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Safety Engagement in the Workplace: Text Mining Analysis

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Abstract: In order to derive safety engagement factors in the workplace and analyze the characteristics of the factors, we collected literature data to be analyzed by a systematic literature review and text mining analysis. We used safety, industrial, occupational, corporate, commitment, engagement, interaction, and participation as key search terms for literature selection and used 143 literature datasets for analysis. We divided the factors of workplace safety engagement into the organizational level and the individual level. In studies after 2005, texts at the individual psychological level appeared in large numbers. Although individual factors have been studied as subfactors at the organizational level, we confirmed that the two types of factors must interact for safety engagement in the workplace. We classified safety engagement factors into cognitive, emotional, behavioral, and relational factors. In particular, relational factors were mainly composed of factors that negatively affected engagement. In the follow-up study, we identified the maturity level among safety engagement factors as divided into four dimensions needed to create a safe workplace environment and to suggest a direction for employees to engage themselves in safety.

Keywords: safety engagement in the workplace; safety engagement factors; safety education; keyword network analysis; text mining

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1. Introduction

1.1. Research Background

Safety is an important concept everywhere in our lives, not only in general life but also in industrial sites, organizations, and businesses, to improve the quality of life of people. Demands for safety in the workplace where people spend most of their day-to-day life are constantly increasing. In order to prevent accidents in the workplace and increase the efficiency of safety management, it is important for employees to comply with safety standards and act safely to keep the organization safe [1–5]. Specifically, in order to improve safety in the workplace, it is necessary to reduce the human errors of workers in order to induce safe behavior and build an environment where they can engage themselves in safety.

Michael et al. [4] suggested quality, production, and safety as three essential factors for responding to the changing environment for continuous growth and management of organizations in modern society. Among them, safety is the most recent concept, and in order to increase the effectiveness of safety management of an organization, mature safety awareness and commitment to safety in the workplace are essential. Previous studies have confirmed that safety behavior, according to safety awareness, attitude, dedication, and commitment of employees, directly affects the formation of safety culture or a safety climate in the workplace [6–10]. Jansson [10] announced that it is difficult to establish a safety culture in an organization by designing a system that emphasizes only engineering factors. Jansson [10] suggested that in order to properly establish a safety culture, it is necessary to comprehensively consider the attitudes, trust, personalities, environments, and social interactions of individual members.

Cooper and Phillips [7] argued that the psychological aspect of a person, the situational aspect of the environment, and the behavioral aspect resulting from the interaction between people and the environment can contribute to a company's safety climate in combination.

The establishment of a safety policy for members, establishment of a safety management system, and establishment of operational procedures contribute to the situational aspect of the company and complementarily influence the safety behavior of members. For the factors affecting accident prevention suggested by Lund and Hovden [11], human attitudes and beliefs can influence behavioral and attitude-change factors, and factors such as social safety, culture, interaction, and physical environment influence structural change that can cause accidents and disasters.

Recent studies related to employee engagement in safety in the workplace have suggested that safety education conducted in an organization can induce employees to engage themselves in safety by means of behavior and attitude formation [12–16]. An organization's occupational safety and health (OSH) department provides safety training for new workers when performing job training. A study by Rauscher et al. [14] announced that safety and health education is essential in the composition of vocational education programs in organizations in the construction field. According to this study, safety education is studied as a field of adult education, and the curriculum for safety education in organizations is regularly updated. When the training curriculum was updated, the experiences of mutual accidents or on-the-ground experiences were shared among workers, and the contents were reflected. The education department of the organization was trying to motivate site workers to work safely in the workplace by means of active participation of organizational members [14–16].

In Korean studies related to safety engagement of workers in the workplace were performed, comprising empirical studies that increase organizational trust and commitment by analyzing the influence of safety awareness contributing to the formation of an organizational safety climate and safety culture [17–20]. According to the results of studies exploring workplace safety engagement conducted so far, the major components of workplace safety engagement are employee commitment, active participation, leadership, behavior, organizational and personal competency, trust, psychological safety, and relationships between members. In order for members to engage with safety in the workplace, it is necessary to raise the safety awareness of members and induce safety compliance and safety behavior. In addition, workplace safety engagement should be formed by inducing active interaction so that the organization and members can be engaged in safety.

A research model for the formation of workplace safety engagement has not yet been established. Theories related to safety in the workplace are being studied, such as general organizational management issues, safety psychology, behavior, and safety management systems. However, the research model that can identify the specific meaning and the interaction between safety-related factors is insufficient. To engage with safety in the workplace and enable organizations to effectively respond to changes in the external environment, organizations must be able to remain secure on an ongoing basis. Therefore, it is necessary to establish a research model that can identify the level of maturity of safety engagement in the current workplace.

1.2. Theoretical Background

1.2.1. The Concept of Safety Engagement

The ultimate goal of workplace safety is to form a safety culture within the organization and to maintain the organization in a safe state by inducing the safety behavior of the executives and managers [5,21]. In order to induce safety compliance and safety behaviors of organizational members, it is first necessary to examine attitude variables that can predict the behavioral tendencies of members. Although individual attitudes and behaviors do not necessarily tend to coincide, previous studies have confirmed that individual attitudes predict individual behaviors well and that the relationship between attitudes and behaviors is very close [21–23]. Attitudes can generally be divided into cognitive, emotional, and behavioral factors.

For safety management, the cognitive factors constituting safety attitude include safety compliance, which recognizes and conforms to safety standards, regulations, and

the overall system. As for emotional factors, there is a sense of safety and an individual's voluntary will that contribute to the manifestation of potential safety concerns of members by means of concrete actions and practices. Behavioral factors include the intention to put members' perceptions and feelings about safety in the organization into action [4,24–26]. According to previous studies on the relationship between safety attitudes and safety behavior at industrial sites, worker safety attitudes at the individual level lead to safety behaviors, which result in active compliance and participation in safety. Kao et al. [24] reported that there is a significant relationship between safety attitudes and safety behavior of managers and workers and that it affects organizational safety performance.

