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How Can We Improve the Government's Research and Technology for Disasters and Safety?

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Abstract

Objective: This study explores how we can improve the government's research and technology for disasters and safety.
Methods: This study employs the Structural Equation Model (SEM) based on 268 experts' perspectives.
Results: R&D performance exerts a directly significant impact on R&D achievement with the coefficient of 0.429. Second, while professionality and environment of R&D do not show a direct effect on achievement, they exhibit an indirect effect on it with the coefficient of 1.124 and 0.354, respectively. Third, R&D professionality exerts a significant impact on the R&D environment (0.964), and R&D environment has a positive effect on R&D performance (0.827).
Conclusion: Governments and policymakers should develop disaster and safety policies by understanding direct and indirect effects and the relationship of factors related to R&D for improving R&D achievement.

People are confronted with disasters and safety accidents every year. Natural disasters kill on average 45 000 people per year, globally, which account for an average of 0.1% of total deaths.[1] On average, there are around 340 million occupational accidents and 160 million victims of work-related illnesses annually.[2] Therefore, developing disasters and safety policies is one of the main responsibilities for governments and disaster planners to protect their citizens.

Governments and policymakers develop many disaster and safety policies and technology to protect their citizens from disasters and accidents.[3] For example, the US Federal Government awards US $69 325 130 for all disaster-related research during 2011-2016.[4] The Australian Government announced up to $1 billion for the Disaster Ready Fund (DRF) over 5 years, from July 1 2023. Round One provided $200 million of Commonwealth investment for 187 projects in 2023-24.[5]

As disasters do not occur regularly, continuously, and happen randomly at any time in various sizes and shapes, it is difficult to accurately understand the effects of investments in their prevention or responses.[6] Therefore, prior studies have tried to explore how research and development (R&D) expenditure for disasters and accidents exerts a significant impact on preventing or minimizing damages of disasters and accidents and highlight that R&D expenditure plays a positive role in them.[7–9] For example, Ye et al. highlight that government investment can reduce the probability of disaster events as well as losses over periods.[9]

However, prior studies have rarely explored how can we improve the government's research and technology for disasters and safety (e.g., Espada Jr et al., 2014; Lin, 2015; Motoyama, 2017).[10–12] This is because it is very difficult to measure what factors play an important role in the improvement of R&D with empirical analyses, and most prior studies analyze the effects of R&D in the industrial, innovation, or economic fields.[13–15]

It is obvious that R&D expenditure on disaster management requires evidence-based risk management methods, which is well proven and backed by information on the scope of application, costs, implementation process, and expected reductions of risk or losses.[16] Not only that, but previous articles have also barely analyzed the relationship between input factors and the improvement of R&D based on disaster experts' perspectives with empirical models.[17–19]

Therefore, there is a research gap; that is, existing literature has scarcely explored the relationship between R&D inputs and outputs in the disaster and safety fields based on empirical data and disaster experts' perspectives. In this background, this study highlights how we can improve governments' research and technology for disasters and safety to cope with disaster and safety accidents effectively by employing econometric models based on disaster experts' perspectives. This study utilizes 268 disaster experts from the National Disaster Management Research Institute data by employing the Structural Equation Modeling (SEM). By doing so, this study could contribute to enhancing R&D outputs and assist governments and policymakers in delivering better disaster management and safety services to their citizens. To the best of my knowledge, this is the first article that explores the factors influencing the improvement of R&D for disasters based on data from disaster experts and econometric models.

This study tests 5 hypotheses by employing SEM as follows:

1. R&D professionality exerts a positive impact on R&D environment.
2. R&D environment plays an important role in R&D performance.
3. R&D professionality positively affects R&D achievement.
4. R&D environment has a significant effect on R&D achievement.
5. R&D performance has a remarkable effect on R&D achievement.

The structure of this article is as follows: Following the introduction, the literature review section covers the importance of R&D for disasters, the development of R&D for disaster and safety accidents, the challenges faced in R&D for disasters, and the relationship between R&D inputs and outputs. The methodology section explains the data and SEM methods used in this study. The results section presents the empirical findings, while the discussion section compares these findings with existing literature. Finally, the conclusion section summarizes the results, discusses the implications, and highlights the limitations of the study. The research method diagram of the paper is presented in Figure 1.

