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안전문화 선행지표 개발을 위한 사건보고율 측정

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Measurement of Incident-reporting Rate for Developing a Leading Indicator of Safety Culture

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Abstract : Various leading indicators of safety culture have been advocated for proactive actions as lagging indicators have limitations in reflecting the attitudes and behaviors due to their reactivity and low sensitivity. This study proposes a model of incident-reporting culture (IRC) and determines the influence of the components on incident-reporting rate (IRR) in order to develop proactive indicators of safety culture. A questionnaire survey was administered to 614 workers at a chemical company in Korea, and the internal psychological aspects were explored by using perceptions, attitude, and backgrounds. The relationship between these factors and IRR was quantitatively confirmed. The workers are more reluctant to report injury than property damage, the perception of severity is the most influencing factor, and most property damages are reported regardless of worker's willingness. These features should be prioritized when improving IRC, and the criteria of IRC need to be aligned with safety culture.

Key Words : incident reporting, reporting culture, safety culture, proactive indicator

1. INTRODUCTION

Data on work incidents, where an incident is a work-related event in which an injury, ill-health or damage occurred or could have occurred, are essential for improving safety culture and safety performance through the development of effective prevention programs[1]. However, incident information has no value if the incident is not reported. Therefore, evaluating incident-reporting culture (IRC) in a society is valuable to achieve the target safety culture and performance. 2 reasons for this motivation have been derived.

First, evaluating IRC can be an alternative to quantitatively measuring the safety culture, because the safety culture determines the safety performance via the occurrence of a safe or unsafe context. Many researchers[2-5] have revealed that the social culture consists of shared values like attitudes, behaviors, beliefs, and so on. These values collectively characterize the culture of the society and influence the individual's behavior and attitude. Cooper[2] supported this claim by revealing that shared values significantly influence the attitude and behaviors of the society members both directly and indirectly. On the other hand, the perception of the individuals toward incidents is critical to determine whether the society can learn from past incidents while preparing for and trying to prevent future ones[6-7]. Choudhry et al.[3] supported this hypothesis by suggesting that the shared safety culture creates an individual perception which determines the result of thinking, speaking and behaving. These studies suggest that a lack of safety awareness of each member brings about unsafe conditions and unsafe behaviors, and eventually forms an unsafe context in which an incident may occur. In other words, the gradual development of the

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unsafe context arising from the lack of a safety culture could contribute to the creation of a current unsafe moment, and finally some of the unsafe contexts lead to a serious incident. Conversely, the unsafe context can be identified by investigating the occurred incident, and eventually the maturity of the safety culture can be measured by investigating various quantifiable proactive indicators based on cultural elements. Therefore, the safety culture can be quantified by evaluating IRC.

Second, IRC can be a proactive indicator of the safety culture. Lagging indicators are reactive as they can show where we have been, and leading indicators are proactive in that we can see what is coming. Lagging indicators such as injury rate and fatality rate have commonly been used as quantitative measures of the safety culture[8]. However, such measures using lagging indicators have clear limitations in indicating the presence or quality of the intrinsic safety culture due to their reactive characteristics[2,9]. In addition, this approach has low sensitivity to reflect the results of safety management activities such as safety inspection, training, safety meeting, etc.[10] Therefore, the development of various leading indicators has been advocated by many researchers for proactive actions to reflect the activities and circumstances quickly before an accident occurs, where an accident indicates an incident that resulted in injury, ill-health or damage. Learning the lessons from incidents that occurred is a proactive process to improve safety management and hence the safety culture by identifying and correcting the things that went wrong[11-13], because the incident report contains a lot of information about the circumstances and behaviors that have affected the incident. As Heinrich[14] argued, minor incidents tend to precede a severe incident. So, the reporting of minor incidents like near misses is a critical activity in the prevention of accidents. It allows an unsafe context to be identified in advance without any losses. This implies that an already occurred incident is a lagging event arising from the safety culture, whereas reporting the incident that occurred is a leading activity to improve the safety culture and prevent future incidents. Therefore, gathering all incident data in the target society should be the primary task in the process of incident investigation and learning.

Based on these 2 reasons for evaluating IRC, achieving the right 'reporting culture' should be a prerequisite for the development of a safety culture, where the reporting culture was defined by Reason and Hobbs[15] as "being prepared to report all incidents occurring in the workplace in a comfortable and psychologically stable condition." This raises the questions of how the IRC can be measured and quantified. In this regard, this paper presents an IRC model based on safety culture models and analyzes the influence of the factors on the incident-reporting rate (IRR) as a proactive indicator of the safety culture, based on the assumption that a good IRR signifies a good reporting culture.