Commitment is a representative concept dealing with attitudes and was actively discussed by organizational psychologists in the United States and Europe in the 2000s, along with studies on the meaning of work, emotions experienced in work performance, and mental health [27–30]. Kaldenberg et al. [30] conceptualized the core factor of immersion as a psychological relationship between the individual, the subject of attitude, and the object of immersion. In this study, they argued that the type of immersion showed a difference according to the reference target of commitment or engagement. By linking the concepts of safety and commitment, Michael et al. [4] conceptualized safety engagement as an attitude of dedication and participation, such as compliance with regulations and with management systems based on safety awareness within the organization.

1.2.2. Previous Studies Related to Safety Engagement

The importance of safety in the workplace is increasingly emphasized, and previous organizational-level studies have focused on topics such as safety culture, safety climate, safety performance, and safety leadership [2–4,12,31–33]. Recently, to improve workplace safety, studies based on interest in human resources have been conducted [31–36]. Existing studies on the organizational dimension focused on the tendency of individuals who are difficult to change when analyzing the relationship between individual characteristics and thinking, so the results of the study were inconsistent and there were limitations in its scope of application. Therefore, it is necessary to study safety-related attitude variables that can be altered by changes in external factors.

In previous studies of safety engagement, the most fundamental cause of on-site accidents was found to be the unsafe behavior of members, and the construction of a behavior-based safety management systems was suggested to improve and eliminate unsafe behavior [33,37–39]. Zohar [33] argued that compliance with safety standards and procedures is the key to establishing a safe workplace and that the retention of systematic systems and manuals has a decisive influence on the results of employees' commitment to safety. In a study by Griffin and Neal [37], members' safety engagement was classified into compliance and participation, and safety engagement was interpreted as behavior-based. The authors defined conformity as behavior by which employees use knowledge and experience of safety in the process of work try to comply with corporate safety regulations and guidelines. In addition, participation was defined as managers motivating members to actively participate in organizational safety-related activities.

Among the major components of safety engagement, organizational management, leadership, organizational learning, knowledge sharing, and interaction were presented as organizational factors. At the individual level, participation, engagement, commitment, behavior, and communication were identified as major factors related to safety engagement [4,28,34,35,40,41]. Rojas et al. [41] emphasized the importance of members' participation and communication among the factors at the individual level. They argued that the role of site managers is very important because they play an important role in facilitating participation and communication among members and ultimately inducing workers' engagement in safety.

1.3. Research Purpose and Scope

It is important to understand the engagement maturity model in the workplace and the relationships between and the meanings of the components in order to achieve workplace safety commitment, identify the level of maturity to keep the organization in a safe state, and enable employees to engage in the workplace. In order to explore the major components of workplace safety engagement and analyze the meanings of these factors, a systematic literature review and text mining were performed as a research method. However, it is not enough to understand the structural relationship between safety competency and safety engagement that can connect an organization's safety management strategy to performance because a simple fact-finding survey only identifies the current situation.

In order to protect the organization and its members from risks caused by changes in the internal and external environment of the workplace, identify future-oriented needs, and establish sustainable strategies, in this study, we integrated the components of the workplace safety engagement research model based on commitment. Specifically, we was intended to analyze the cognitive, emotional, behavioral, and relational aspects of individual members and organizations in an integrated manner. In addition, we attempted to understand organic interactions through relationship analysis of the various components constituting workplace safety engagement maturity.

We conducted a systematic literature review and text mining as research methods to analyze major factors of workplace safety engagement. For the traditional content analysis method, in which a certain analysis standard is set and the content is analyzed based on the criterion, there is room for the researcher's subjectivity to intervene in the arbitrarily formed area of analysis. Xu et al. [42] argued that it is essential to conduct research using text analysis methods to derive complex and diverse risk factors and to understand the relationship structure. The text analysis method extracts meaningful concepts or characteristic factors based on structured or unstructured text data and derives information such as patterns and trends between the factors [42–44]. Text analysis is a type of the meta-analysis to supplement the traditional research method and to secure the objectivity of the research. This method can identify factors and correlations that have an important influence on meaning formation based on the analysis of the frequency and network of big data composed of text and the analysis of phenomena and structures through visualization of the derived results [44,45].

In this study, text analysis was performed by collecting unstructured text data from existing studies to confirm the validity of research using big data in the field of safety research and to derive and analyze safety engagement factors in the workplace. Using this research method, the main factors constituting safety engagement were identified, and the interactions between factors were analyzed by confirming the interactions. In addition, a complex structure was visualized through network analysis among safety participation factors. Research trends related to safety in the workplace were analyzed, and model components and detailed factors were derived through text analysis. In addition, we tried to determine the relationship between keywords through network analysis to understand the structure of the relevant area and analyze its meaning. Through this process, basic research was conducted to prepare an academic framework for workplace safety engagement.

2. Materials and Methods

The aim of in this study is to explore what safety engagement factors in organizations are and in what flow they have been studied. We conducted a systematic literature review and text mining to derive the factors of safety engagement and to analyze the characteristics of the factors. In this study, we collected the literature data to be analyzed by applying the PRISMA flow chart [13,46,47] presented in the *Cochrane Handbook*. The search and derivation of documents to be used for analysis consisted of four steps: identification, screening, eligibility, and inclusion.

2.1. Materials

In this study, we limited the literature data to be used for analysis to research papers (excluding dissertations or conference proceedings) that we reviewed according to certain criteria. We conducted a title–abstract–keywords search to collect analysis data.