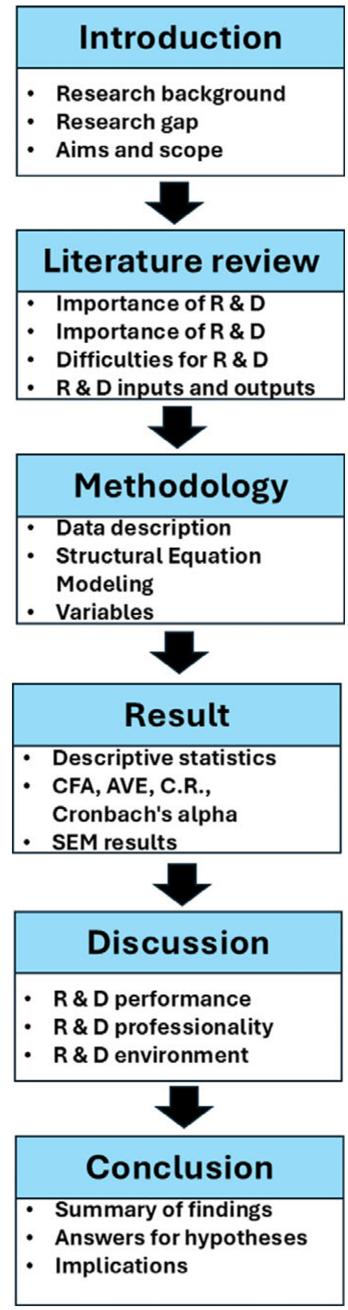

Figure 1. The research method diagram.

Literature Review

Disasters are catastrophic events that occur regularly, not rarely. Disasters from earthquakes and storms to floods and droughts kill approximately 40 000-50 000 people per year.[20] The Emergency Events Database (EM-DAT) reveals a staggering total of 399 disasters linked to natural hazards in 2023. These calamities result in 86 473 fatalities and impact 93.1 million people. Economic losses soared to an estimated US $202.7 billion.[21] The International Labour Organization reports that nearly 3 million workers die every year due to work-related accidents.[22]

Disasters create numerous opportunities for R&D advancement and make governments and organizations develop substantive content because R&D is the root of informed decision-making in disaster risk reduction.[23–24] R&D for disasters have always existed in some form in all countries.[25] The task of managing disasters and safety accidents is heavily dependent on research and development for disasters and safety. The application of R&D can substantially reduce losses of lives and property.[16]

Many governments and policymakers have developed better R&D systems to cope with disasters and safety accidents. For example, in 1997, the National Science Council in Taiwan reviewed and approved the proposal to formally establish the National Science and Technology Program for Hazards Mitigation (NAPHM) to organize R&D efforts in the related government ministries in a more systematic way, integrating research results and transforming them into useful applications in disaster reduction and tying research work closely with practice.[26] The Japanese government has concentrated resources in leading research universities to enhance interdisciplinary research and collaborative, co-creative approaches to disasters.[27] The South Korea government developed the Integrated Disaster and Safety Information System to support cross-government communication and collaboration for a rapid inter-agency response which handles all phases of a disaster (prevention, preparedness, response, and recovery) in the most integrated manner.[28]

Especially, with the development of R&D and technologies, investing in R&D could contribute to minimizing the damages of disasters and helping governments and policymakers develop better responses and recovery plans for disaster and safety accidents.[29–30] For example, Callaghan highlights that R&D may contribute to improved real time disaster response and resilience across contexts.[29] Krichen et al. highlight that technologies, such as remote sensing, radars and satellite imaging, internet of things, smartphones, and social media, can be utilized in the management of natural disasters in order to predict, respond, and recover more effectively.[30]

However, it is still vague how R&D input plays an important role in R&D output.[31–32] For example, Wu et al. report that the optimal proportion of expenditure for disaster prevention and mitigation has always been a difficult issue that people are concerned about.[8] Fahlevi et al. cannot find the relationship between the disaster budget and the level of disaster risks among districts or cities in the Aceh province, Indonesia.[33]

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It would be particularly useful if we could determine why one governmental effort is evaluated to be a success, while another is judged as a failure.[34] Also, although R&D provide the means to substantially reduce losses caused by disasters, implementing R&D measures has been slow, and it is important to understand the factors that contribute to R&D achievement.[35]

Scholars have tried to measure achievement of R&D, and the factors related to R&D output, but it is very difficult to measure because there are very few data sources and articles, and some of those available include uncertainties, multiple consequences, a cumulative nature, and transferability (see e.g., Aksnes et al., 2017; Hall, 2007; Melkers, 1993).[36–38] For instance, Aksnes et al. report that there are methodological difficulties in measuring research productivity by comparing official R&D statistics from 18 OECD member countries.[36] Hall reports that Measuring R&D output needs knowledge of its private depreciation or obsolescence rate, which is inherently variable and responds to competitive pressure.[37]