2. INCIDENT-REPORTING CULTURE MODEL

A valid conceptual model should be developed in advance for a quantative measurement of IRC given the vague existing concept of the safety culture regarding incident reporting. Many studies[16-20] have argued for an interactive relationship between psychological, situational and behavioral factors in the safety culture, and revealed that the relationship in the safety culture is applicable to the "accident causation chain" at all societal levels. The Advisory Committee for Safety in Nuclear Installations[21] also revealed an "implicit recognition" of this interactive relationship between each of the elements such as perceptions, attitudes, safety behavior, organizational safety systems. These concepts were reflected by Bandura's models[22-24] of Social Learning Theory and Social Cognitive Theory. Both explained psychosocial functioning in terms of "triadic reciprocal causation" between each of the elements. Bandura's models were believed to offer a perfect framework to analyze the organizational safety culture for many reasons[2]. Subsequently, Cooper[2] reflected Bandura's reciprocal model in a concept of the safety culture, which consisted of 3 elements with the following measurement methods: internal psychological factors - safety climate questionnaires; behavioral factors - checklist, observations and outcome measures; and situational features - safety management system audits and inspections. Since each of the factors can be directly measured, it is possible to explore both the qualitative and quantative aspects of the safety culture[25].

On this background, this study adopted and modified Bandura's[22-24] and Cooper's[2] model to propose the IRC model. The developed model consisted of 3 elements with subfactors as shown in Figure 1.

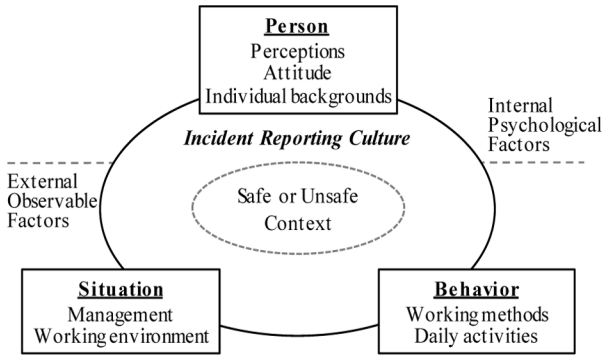

Fig. 1. Proposed model of incident-reporting culture (IRC) based on safety culture models.

It was based on the assumption that the culture of any society is influenced by the interactions among personal factors (e.g., perceptions, attitude, individual backgrounds), situational factors (e.g., management system, working environment), and behavioral factors (e.g., working methods, daily activities). In other words, safe or unsafe context is formed according to this culture shared by members, and the existence or quality of the context can be quantitatively measured by using the components of the elements. In this study, the personal factors were selected to explore the internal psychological aspects rather than the external observable factors of the situational and behavioral factors. The scope was arbitrarily selected by the researcher in the sense that understanding the variation of cultural aspects of individual members first helps to understand the external environment and behavioral factors. In addition, the survey method for these cultural aspects has the advantage of generating results easily and quickly using a questionnaire.

3. METHODS

A questionnaire was developed to quantify how the individual responds to the unsafe contexts according to the personal factors.

3.1 Structure of the questionnaire

The structure of the questionnaire was based on Cooper's model[2], 2 previous studies[26-27], and practices in industry. A draft questionnaire was reviewed by experts, and piloted by 12 workers considering business unit, job title, and service years before being finalized. The final version was structured by 3 parts with 22 questions in total as shown in table 1.

Table 1. Structure of questionnaire for surveying personal factors (internal psychological aspects)

Part	1. Perceptions	2. Attitude	3. Backgrounds
Objective	Incident reporting rate (IRR) by 18 incident examples which were classified by incident type and consequence severity	Willingness to report (WTR): How much do you agree on "all incidents should be reported"?	Job title: employee, supervisor, manager Service years: ≤5, ≥6 to ≤15, ≥16 years Age: ≤35, ≥36 to ≤44, ≥45 years old
# of questions	18 (incident examples)	1	3

