability of the suggested technique, the results obtained by the actual survey and application thereof were compared with the results obtained using the IPA technique. Consequently, unsafe behaviors posing potential risks that were not found in IPA were confirmed in IDA. Moreover, through IDA, it was possible to identify which unsafe behaviors required urgent measures. The IDA suggested in this research supports the decision making of the safety manager by assessing potential risks and highlighting the items that require urgent measures. Therefore, it is expected to help the safety managers in effectively conducting safety management tasks in the construction sector.

In this research, an improved analysis method that can show up potential risks resulting from the unsafe behavior of construction laborers was suggested. However, the subject of the analysis in this research was limited to one factor, unsafe behavior, and, thus, it is difficult to confirm that the IDA suggested in this research is also effective in deriving potential risks in other areas. Therefore, future studies wherein IDA is applied to various subjects, including job stress and safety management level assessment in the sector, are necessary to verify the applicability of IDA.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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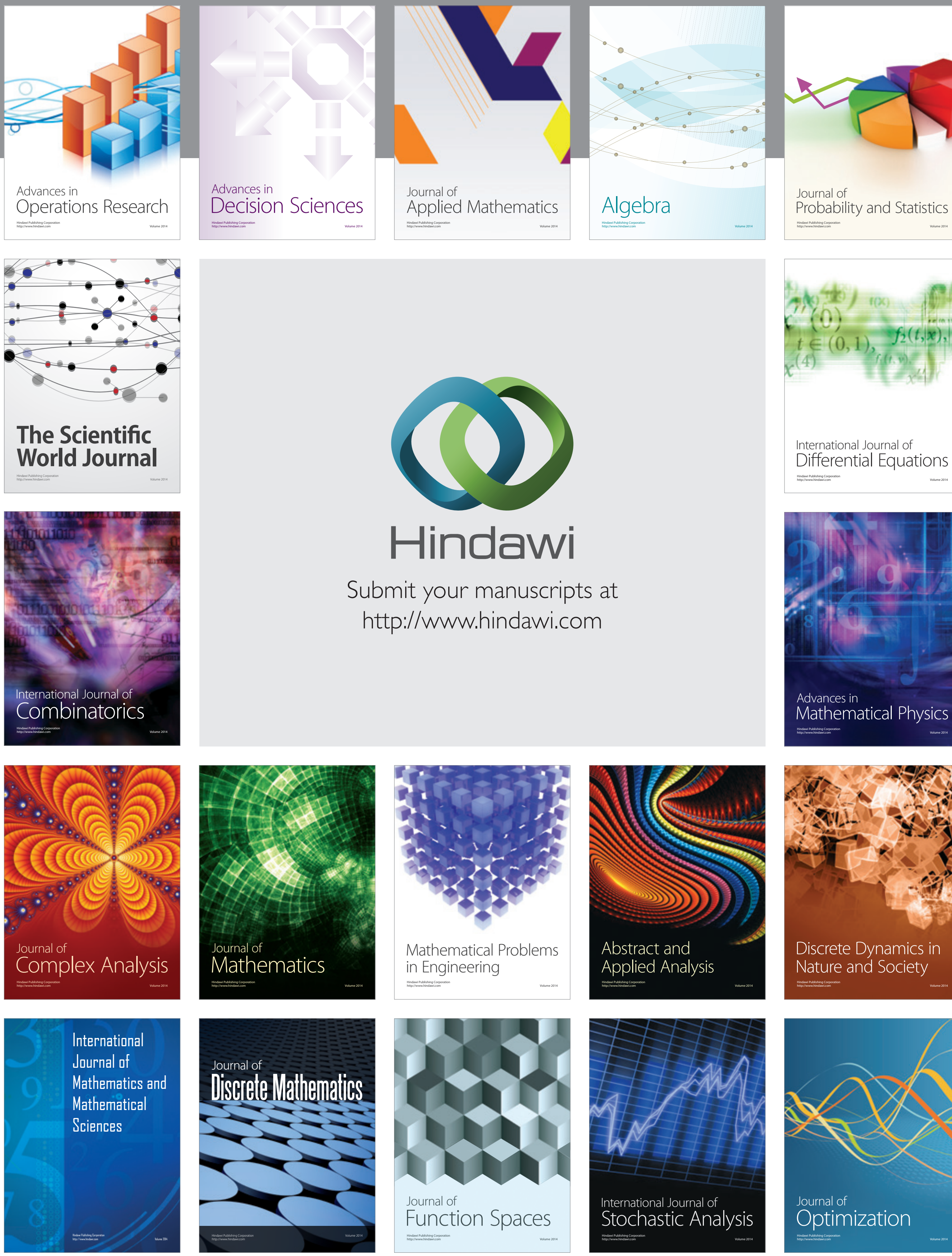
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