Some scholars have highlighted how R&D inputs play an important role in R&D outputs. For instance, Guo et al. highlight that innovation outputs are significantly increased after the R&D investment from the government in China.[39] Mansfield shows that R&D investments play an important role in innovative output based on data for over 100 firms in a dozen industries.[40] Chen et al. show that R&D environment plays an important role in improving scores on the output-oriented R&D efficiency index across 24 countries.[41] Winthrop et al. highlight that a strong relation exists between government R&D expenditures and national technology advancement in the US by analyzing the aerospace industry as a case study.[42]

As we can see above and below, prior studies have rarely highlighted what factors play an important role in R&D outputs in the disaster fields and dominantly focus on the industrial, innovation, or economic fields (Table 1).[43–49] Therefore, this study explores what factors exert a significant impact on R&D achievement for disasters and safety by employing the SEM model in the next section.

Table 1. The summary of selected literature review

Authors	Year	Summary
Aksnes et al.	2017	There are methodological difficulties in measuring research productivity.
Basher	2013	The application of R&D can substantially reduce losses of lives and property.
Callaghan	2016	R&D may contribute to improved real time disaster response and resilience across contexts.
Chen et al.	2011	R&D environment plays an important role in improving scores on the output-oriented R&D efficiency index.
Hall	2007	Measuring R&D output needs knowledge of its private depreciation or obsolescence rate.
Hamilton	2000	Implementing R&D measures has been slow, and it is important to understand the factors that contribute to R&D achievement.
Guo et al.	2014	Innovation outputs are significantly increased after the R&D investment from the government.
Krichen et al.	2024	technologies, such as remote sensing, radars and satellite imaging, internet of things, smartphones, and social media, can be utilized in the management of natural disasters.
Mansfield	1981	R&D investments play an important role in innovative output.
Shaw	2016	R&D for disasters have always existed in some form in all countries.
Schneider	2018	It would be particularly useful if we could determine why one governmental effort is evaluated to be a success, while another is judged as a failure.
Winthrop et al.	2002	A strong relation exists between government R&D expenditures and national technology advancement.
Wu et al.	2021	The optimal proportion of expenditure for disaster prevention and mitigation has always been a difficult issue that people concern about.

Methodology

This study utilizes investigation and analysis on technology level related to disaster and safety management in 2021 from the National Disaster Management Research Institute in Korea. The investigation and analysis on technology level related to disaster and safety management data is to analyze technology level and technology satisfaction in the disaster and safety field by comparing with countries through the highest technology. The survey is based on experts and the public on disaster and safety R&D performance. The survey presents directions for future disaster and safety research and development through analysis of survey results (National Disaster Management Research Institute, 2021).[50]

The survey is conducted with 626 individuals who are responsible for the performance and utilization of disaster safety R&D outcomes. The survey is conducted online, and 270 participants take part in the survey. The National Disaster Management Research Institute secures a list of disaster safety experts from local governments and central ministries using official documents. The socio-demographic characteristics of experts are as follows: there are 210 males and 60 females. By age group, 7 participants are in their 20s, 57 in their 30s, 116 in their 40s, 78 in their 50s, and 12 are 60 years or older. The main topics of the survey include evaluating research quality and expertise, technology development environment, and social and economic performance.[50]

This study employs SEM to examine how we can improve governments' R&D for disaster and safety. SEM can be defined as a class of methodologies, which tests to represent hypotheses about the means, variances, and covariances of observed variables in terms of a smaller number of structural parameters provided by a hypothesized underlying conceptual or theoretical model.[51] To be specific, the SEM is an advanced statistical model that defines latent variables representing unobservable abstract concepts using observable measurement variables and identifies causal relationships between latent variables. SEM constructs models to highlight causal relationships between unobservable latent variables (or constructs, e.g., attitudes) and observed variables (e.g., survey responses).[52] Structural equation models are particularly suitable for empirically analyzing models with multiple dependent variables, as they allow for the simultaneous analysis of individual explanatory variables and relationships for a series of dependent variables.[53]

SEM is broadly divided into 2 techniques: Covariance Based-Structural Equation Modelling (CB-SEM) and Partial Least Squares-Structural Equation Modelling (PLS-SEM). CB-SEM is a statistical method. CB-SEM is mainly utilized to confirm or reject