In the first part, IRR was measured by 6 scenarios and 3 alternative consequences for each scenario as shown in the table 2. The questions for measuring perceptions of incident type and consequence severity were embedded into these questions. The scenarios were categorized into 2 types (bodily injury: damage done or potential to people; property damage: damage done or potential to tangible property) as per the general classification in a society. The injury scenarios were cited from a previous study[27], and the property damage scenarios were obtained from general cases in a chemical industry. Then, 3 alternative consequences by severity were given for each scenario (i.e., in total 18

Table 2. Incident examples for measuring incident-reporting rate (IRR): Scenarios by type and alternative consequences by severity

Type	Scenario	Consequences by severity
Bodily injury	As you walked, your foot was caught in a hose	You fell and got an injury on your palm.(S) You fell but fortunately not hurt.(M) You almost fell over but got back to balance.(T)
	You got something on your eye while working	It got into your eye, and you received a treatment at the hospital.(S) You washed it out yourself and got better.(M) Thanks to goggles, it didn't get in your eye.(T)
	As you came down the stairs, you slipped on the floor	You suffered an ankle injury and could not go to work the next day.(S) You fell but fortunately not hurt.(M) You did not fall by grabbing the guardrail.(T)
Property damage	You hit a pillar while driving a forklift for unloading goods	Damage to the pillar and the forklift.(S) No damage to the pillar and the forklift.(M) No damage thanks to the shock absorber on the pillar.(T)
	You were repairing a pump after shutting off the power	The pump suddenly restarted and damaged.(S) The panel power suddenly turned on, but the pump did not restart.(M) You stopped someone trying to manipulate the pump power panel.(T)
	The pressure increased abnormally during operation	Safety valve was activated, and the gas was vented to air.(S) The pressure increased but it didn't reach the relief valve activation.(M) The overpressure gas was routed to absorber for safe.(T)

Consequence severity: (S) - severe; (M) - moderate; (T) - trivial

incident cases) to measure the awareness level of reporting different outcomes triggered from a single root cause. The definition of the severity level was made as follows with reference to the National Patient Safety Agency[28] and a previous study[26]: severe - any injury, disability, or damage; moderate - any incident that occurred with no harm/no damage; trivial - any incident that had potential to cause harm/damage but was prevented. For example, in the first scenario "As you walked, your foot was caught in a hose.", the consequences were given according to the severity level as follows: "You fell and got an injury on your palm.", "You fell but fortunately not hurt.", "You almost fell over, but got back to balance." The level of IRC increases as the incident with lower severity is reported.

The IRR was calculated by counting how many incidents were reported among the 18 examples. Each question required an answer of either "I will report" or "I won't report" on each incident. The reason for presenting the binary type of answer rather than a scale is to require the respondents to make a clear decision because it is a matter of reporting or not reporting. The validity of the questions and responses were confirmed by Cronbach's alpha test, and the result showed sufficient reliability ($\alpha = 0.875$)[29-30].

In the second part, the attitude toward incident-reporting activity was assessed using a single question that asked willingness to report (WTR) for all incidents because the willingness is the basic premise of reporting incidents. The phrase was expressed passively as like "all incidents should be reported" instead of expressing obligatorily as like "you should report all incidents", because the latter could give implicit pressure to distort the answers. Workers indicated how much they agree with the phrase on a 5-point Likert-scale. The response results were aggregated as "low (from very contrary to normal)", "medium (agree)", and "high (very agree)".

In the last part, 3 questions were posed to ask about how individual background factors such as age, service years and job title affect the IRR. These factors play a role of background in shaping the culture of society over time[9,16,31]. Especially, the job title is used to distinguish between responsibility and authority, and it is the basic unit in which the organizational culture is formed. In this regard, each scale of the questions was ranged as follows. Job title: employee, supervisor, manager; Service years: ≤5 years, ≥6 to ≤15 years, ≥16 years; Age: ≤35 years old, ≥36 to ≤44 years old, ≥45 years old.

3.2 Participants

One of the chemical companies in Korea was invited to the questionnaire survey. The company was a part of a multi-national corporation producing specialty gases and chemical products. The survey was administered to all 614 workers by sending the questionnaire via an individual e-mail and collecting in a designated box with anonymity. The purpose of the survey, definitions of terms, and promise of anonymity were presented on the cover sheet to encourage the response rate.

3.3 Statistical analysis

Minitab (version 17.3.1) were used for the statistical analysis. Pearson Chi-Square (χ^2) Test for Association was used for analyzing the associations between the IRR and the factors. The validity of the questionnaire was judged by Cronbach Alpha value which was obtained by the Item analysis in Minitab. The criterion for statistical significance was set at p-value <.05.