Initial search terms for literature search were set to "safety" and "engagement". First, "safety" was set as the main search word (a search word that must be included) in the initial stage. In addition, search terms to be included at least once were set as "commitment", "engagement", "interaction", and "participation", which are words with the same or similar meaning to that of engagement. The reason why words with similar meanings to that of engagement were set together as a search term was to extensively include in the initial search stage related research literature on "safety engagement". In this study, the workplace environment where "safety engagement" is formed is limited to industrial or corporate organizations. In order to limit the searched literature field to "industrial safety" or "occupational safety", secondary search terms were set as hospital, patient, food, crime, transportation, etc., and related contents were excluded from the literature. Table 1 presents the initial search keyword settings.

Table 1. Search keyword conditions presented in detail.

Search Keywords	Details
	"safety"
AND	industrial; OR occupational; OR corporate
AND	commitment; OR engagement; OR interaction; OR participation
NOT	-hospital; -nurse; -patient; -crime; -food; -traffic; -road

We conducted the literature search from 10 May to 24 May, and the search took a total of two weeks (15 days). We retrieved 282 articles in the first stage. The databases used for the search were the Korean Studies Information Service System (KISS), Korean Education and Academic Information Service, National Digital Science Leaders (NDSL), Database Periodical Information Academic (DBpia), Google Scholar, Science Direct, Web of Science, Springer, Scopus, and SAGE.

We performed web crawling using the Python 3.8 program to search the literature and extract titles, keywords, and abstracts. When doing web crawling using a Python program, we used "beautifulsoup" as the main library. When collecting data, we used "pandas, beautifulsoup, request, selenium, and re" as essential libraries. The retrieved documents were saved as csv files.

2.2. Methods

2.2.1. Systematic Literature Review

We conducted this study by referring to the systematic literature-review handbook of the Cochrane collaboration and the systematic literature-review guidelines presented by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) group to derive the articles for systematic review. The flow chart presented by the PRISMA group has the advantage that it can secure the clarity of the research object in the systematic literature-review stage.

Among the 282 articles searched in the initial search stage, 43 duplicate documents and no original documents were deleted, and a total of 239 articles were transferred to the screening stage. Figure 1 presents a systematic literature-review process for deriving literature to be analyzed.

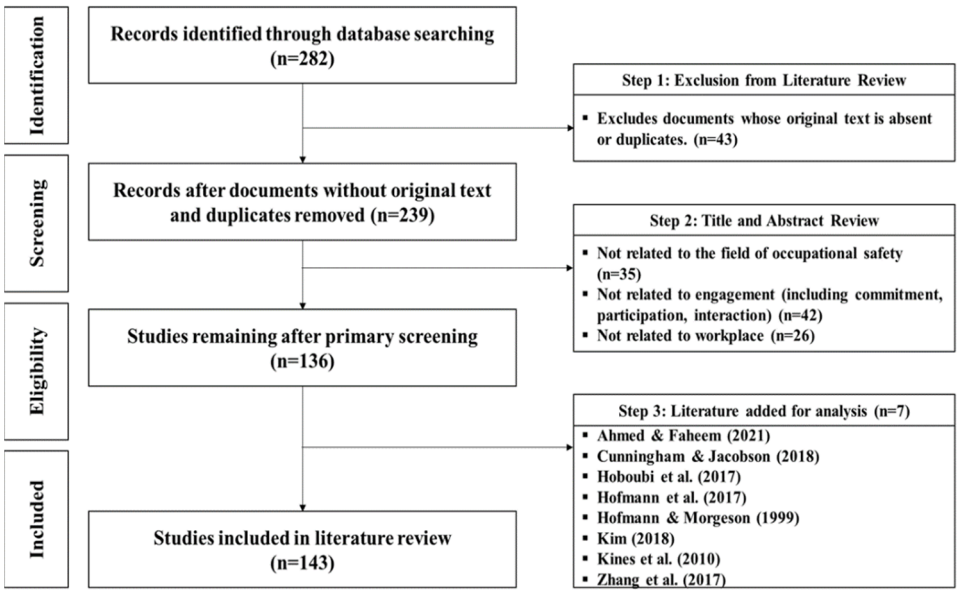


Figure 1. Literature selection for the analysis of safety engagement factors using the PRISMA flow chart.

We applied the PICO process in the screening step. The PICO process is a literature-derived method consisting of participation, intervention, comparison, and outcomes. It is widely used in literature reviews and qualitative meta-analysis as a method to construct a search strategy suitable for research purposes [12,13,48,49]. In order to limit the field of research, we limited the research fields to safety management, risk management, and workplace; interventions that could lead to safety engagement of members were suggested as compliance, consciousness, attitude, and behavior. These are the main components that can achieve an organizational safety goal, and the items derived from the studies of Neal et al. [9] and Turner et al. [50] were applied.

The PICO process was applied to select the searched documents. P (participants) was limited to industrial fields, such as "safety management, risk management, workplace," to limit the research field, including workplace, safety, organization, and individual. As I (intervention), safety compliance, safety awareness, safety attitude, and safety behavior that can affect workplace safety commitment were presented. C (comparison) was not set as a comparison object in this study to analyze various factors of workplace safety engagement and to explore each relationship. O (outcomes) was set as safety engagement or safety commitment, safety interaction, and safety participation as organizational performance due to engagement factors. Table 2 shows the PICO process in detail.

Table 2. Detailed search terms and conditions for the PICO process.

Classification	Details
Participation	safety management; OR risk management; OR workplace
AND	
Intervention	safety compliance; OR safety awareness; OR safety attitude; OR safe behavior
AND	
Comparison	no control group
AND	
Outcome	safety engagement; OR safety commitment: OR safety interaction; OR safety participation

In order to prevent the loss of essential data to be analyzed, we checked the existing literature-review research data about safety engagement, participation, commitment, and behavior, along with a database search. In these studies, we identified literature related to safety commitment, organizational safety climate, psychological safety, and safety compliance and added seven articles to the analysis. Finally, we selected 143 articles to be used as data for the analysis of safety engagement factors.