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theories and their underlying hypotheses. CB-SEM confirms or rejects hypotheses by determining how closely a proposed theoretical model can reproduce the covariance matrix for the dataset of the studies.[54] CB-SEM uses a statistical model to estimate and test correlations between dependent and independent variables and the hidden structures in between.[51,52,55] PLS-SEM is a sequence of regressions in terms of weight vectors, which obtain at convergence satisfy fixed point equations. PLS-SEM is similar to using multiple regression analysis, and the primary objective is to maximize explained variance in the dependent constructs but additionally to evaluate the data quality based on measurement model characteristics.[51,52,56]

This paper employs CB-SEM because the methodology is more appropriate when the data has enough samples, which is higher than 200.[57–59] This study runs SPSS and AMOS 28 for the analysis by applying the Maximum Likelihood estimation method.

The dependent variable consists of satisfaction, improvement, and utility of R&D for disaster and safety. The independent variables are Professionality factors, environmental factors, and performance factors. Professionality factors are measured by system, reliability, and effort factors. Environmental factors are measured by support and service factors. Performance factors are measured by contribution, practicality, ability, and investment factors (Figure 2). The final sample of this study is 268 experts because 2 experts have error values.

Results

Table 2 shows the descriptive statistics of the experts (Table 2). The ratio of male and female is 208 (77.6%) and 60 (22.4%), and age is as follows: 20s (7, 2.6%), 30s (57, 21.3%), 40s (115, 42.9%), 50s (77, 28.7%), and 60 above (12, 4.5%). The institutes are central institutes (78, 29.1%), local institutes (19, 7.1%), and other institutes (171, 63.8%). Their specialized fields are classified into natural

Table 2. Socio-demographic characteristics

Category	Variable	Number	Percentage
Gender	male	208	77.6
	female	60	22.4
Age	20s	7	2.6
	30s	57	21.3
	40s	115	42.9
	50s	77	28.7
	60 above	12	4.5
Institute	Central institutes	78	29.1
	Local institutes	19	7.1
	Other institutes	171	63.8
Related fields	Natural disasters	76	28.4
	Life safety	80	29.9
	Social disasters	61	22.8
	Mixed disasters	32	11.9
	Other	19	7.1
R&D relationship	The Ministry of Interior and safety	54	20.1
	Other	214	79.9
Career	1 year	22	8.2
	1~5 years	32	11.9
	5~10 years	48	17.9
	10~15 years	45	16.8
	15 years above	121	45.1