4. RESULTS

In total, 520 (84.7%) of 614 workers responded to the survey. The age factor was excluded from the analysis since it was strongly correlated with service years. The IRRs according to 5 factors were summarized by each subfield in Figure 2. The reporting rate answered as "I will report" was 68.2% in total. As would be expected, the IRR of injury (57.6%) was significantly lower than that of property damage (78.9%). The biggest difference (46.3% point) in reporting rates was by the perception of consequence severity. The maximum (93.7%) and minimum (47.4%) reporting rates also belonged to this factor when the severity was severe and trivial, respectively. The second biggest difference was the perception of incident type (21.3% point). The IRR according to WTR showed a 14.9%-point gap from 76.5% to 61.6% as WTR decreased. The background factors indicated relatively small differences of ±5% on average, and the service years had smallest difference among all factors.

The Chi-Square (χ^2) Test for Association indicated that individual perceptions of both incident type (χ^2=484, p<.001) and consequence severity (χ^2=1519, p<.001)

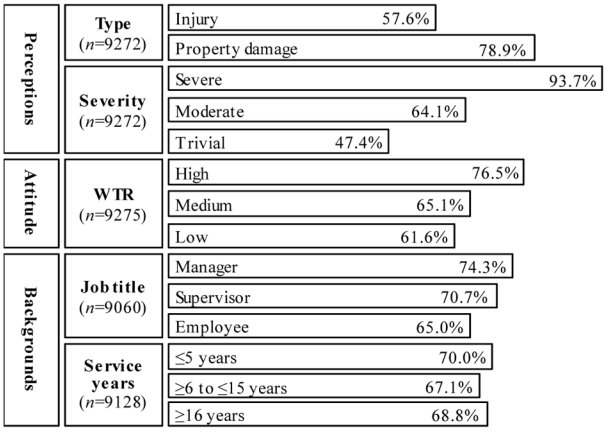

Fig. 2. Incident-reporting rate (IRR) by personal (internal psychological) factors

significantly affected the reporting rate of all incidents as shown in Table 3. The IRR showed significant differences at each incident type, and the both types decreased significantly along with the severity. The decrease was biased to injury (from 88.6% to 32.2%) compared to the property damage (from 97.5% to 62.6%), and the gap of value between types in the same severity also increased from 8.9% point up to 30.4% point as the severity decreased. The attitude (WTR) significantly affected most of the IRRs just except for severe property damage incidents (χ^2=4.5, p=.107). The IRR for these incidents was very high (97.5%), but there was no significant difference according to the WTR. The people having higher WTR showed higher IRR within significant items. The job title significantly affected only IRR of moderate (χ^2=26.7, p<.001) and trivial injury incidents (χ^2=17.7, p<.001) - i.e., most of the incidents were not affected by the job title, particularly, there was no property damage incident affected by the job title. The higher job title showed higher IRR within the significant items. The service years affected only the IRR of trivial injury incidents (χ^2=7.5, p=.023) - i.e., most of the incidents were not affected by the service years. There was no order of WTR by service years within the significant item. The magnitude of the difference using Chi-square value decreased in the order of severity, type, WTR, job title, and service years.

5. DISCUSSION

This study was based on the concept that a safety culture with successful IRC will increase the society's ability to prevent future accidents by identifying the causes and developing the necessary corrective measures. To support this concept, an IRC model was constructed with measurable factors, and the influence of the personal factors on IRRs were analyzed. The results proved the validity of the proposed IRC model and confirmed that evaluating IRC from a safety culture perspective is worthwhile considering

Table 3. Influence verification of personal factors for incident-reporting rate (IRR)