2.2.2. Text Mining

Data can be divided into structured data with a fixed structure and unstructured data with no fixed structure. Mining using structured data is called data mining, and mining using unstructured data is called text mining [42,51]. Text mining refers to extracting statistically meaningful concepts or characteristics from unstructured text data and deriving patterns or trends among them [52,53]. Text mining is applied to research by analyzing and visualizing the frequency of texts and deriving meanings by analyzing networks between texts.

We performed text frequency analysis and keyword network analysis using the R program (4.1.0 version), an open software, for the 143 articles that we finally selected by means of a systematic literature review. We visualized the analyzed words using a word cloud, which is a representative technique used to analyze unstructured text data [12,54]. Words such as nouns or adjectives are extracted from preprocessed text data using computer programs such as R or Python, the frequency of appearance is calculated, and the result value is visualized and analyzed. Depending on the size of the word, high or low frequency of occurrence is indicated, and each word is expressed in a different color.

Network analysis, mainly used in the social sciences, is divided into social network analysis and keyword network analysis. Both analysis methods are used to determine the role of key link words in the network by measuring the influence of an entity based on the network connection structure and the connection strength or frequency between entities [55–57]. In social network analysis, an individual is considered a node, and an individual's social relationship is considered a link when constructing a network for analysis [13,58]. The influence between keywords within the keyword network can be measured by means of the centrality index.

The purpose of qualitative research is to interpret the meaning of a variable or concept in a specific context or situation. Because it is difficult to analyze the meaning of structural phenomena in the existing content analysis, we found that the network analysis of the safety engagement factors could explain a new part that could not be analyzed or explained in previous studies.

For keyword network analysis, we did data cleaning and preparation work using the stringr package to obtain the specified start and end points from the string, extracted patterns, and constructed a data frame using the dplyr package. In this study, we applied the text presented in the literature data to the analysis as-is but derived the final keywords by means of several purification processes. Singular and plural nouns were classed as singular, keywords that can be classified with similar meanings were integrated, and the final keywords were derived by cleaning and controlling the search and spacing. We used the wordcloud2 package to visualize the derived keywords according to text frequency.

3. Results

In this study, we analyzed the results by dividing them into before and after based on the study of Michael et al. [4], who, in 2005, conceptualized factors at the individual level and specifically created the concept of safety commitment. The authors reported that engagement factors, such as the manager's role, commitment, and participation, directly affects workers' safety participation. In previous studies, individual-level factors focused on behaviors, such as a reduction in the accident rate. However, Michael et al. specifically classified psychological factors, such as engagement, commitment, active participation, and the attitude of workers affected by the manager's role (leadership).

In the study of Griffin and Neal (2000) [37], individual psychological dimensions, such as safety compliance, behavior, and motivation, were also assessed, but these were included in the safety performance and outcomes as a subfactor of organizational climate. In addition, because it was not an individual-level study but an organizational-level study and was a study of safety and goal achievement, we considered Michael et al.'s study to be representative of the times.

3.1. Text Frequency Analysis

By text mining, we identified most of the major factors constituting safety engagement as being organizational factors, such as climate, culture, and management. In studies before 2005, except for safety, a key search term, climate, accidents, organizational, management, behavior, and leadership were major components. In studies before 2005, most of the texts were at the organizational level. There were some that corresponded to the individual level, such as behavior, attitude, and motivation, but not many.

We used 1194 words for text analysis and identified 82 keywords related to safety. The words with high frequency included climate, behavior, accidents, organizational, management, performance, construction, and relationship. Excluding behavior, we confirmed that studies were mainly conducted to achieve safety performance by considering safety as a part of organizational management and controlling accident rates [2,3,7,8,31–33,37,59]. Industrial (or occupational) safety-related research was mainly done in the construction field [32,60].

In the initial safety-related research, we confirmed that safety education was carried out with the concept of practice, such as practice and training. In order to form or improve human behavior and attitudes by means of safety education, as an educational program was implemented during on-the-job training [7,60–63]. The safe behavior of members was considered to be simple habit, not a psychological action. Table 3 shows the keywords and frequency analysis results prior to 2005.

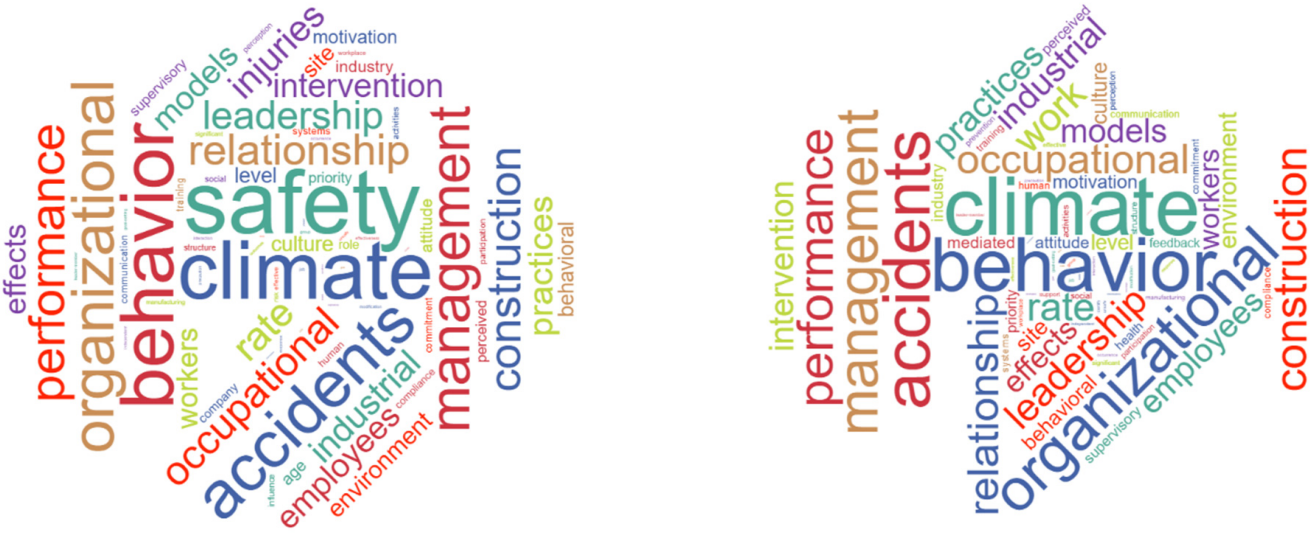
Table 3. Keywords and frequency analysis results in documents prior to 2005.