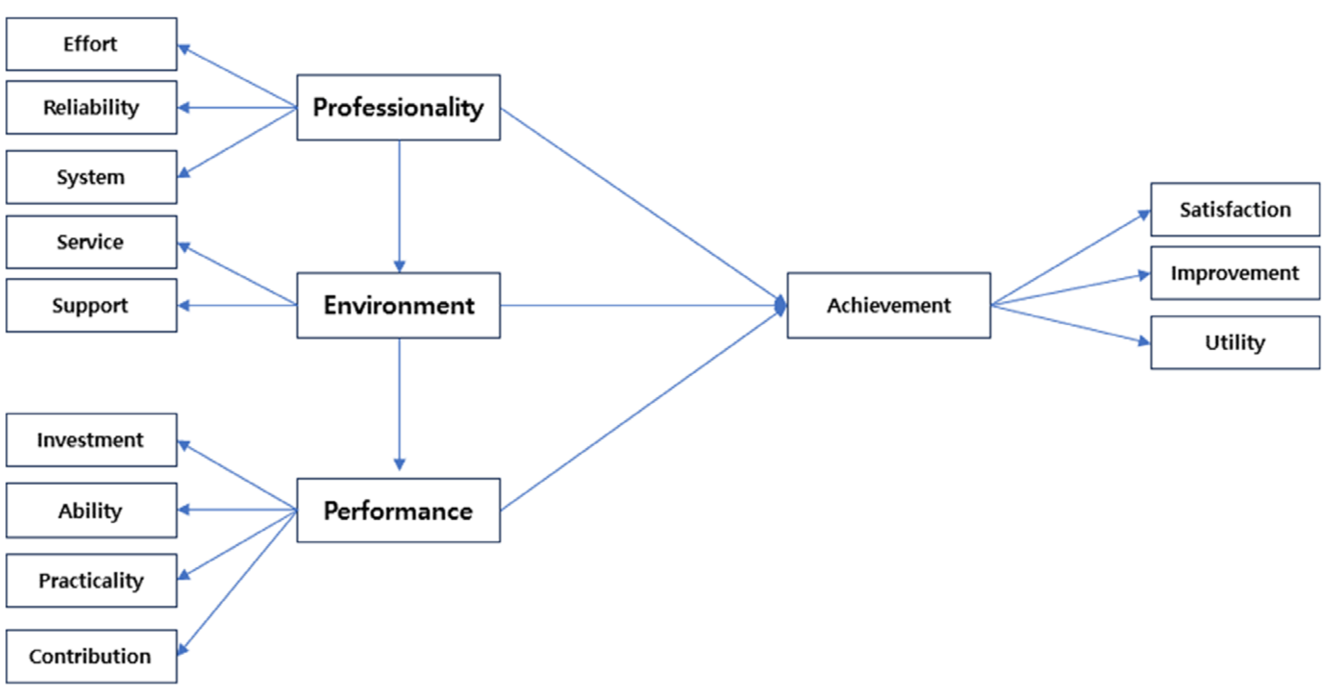

Figure 2. SEM model.

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Table 3. Descriptive statistics

Category	Variable	Mean	Standard Deviation	Range
Professionality	System	2.638	0.865	0~4
	Reliability	2.679	0.794	0~4
	Effort	2.951	0.817	0~4
Environment	Support	2.239	0.961	0~4
	Service	2.343	0.933	0~4
Performance	Contribution	2.746	0.876	0~4
	Utility	2.679	0.888	0~4
	Ability	3.474	0.711	0~4
	Investment	3.358	0.768	0~4
Achievement	Satisfaction	2.549	0.844	0~4
	Improvement	2.638	0.779	0~4
	Utility	2.623	0.791	0~4

Table 4. Standardized λ

Variables			Estimate
Effort	<---	Professionality	.734
Reliability	<---	Professionality	.887
System	<---	Professionality	.848
Service	<---	Environment	.915
Support	<---	Environment	.739
Investment	<---	Performance	.500
Ability	<---	Performance	.523
Practicality	<---	Performance	.878
Contribution	<---	Performance	.919

disasters (76, 28.4%), public safety (80, 29.9%), social disasters (61, 22.8%), large-scale complex disasters (32, 11.9%), and others (19, 7.1%), respectively. The relationship with R&D is classified into the Ministry of Interior and Safety (54, 20.1%) and the others (214, 79.9%). Experience is classified into less than 1 year (22, 8.2%), 1-5 years (32, 11.9%), 5-10 years (48, 17.9%), 10-15 years (45, 16.8%), and over 15 years (121, 45.1%).

This study employs Confirmatory Factor Analysis (CFA) before running SEM to check whether the SEM is an appropriate model for this study or not (see Table 3 for the descriptive statistics). CFA is used to test the construct validity to see if the survey measured what it intended to measure.[60–61] First, this study checks convergent validity based on the standardized λ values, which show the impact of latent variables on observed variables. Values above 0.5 are considered good, and values above 0.7 are considered excellent. All variables in this study are higher than 0.5, and most variables are higher than 0.7 (Table 4).

Next, this study examines Average Variance Extracted (AVE) and Composite Reliability (C.R.). Generally, AVE values of 0.5 or higher, and C.R. values of 0.7 or higher, are recommended. In this paper, AVE values are 0.759, 0.713, and 0.658, and C.R. values are 0.904, 0.831, and 0.877, indicating very high validity (Table 5). For discriminant validity, AVE values should be greater than the square of the correlation coefficient, and the difference between the correlation coefficient and twice the standard error should not equal 1. This condition is met for all variables in this paper.

Furthermore, this study tests Cronbach's alpha value, which verifies reliability by comparing the amount of shared variance or covariance among the items making up an instrument to the amount of overall variance.[62] Generally, a Cronbach's alpha coefficient of 0.6 or higher, and more strictly, 0.7 or higher is considered to indicate high reliability. In this paper, the coefficient is at least 0.8 (0.864, 0.807, and 0.824, respectively), demonstrating very high reliability for the variables.

After running SEM, this study checks the validity of the model. There are various methods for assessing the validity of a structural equation model, such as RMR (root mean square residual), GFI (Goodness Fit Index), NFI (Normed fit index), CFI (Comparative Fit Index), and TLI (Tucker-Lewis index). Generally, an RMR below 0.05 and other validity indices above 0.9 indicate an excellent model. In this paper, RMR is 0.04, GFI is 0.9, NFI is 0.9, CFI is 0.9, and TLI is 0.9 (Table 6).