Perceptions						Attitude			Backgrounds					
Type (n=9272)			Severity (n=9272)			WTR (n=9275)			Job title (n=9060)			Service years (n=9128)		
	IRR(%)	p		IRR(%)	p		IRR(%)	p		IRR(%)	p		IRR(%)	p
Bodily injury	57.6	<.001*	Severe	88.6	<.001*	High	94.0	<.001*	Manager	91.7	.204	≤5 years	90.1	.385
						Medium	88.0		Supervisor	89.0		≥6 to ≤15	88.7	
						Low	79.4		Employee	87.5		≥16	87.0	
			Moderate	51.9		High	67.4	<.001*	Manager	62.1	<.001*	≤5 years	56.3	.153
						Medium	46.5		Supervisor	57.5		≥6 to ≤15	50.1	
						Low	58.3		Employee	46.0		≥16	51.7	
			Trivial	32.2		High	43.8	<.001*	Manager	42.7	<.001*	≤5 years	36.0	.023*
						Medium	27.0		Supervisor	33.8		≥6 to ≤15	28.9	
						Low	25.9		Employee	28.3		≥16	34.8	
Property damage	78.9		Severe	97.5	<.001*	High	98.6	.107	Manager	99.3	.340	≤5 years	98.2	.196
						Medium	96.8		Supervisor	97.9		≥6 to ≤15	96.9	
						Low	97.9		Employee	97.1		≥16	98.4	
			Moderate	76.4		High	86.0	<.001*	Manager	80.3	.120	≤5 years	77.0	.963
						Medium	73.0		Supervisor	78.2		≥6 to ≤15	76.3	
						Low	66.9		Employee	74.6		≥16	76.4	
			Trivial	62.6		High	68.9	.002*	Manager	62.3	.811	≤5 years	62.4	.616
						Medium	59.2		Supervisor	63.9		≥6 to ≤15	61.7	
						Low	61.2		Employee	62.1		≥16	64.6	

n: total number of incidents responded
IRR(%): the rate of "I will report" on presented incident examples
* indicates that reporting rates of the incidents (IRR) in the column are significantly affected by the factor at p<.05.

its influence on the mechanism from the individual's perceptions and attitude to the accident occurrence. The validity of this viewpoint has also been proved in previous studies[2,16-20] showing that the quantification method of the safety culture can be applied to the accident causation chain.

Quantification not only transforms the abstract concept of culture into an engineering concept but is also a very useful way of identifying the status and trends of the various circumstances and the activities in management aspect. This methodology will also assist in constructing a proactive process for eliminating the causes of accidents before they occur. The evaluation of various safety activities and programs in the workplace can be quickly reflected in safety management practices by analyzing the related factors in the same way. This could compensate for the limitations of lagging indicators such as reactivity and low sensitivity including high cost. Fulfilling the role of an indicator may necessitate further experimental research with a wider range of societies, but the approach can be equally applied to various societies based on this theoretical verification, and its applicability will thereby be enhanced with diversity of those results.

It maybe more valid to investigate actual incidents rather than posing hypothetical incident examples in a questionnaire. However, it is almost impossible to get a meaningful picture of all incidents occurring and all reported incidents. For example, subjects will struggle to remember all incidents when asked "How many incidents have you experienced in the past year, and how many have you reported?" Furthermore, the definition of an incident will vary for each person. Even perfect memories and identical definitions will not guarantee honest answers. Therefore, an alternative method was used based on the suggestions of previous research[16]. Presenting incident examples gave all subjects the same definition, eliminated the need to remember the past, and removed the fear of being blamed. Also, the anonymity may have led to honest answers. This approach is likely to have afforded the closest values to the actual IRR.

5.1 Influence of perceptions

The perception of incident type is critical to IRC considering the influence on IRR. This influence was reflected much more strongly in injury incidents (IRR: 57.6%) than in property damage incidents (IRR: 78.9%). This result supports the finding by Van der Schaaf and Kanse[32] that "a perceived importance of reporting specific types of incidents affects underreporting or a biased reporting of incidents." This tendency can be attributed to 2 reasons. First, the bias of difficulty in hiding the incidents may differ between the 2 types. Nobody wants to attract negative attention toward their own unsafe behaviors[27]. The evidence of property damage is usually overt, whereas an injury may be easily hidden unless serious depending on the worker's WTR. Second, barriers against reporting incidents such as managers' reactions[8], unclear outcomes[12], and workers' fear[33] may be stronger in injury incidents. For instance, WTR may be low if workers feel they will be blamed or punished for the incident. In this respect, concern needs to be focused on how society can improve the individual perceptions of injury rather than of property damage. Specifying the targets and goals based on an analysis of the factors affecting the incident-reporting activity will be helpful to resolve this concern.