No.	Word	Weight	Centrality	No.	Word	Weight	Centrality
1	safety	272	0.2278	42	human	7	0.0059
2	climate	97	0.0812	43	systems	7	0.0059
3	behavior	46	0.0385	44	training	7	0.0059
4	accidents	41	0.0343	45	structure	6	0.0050
5	organizational	31	0.0260	46	social	6	0.0050
6	management	29	0.0243	47	influence	6	0.0050
7	performance	26	0.0218	48	participation	6	0.0050
8	construction	24	0.0201	49	perception	6	0.0050
9	relationship	23	0.0193	50	activities	6	0.0050
10	occupational	22	0.0184	51	prevention	6	0.0050
11	work	21	0.0176	52	effective	5	0.0042

Table 3. *Cont.*

No.	Word	Weight	Centrality	No.	Word	Weight	Centrality
12	rate	21	0.0176	53	manufacturing	5	0.0042
13	leadership	21	0.0176	54	workplace	5	0.0042
14	injuries	20	0.0168	55	support	5	0.0042
15	industrial	19	0.0159	56	risk	5	0.0042
16	practices	19	0.0159	57	significant	5	0.0042
17	intervention	18	0.0151	58	identify	4	0.0034
18	models	18	0.0151	59	effectiveness	4	0.0034
19	effects	17	0.0142	60	goal-setting	4	0.0034
20	employees	17	0.0142	61	group	4	0.0034
21	workers	16	0.0134	62	independent	4	0.0034
22	environment	14	0.0117	63	interaction	4	0.0034
23	site	13	0.0109	64	job	4	0.0034
24	behavioral	12	0.0101	65	leader-member	4	0.0034
25	culture	12	0.0101	66	modification	4	0.0034
26	level	12	0.0101	67	occurrence	4	0.0034
27	motivation	11	0.0092	68	outcomes	4	0.0034
28	age	10	0.0084	69	precaution	4	0.0034
29	attitude	10	0.0084	70	response	4	0.0034
30	industry	10	0.0084	71	unsafe	4	0.0034
31	mediated	10	0.0084	72	conditions	3	0.0025
32	supervisory	9	0.0075	73	consciousness	3	0.0025
33	perceived	9	0.0075	74	events	3	0.0025
34	priority	9	0.0075	75	knowledge	3	0.0025
35	feedback	8	0.0067	76	goal	3	0.0025
36	health	8	0.0067	77	implications	3	0.0025
37	role	8	0.0067	78	information	3	0.0025
38	company	8	0.0067	79	LMX	3	0.0025
39	commitment	7	0.0059	80	validity	3	0.0025
40	communication	7	0.0059	81	prevent	3	0.0025
41	compliance	7	0.0059	82	SCQ	3	0.0025

Figure 2 visualizes the frequency analysis result. Figure 2a shows the overall results included for the keyword safety, and Figure 2b presents related texts excluding safety.



(**a**) (**b**)

Figure 2. Analysis of main text frequency in studies prior to 2005: (**a**) data with full text representation; (**b**) text data except safety.

In the study considering literature published after 2005, we used 6399 words in the analysis, and the number of keywords increased to 180. Newly introduced words included BBS, data, individual, engagement, ergonomics, macroergonomics, demands-resources, transactional, behavior-based, stress, topic, modeling, transformational, empowering, and coaching. Among them, BBS (behavior-based safety), which showed the highest frequency, is a study of individual psychology of organizational safety management [64–68]. The BBS program was developed to induce members to engage in safe behavior by a positive rather than negative method, such as reprimanding, accusing, or fines, in order to reduce members' unsafe behavior. It started in the 1970s following Skinner's operant condition theory and developed into a process of improving worker behavior, along with safety culture factors [64–66]. All members were encouraged to participate in the safety management of the organization, and education and training were conducted for all members. This program applies the principles of applied behavior analysis to occupational safety.

In safety-related research, fields related to safety psychology, such as ergonomics and macroeconomics, began to develop, and in particular, studies on stress and job burnout in individual psychology were conducted. In studies after 2005, the job demands-resources (JD-R) model was applied to analyze factors such as organizational safety and improvement, inducing individual safety behaviors, and safety compliance in the workplace [38,69,70]. Job resources in the field of safety management are divided into the organizational level and the individual level. Job resource factors at the organizational level include interrelationship and cooperation within and outside the organization, the integrated safety-policy management system, the internal competency analysis system, and the organization's safety culture. At the individual level, job resources include a sense of duty, job satisfaction, self-efficacy, motivation, safety awareness, compliance, behavior, participation, commitment, and engagement in the individual's work.

Table 4 presents the text mining results. The contents of Table 4 are visualized and presented in Figure 3. Figure 3a is a word cloud that presents all words, and Figure 3b is a word cloud leaving out the key search word safety.

Table 4. Keywords and frequency analysis results in documents since 2005.