The SEM results show that R&D performance leads to an increase of 0.429 in R&D achievement (Tables 7 and 8; Figure 3). Also, R&D professionality and R&D environment play an indirectly positive role in achievement with coefficients of 1.124 and 0.354, respectively, whereas they do not have a direct impact on achievement. In addition, R&D professionality exerts a significant

Table 5. Validity test

			Unstandardized	Standardized	S.E.	C.R.	AVE	C.R.	Cronbach's α
Effort	<---	Professionality	1	0.734			0.759	0.904	0.864
Reliability	<---	Professionality	1.173	0.887	0.082	14.381			
System	<---	Professionality	1.222	0.848	0.089	13.763			
Service	<---	Environment	1	0.915			0.713	0.831	0.807
Support	<---	Environment	0.832	0.739	0.064	12.916			
Investment	<---	Performance	1	0.500			0.658	0.877	0.824
Ability	<---	Performance	0.977	0.523	0.15	6.528			
Practicality	<---	Performance	2.046	0.878	0.242	8.465			
Contribution	<---	Performance	2.113	0.919	0.247	8.566			

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Table 6. The validity of the SEM model

	Criteria	Model
RMR	0.05 below	0.04
GFI	0.9 above	0.9
NFI	0.9 above	0.9
CFI	0.9 above	0.9
TLI	0.9 above	0.9

impact on R&D environment (0.964), and R&D environment has a positive effect on R&D performance (0.827).

Discussion

Disasters and safety accidents threaten citizens' lives every day, and it is one of the most important responsibilities of governments and policymakers to protect citizens and properties. In this background, while many governments and researchers increase their R&D inputs for disaster and safety issues, the relationship between R&D inputs and outputs is barely highlighted in the disaster fields by employing econometric models based on experts' perspectives. Therefore, this study explores the relationship between R&D input and output factors for disasters and safety by employing SEM.

This study includes some important findings which are consistent with prior studies: first, this study finds that R&D performance plays an important role in R&D achievement, which is consistent with previous articles.[63–64] For example, Pandit et al. highlight that R&D performance is positively associated with R&D achievement based on the United States Patent and Trademark Office data, such as patent applications, grants, and citations for US and non-US firms, individuals, and government entities.[63]

Table 8. SEM results

		Environment	Performance	Achievement
Professionality	Total effect	***0.964		0.848
	Direct effect	***0.964		–0.276
	Indirect effect			***1.124
Environment	Total effect		***0.827	1.166
	Direct effect		***0.827	0.812
	Indirect effect			***0.354
Performance	Total effect			0.429
	Direct effect			***0.429
	Indirect effect			

Note. The significance of the total effects for Professionality and Environment is not marked because they show different direct and indirect effects.

Second, R&D professionality exerts a significant impact on R&D achievement, which concurs with the prior research (e.g., Diéguez-Soto et al., 2016; Gupta et al., 1986; Oxley & Sampson, 2004).[65–67] For instance, Diéguez-Soto et al. show that professionalism in management exerts a positive influence on innovation from both technological and management perspectives through a survey questionnaire addressed to 583 managers of small and medium-sized family firms in Murcia, Spain.[65]

Table 7. Coefficient value

			Unstandardized	Standardized	S.E.	C.R.
Environment	<---	Professionality	***1.223	0.964	0.096	12.759
Performance	<---	Environment	***0.413	0.827	0.054	7.687
Achievement	<---	Professionality	–0.343	–0.276	0.6	–0.572
Achievement	<---	Environment	0.797	0.812	0.517	1.541
Achievement	<---	Performance	***0.842	0.429	0.198	4.26
Effort	<---	Professionality	1	0.737		
Reliability	<---	Professionality	***1.152	0.874	0.081	14.253
System	<---	Professionality	***1.236	0.861	0.088	14.038
Service	<---	Environment	1	0.819		
Support	<---	Environment	***0.864	0.687	0.071	12.186
Investment	<---	Performance	1	0.500		
Ability	<---	Performance	***0.965	0.518	0.148	6.525
Practicality	<---	Performance	***2.054	0.884	0.24	8.557
Contribution	<---	Performance	***2.095	0.914	0.242	8.645
Satisfaction	<---	Achievement	1	0.887		
Improvement	<---	Achievement	***0.858	0.825	0.048	18.021
Utility	<---	Achievement	***0.956	0.906	0.044	21.677