The perception of consequence severity showed the strongest influence on IRR, which resulted in a difference of up to 46.3% point between the scales. This was more than double that of the incident type (21.3% point) and increased up to 56.4% point in injury incidents. This difference is likely to be attributable to the process of deciding the importance of the incident[32]. For instance, these types of incidents such as minor scratches, trivial damage, and similar and repetitive incidents may be simply accepted as a part of the job, and not considered as an incident, due to the negligible harm or damage[26-27,34]. This suggests that workers only consider the consequence when determining the importance of the incident. However, this is not a valid process because such consideration failed to address the underlying causes. In Heinrich's injury triangle model[14], he argued that "a large number of near misses and minor incidents have the same underlying causes as the major incidents." This emphasizes the importance of preventing serious incidents by eliminating or controlling the causes of minor incidents. Cooper[2], Glendon and Litherland[10], and Havold[35] also indicated that injury rate cannot simply represent the safety culture because the consequences could vary widely even in the case of the same underlying cause. Most importantly, the consequences cannot be selected, it is just 'luck'. The only thing society can select is the cause before the outcome occurs. Therefore, the causes must be

taken into the account when determining the importance of incidents. On this basis, all 18 incidents presented in the questionnaire should be reported regardless of the consequence severity since each scenario have the same underlying causes.

5.2 Influence of attitude

WTR, which was used on behalf of individual attitude in this study, is an important factor for the success of the reporting culture[15,27], as attested to in many previous studies[11-12,33,36] that revealed the factors affecting WTR. This basic premise was supported by the present study results identifying the statistical significance in the relationship between WTR and the IRR, except for serious property incidents. Most noteworthy, the IRR in the case of severe property damage reached up to 97.8% regardless of WTR, which implies that the workers at this company would report most of the incidents regardless of their WTR if an actual property damage was involved in the incident. As discussed earlier, this may be because the exposure of serious damage strongly suppressed the workers'willingness to hide the incident compared to an injury.

5.3 Influence of individual backgrounds

Job title and service years did not affect the IRR in most of the statistics except for a couple of levels. The background factors influence or are influenced by situational factors and behavioral factors, in that the components of the safety culture interact with each other[2, 22-24]. In this respect, the job title drives the hierarchical culture, and the service years can be recognized as indicating the period of influence by management systems or working environments. Therefore, the absence of any IRR difference between the job titles implies no difference in the hierarchical culture in incident reporting. The lack of any correlation to the service years indicates that the IRC has not changed for a long time. Although this study did not explore the nature of the hierarchical culture or of the long-term stagnant culture, the lack of relations to the IRR, if they are desirable results, can be a positive signal in terms of IRC.

6. CONCLUSION

The importance of incident reporting has been emphasized in many studies, but little research explored and presented that in terms of culture and practical quantification methods. This study, for that needs, quantitatively confirmed the relationship between personal factors (perceptions, attitude, backgrounds) and IRR by proposing IRC model and analyzing the questionnaire survey results. As the results, the followings were revealed: first, the subject population is more reluctant to report injury incidents than those resulting in property damage; second, the perception of consequence severity is the most influencing factor on IRR - i.e., the lower the severity, the lower the IRR; third, most instances of property damage are reported regardless of worker's WTR if the incident resulted in actual damage; finally, there is no difference in IRC by hierarchy, and IRC has not been changed for a long time. These features and the related factors should be prioritized for consideration in further studies to improve safety culture and safety performance. This methodology presents quantifiable proactive indicators of safety culture that are determined from cultural elements inherent in society based on the IRC model and insights into the components. Amplifying these indicators in performance tracking will support the development of a strong safety culture and inspire continuous improvement by identifying unsafe contexts in advance. In addition, this study, on the chemical industry, is expected to promote the diversity of research field and the applicability beyond patient safety where the most researches mainly focused on factors affecting incident reporting.

Despite the precise definitions and criteria that were applied as much as possible in this study, some limitations remain. First, the IRR and its relationship with factors may vary depending on the incident examples and the level of society's culture. The types of incidents that have been experienced should be vary according to the industry or organizations. Therefore, the incident examples can be altered as necessary according to the characteristics of the society. The quality of analysis will be improved by presenting the specific issues into the incident examples. Second, the 5 personal factors used for analyzing the influence of internal psychological aspects may not be sufficient in terms of the kind of factors to explore the whole aspects. These factors affecting the internal psychology of the members may be different according to the characteristics of the society or organizations. Therefore, increasing the accuracy of the results will require more various factors taken from various societies, and the interrelation between the factors should

be examined singly and in combination. In future study, the criteria of IRC level need to be developed in relationship with the safety culture level. In addition, the other external factors of the proposed IRC model need to be measured for further improvement of the model.

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