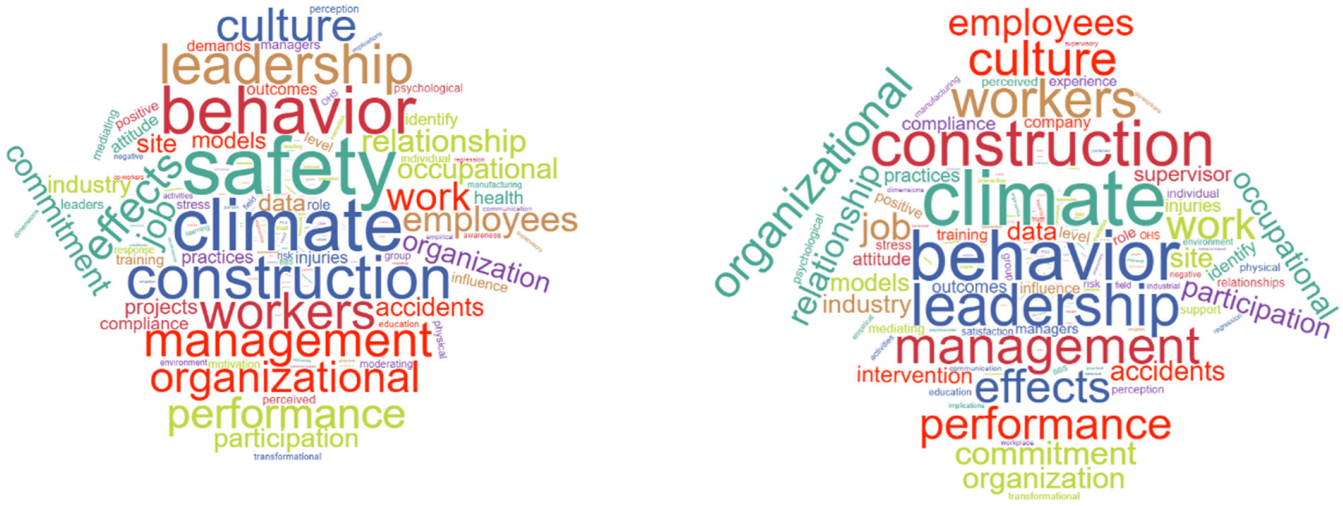
No.	Word	Weight	Centrality	No.	Word	Weight	Centrality
1	safety	1303	0.2036	91	resources	12	0.0019
2	climate	339	0.0530	92	prevention	12	0.0019
3	behavior	304	0.0475	93	OSH	12	0.0019
4	construction	186	0.0291	94	framework	12	0.0019
5	leadership	157	0.0245	95	chemical	12	0.0019
6	workers	124	0.0194	96	assessment	12	0.0019
7	management	123	0.0192	97	values	11	0.0017
8	culture	117	0.0183	98	PCS	11	0.0017
9	effects	110	0.0172	99	behavior-based	11	0.0017
10	organizational	108	0.0169	100	team	10	0.0016
11	performance	106	0.0166	101	recognition	10	0.0016
12	work	102	0.0159	102	program	10	0.0016
13	employees	91	0.0142	103	practitioners	10	0.0016
14	job	89	0.0139	104	group-level	10	0.0016
15	commitment	81	0.0127	105	behavioral	10	0.0016
16	relationship	81	0.0127	106	rate	9	0.0014
17	occupational	72	0.0113	107	predictor	9	0.0014
18	organization	71	0.0111	108	policies	9	0.0014
19	participation	68	0.0106	109	plant	9	0.0014
20	site	65	0.0102	110	passive	9	0.0014
21	accidents	64	0.0100	111	multi-level	9	0.0014
22	data	62	0.0097	112	intention	9	0.0014
23	industry	61	0.0095	113	hierarchical	9	0.0014
24	models	61	0.0095	114	enterprises	9	0.0014
25	intervention	53	0.0083	115	characteristics	9	0.0014
26	projects	53	0.0083	116	topic	8	0.0013
27	supervisor	51	0.0080	117	modeling	8	0.0013
28	health	47	0.0073	118	metro	8	0.0013
29	practices	46	0.0072	119	HSO	8	0.0013
30	compliance	45	0.0070	120	farmworkers	8	0.0013
31	injuries	43	0.0067	121	effectiveness	8	0.0013
32	attitude	43	0.0067	122	aviation	8	0.0013
33	outcomes	42	0.0066	123	attention	8	0.0013
34	demands	40	0.0063	124	validity	7	0.0011
35	company	40	0.0063	125	relation	7	0.0011
36	training	38	0.0059	126	nuclear	7	0.0011
37	influence	37	0.0058	127	mutual	7	0.0011
38	level	37	0.0058	128	multiple	7	0.0011