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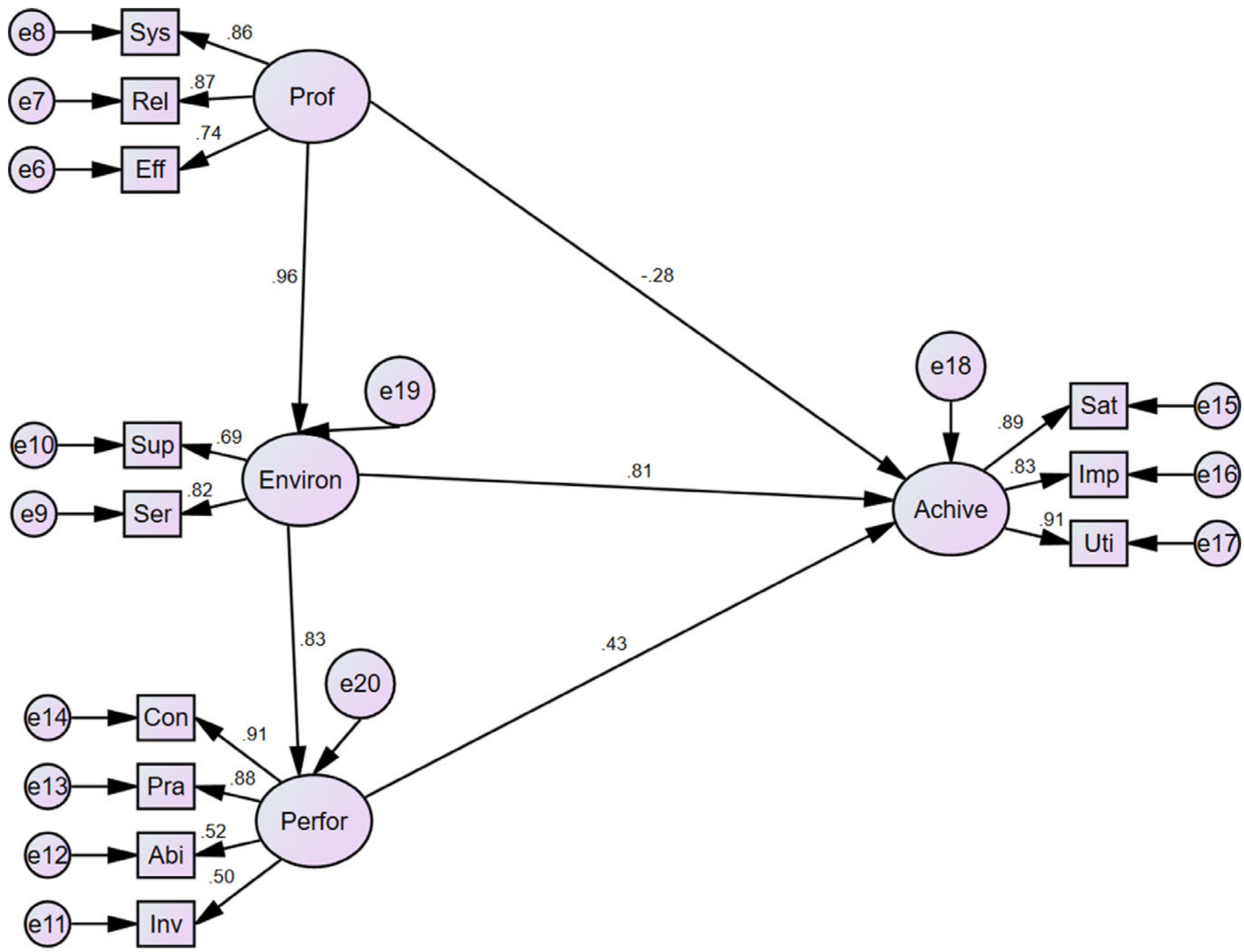

Figure 3. SEM results.

Third, R&D environment plays a positive role in R&D achievement, which is a similar finding of previous studies (see e.g., Audretsch & Vivarelli, 1994; Teirlinck & Khoshnevis, 2020; Von Zedtwitz & Gassmann, 2002).[68–70] Teirlinck and Khoshnevis report that an environment specialized in the focus firm's activities exerts a positive effect on R&D output efficiency based on the 122-space research of active private firms from 2011-2015.[69]

Fourth, R&D professionality is positively related to R&D environment, which is a similar finding of previous articles (e.g., Malecki & Bradbury, 1992; Parboteeah et al., 2005; Schumann Jr et al., 1995).[71–73] For example, Parboteeah et al. report that professional development activities are relevant to the work environment through 949 full-time employed engineers of the R&D organization.[72]

Fifth, R&D environment has a positive effect on R&D performance, which is consistent with previous literature (e.g., Baek & Lee, 2022; Hung & Chou, 2013; Pillai et al., 2002).[73–75] Baek and Lee (2022), using a large dataset of 1087 government-funded R&D projects in Korea, highlight that environmental factors positively affect R&D performance.