Table 4. *Cont.*

No.	Word	Weight	Centrality	No.	Word	Weight	Centrality
39	role	36	0.0056	129	monitoring	7	0.0011
40	positive	36	0.0056	130	HSE	7	0.0011
41	managers	35	0.0055	131	feedback	7	0.0011
42	leaders	34	0.0053	132	effective	7	0.0011
43	experience	34	0.0053	133	cultural	7	0.0011
44	perceived	32	0.0050	134	business	7	0.0011
45	stress	32	0.0050	135	action	7	0.0011
46	mediating	31	0.0048	136	engagement	6	0.0009
47	individual	31	0.0048	137	worksite	6	0.0009
48	systems	30	0.0047	138	self-efficacy	6	0.0009
49	support	30	0.0047	139	rules	6	0.0009
50	relationships	30	0.0047	140	respondents	6	0.0009
51	psychological	30	0.0047	141	psychology	6	0.0009
52	motivation	30	0.0047	142	productivity	6	0.0009
53	physical	28	0.0044	143	power	6	0.0009
54	perception	28	0.0044	144	musculoskeletal	6	0.0009
55	moderating	28	0.0044	145	members	6	0.0009
56	group	27	0.0042	146	explore	6	0.0009
57	risk	27	0.0042	147	discomfort	6	0.0009
58	satisfaction	26	0.0041	148	resilience	5	0.0008
59	response	26	0.0041	149	precaution	5	0.0008
60	education	25	0.0039	150	lack	5	0.0008
61	transformational	25	0.0039	151	guidelines	5	0.0008
62	OHS	24	0.0038	152	factory	5	0.0008
63	manufacturing	23	0.0036	153	emotional	5	0.0008
64	environment	23	0.0036	154	capital	5	0.0008
65	field	22	0.0034	155	burnout	5	0.0008
66	industrial	21	0.0033	156	age	5	0.0008
67	awareness	21	0.0033	157	transactional	4	0.0006
68	activities	21	0.0033	158	supportive	4	0.0006
69	negative	21	0.0033	159	regulations	4	0.0006
70	communication	20	0.0031	160	preparation	4	0.0006
71	empirical	19	0.0030	161	pain	4	0.0006
72	dimensions	19	0.0030	162	knowledge	4	0.0006
73	BBS	19	0.0030	163	ill	4	0.0006
74	learning	19	0.0030	164	events	4	0.0006
75	workplace	19	0.0030	165	consciousness	4	0.0006
76	regression	18	0.0028	166	well-being	3	0.0005
77	implications	18	0.0028	167	SEM	3	0.0005

Table 4. *Cont.*

No.	Word	Weight	Centrality	No.	Word	Weight	Centrality
78	trust	17	0.0027	168	self-management	3	0.0005
79	supervisory	17	0.0027	169	relevance	3	0.0005
80	co-workers	17	0.0027	170	regulation	3	0.0005
81	mediates	16	0.0025	171	persistent	3	0.0005
82	interaction	16	0.0025	172	macroergonomics	3	0.0005
83	leading	16	0.0025	173	leader-member	3	0.0005
84	person	14	0.0022	174	government	3	0.0005
85	social	13	0.0020	175	engineering	3	0.0005
86	psychosocial	13	0.0020	176	empowering	3	0.0005



(**a**) (**b**)

Figure 3. Analysis of main text frequency in studies since 2005: (**a**) data with full text representation; (**b**) text data except safety.

3.2. Keyword Network Analysis

Overall, the 'safety–climate' link showed the strongest connection. In addition, links between texts at the organizational level, such as safety, culture, organizational, and management, were strong. In studies before 2005, we confirmed that the network consisted of 90 nodes and 141 edges. Most of the industry was construction, but research was also conducted on wood-processing and power-plant fields. For organizational safety performance, the accident rate and individual safe behavior were studied. The main links were 'safety–performance–goal-setting' and 'safety–goal-setting'.

At the individual psychological level, we confirmed that behavior and safety had the strongest connection. Because individual safe behavior was classified as an organizational safety outcome, we mainly studied behavior and safety awareness as subfactors at the organizational level. Links were identified in words such as 'a-type' and safety, human, and factors. Here, 'a-type' is classified as a disaster-causing type among individual personality types, one that mainly shows unsafe behavior [27,63]. In order to reduce the accident rate, a study on the personality or characteristics of individuals was conducted.

A study by Griffin and Neal (2000) [37] suggested that the safety climate influences individual safety behavior. They reported that individual safe behavior was recognized

as an organizational safety achievement, and motivation and knowledge to induce safe behavior of members could be obtained by means of education. From this time on, the importance of safety education was emphasized, but safety education was developed based on training in the work process, not research in the sense of theoretical education or academics.

Neal et al. [9] and Griffin and Neal [37] conducted studies on the level of individual psychology, such as safety compliance, behavior, and motivation, but these were studies of the individual as a subfactor at the level of organizational structure. The values of safety, managers' attitudes, and members' views on safety-related policies correspond to the safety climate, but self-reports on individual beliefs and behaviors do not correspond to the safety climate. In relation to safety, only personal perceptions in the field were classified as a safety climate.

The workplace was linked to a safety guard or events of thought or accident. Studies before 2005 regarded safety in the workplace as meaning lowering accident rates rather than preventing human injury [40,70,71]. A safety guard is a safety device that includes a system, equipment, and equipment and decreases the risk of accidents in case of a malfunction. In order to increase safety in the workplace, a study on the performance improvement by safety guards was conducted. Figure 4 shows the network analysis visualization data for studies prior to 2005.