Conclusions

Governments' expenditure and investments in R&D are funded by taxpayers' valuable contributions and should be effectively utilized to enhance R&D outputs. While many prior studies have examined the relationship between R&D inputs and outputs, they have primarily focused on business, innovation, and industrial sectors. In contrast, the input factors influencing R&D outputs in the field of disaster management have been scarcely addressed, even though R&D technology and investments can play a crucial role in protecting citizens' lives and property. In this context, this study explores how R&D achievements for disaster and safety management can be improved through using SEM.

This study shows several important results: first, this study shows that R&D performance directly exerts a significant impact on R&D achievement with the coefficient of 0.429. Second, while professionality and environment of R&D do not show a direct effect on achievement, they exhibit an indirect effect on it with the coefficients of 1.124 and 0.354, respectively. Third, R&D professionality exerts a significant impact on R&D environment (0.964), and R&D environment has a positive effect on R&D performance (0.827). In sum, this study answers the hypotheses as follows:

1. R&D professionality exerts a positive impact on R&D environment.
2. R&D environment plays an important role in R&D performance.
3. R&D professionality indirectly affects R&D achievement.
4. R&D environment has an indirect effect on R&D achievement.
5. R&D performance has a direct effect on R&D achievement.

This study offers several important implications: First, governments and researchers should focus on enhancing R&D performance, including factors such as contribution, practicality, capability, and investment, as these directly impact R&D outcomes. To achieve this, governments and researchers could develop networks between new R&D technologies, firms, and institutions to increase the contribution and applicability of emerging technologies. Second, governments and researchers should improve the professionalism of the R&D environment and its outcomes. This could be achieved by investing more in R&D systems, reliability, and efforts to create a better environment for research and innovation. Third, policymakers and researchers should foster a more supportive R&D environment to boost performance and outcomes. They should aim to provide valuable support and services for experts and professionals, enabling them to generate more and higher-quality R&D outputs for their citizens.

This study makes significant contributions to both the theoretical and practical frameworks in the disaster and safety literature. First, methodologically, it demonstrates how R&D inputs have a significant impact on R&D outputs in the disaster and safety field by employing CB-SEM, a technique that can be used to confirm or reject theories and their underlying hypotheses. The study confirms the 5 hypotheses outlined above, and future researchers can use these hypotheses to develop R&D research models based on the factors related to R&D outputs in the disaster and safety sector. Also, this study highlights the specific relationships and values among R&D professionalism, R&D environment, R&D performance, and R&D achievement. Governments and R&D practitioners can use these specific findings to inform the development of R&D policies and procedures aimed at improving R&D outputs.

While the key strengths and advantages of this study lie in its exploration of the relationship between R&D inputs and outputs, as well as the specific paths and values in the disaster and safety field, based on an empirical model and data from 268 trustworthy disaster and safety experts hired by the national government using CB-SEM, the study has some limitations. First, this study examines the relationship between R&D inputs and outputs in the disaster and safety field only in South Korea, and the relationship may differ in other countries. Future international researchers should investigate how R&D inputs impact outputs in their respective countries. Second, this study relies solely on data from 2021, and recent developments in R&D may yield different results, as R&D changes and evolves rapidly. Future research should incorporate the most current data to further explore the association between R&D inputs and outputs. Third, while this study draws on input from disaster and safety experts, future research would be more comprehensive if actual R&D input and output data (e.g., R&D expenditure in each related field and patent numbers for disaster and safety technologies) are included. Future scholars could utilize such data to further enhance the theoretical and methodological implications for R&D inputs and outputs.

This study highlights how governments can improve R&D for disasters and safety by employing CB-SEM. It offers both theoretical and empirical perspectives, demonstrating that R&D professionalism, R&D environment, and R&D performance play a significant role in R&D achievement based on econometric models. By doing so, policymakers and safety practitioners can develop disaster and safety policies informed by these specific frameworks and values, which have not been emphasized in previous studies. The study anticipates that these implications will enhance disaster and safety R&D outputs and provide citizens with more secure and stable environments through government initiatives.

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