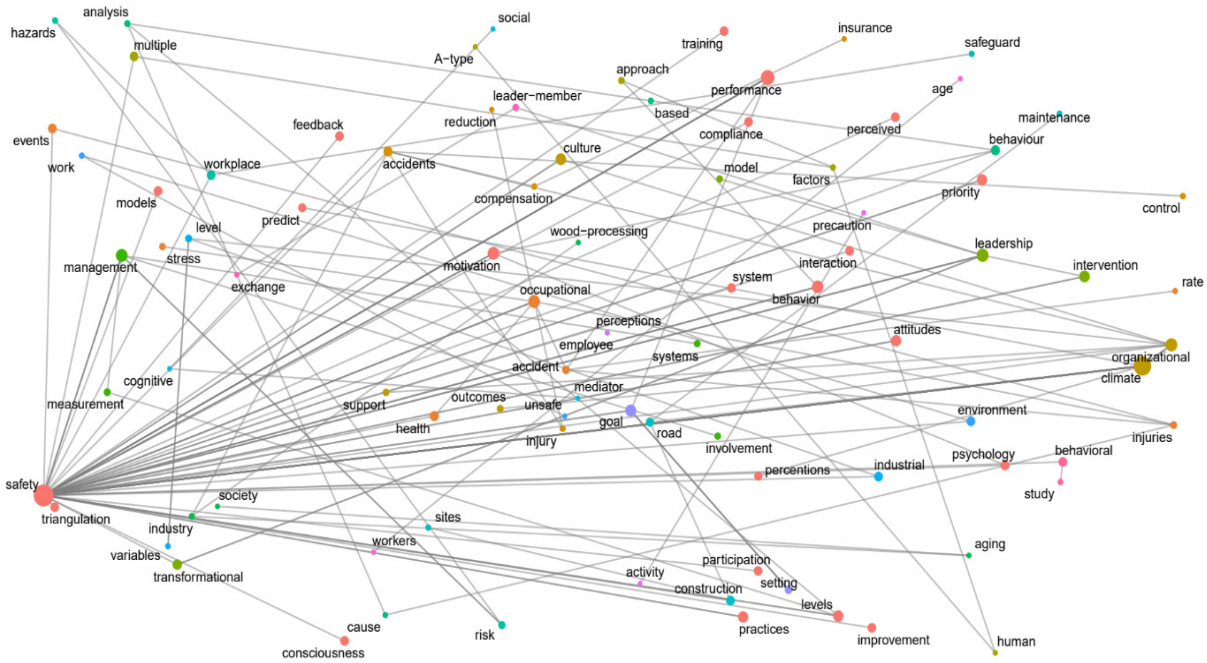


Figure 4. Visualization of keyword network analysis results for studies prior to 2005.

The network of studies since 2005 consisted of 227 nodes and 462 edges. We confirmed that a link had the strongest safety–climate relationship. Overall, in the field where safety is studied, the links at the organizational level were just as important for safety as were climate, culture, leadership, and management. At the individual level, research on behavior-based safety programs was being actively conducted. At the individual level, keywords such as behavior, commitment, and participation can be viewed as components of engagement, which includes active and voluntary participation.

In networks in research after 2005, the concept of behavior-based safety (BBS) was introduced. Among the factors at the individual level, it was announced that behavior-based safety programs affect organizational safety performance and can have positive or negative effects. In addition, we found the safety–education link to be the main link, and training, practice, workshops, etc., were identified as related nodes [64–68]. HR (human

resources), practice, and behavior were also linked, and safety education was being studied as a field of vocational education or lifelong education. As a field of lifelong education or HR development, experiential learning, workplace learning, and social exchange theory have been widely used as the basic theories of safety education-related research [13–16,39]. It was intended to prevent risks in advance by sharing risks and accident experiences at industrial sites.

Recently, research has shown that the leadership of on-site safety managers who directly interact with and communicate with workers in the field directly affects the safe behavior and attitudes of workers. The importance of the role and leadership of on-site safety managers was emphasized [4,12,59,64–68]. In terms of type of leadership, transactional and transformational leadership were studied the most, but research was conducted targeting various types, such as coaching, empowering, and safety leadership. Figure 5 presents a visualization of the network analysis results for studies after 2005.

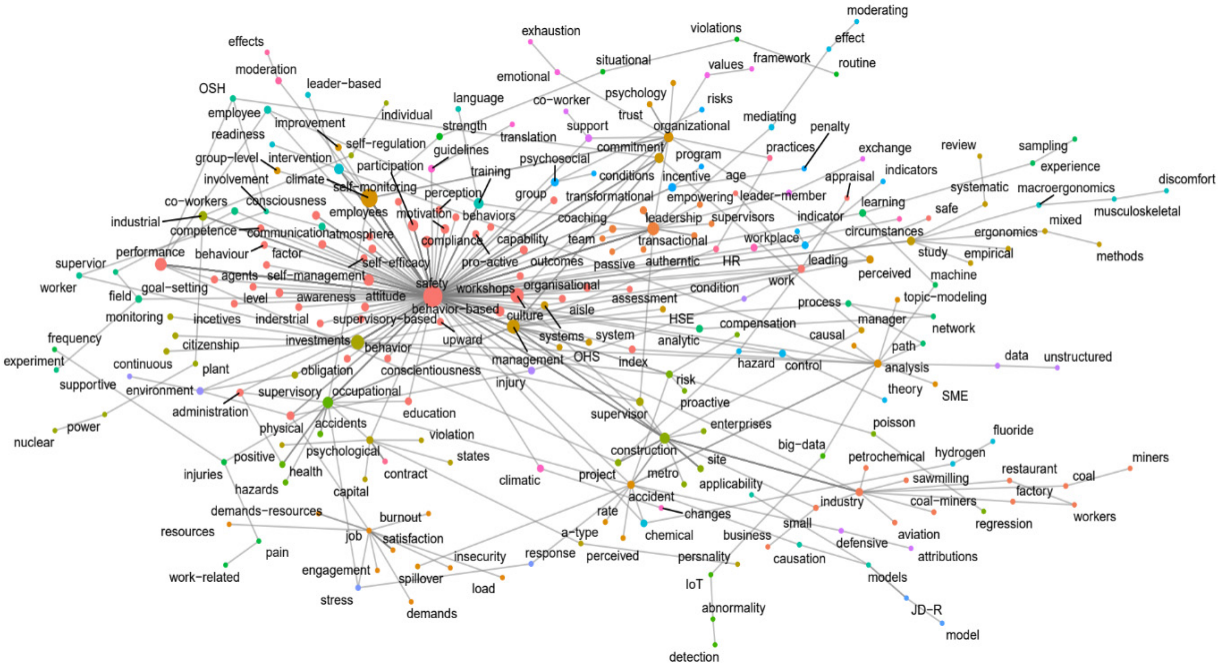


Figure 5. Visualization of keyword network analysis results for studies since 2005.

4. Discussion

4.1. Text Frequency Analysis

According to the results of text frequency analysis, the number of major keywords increased from 82 to 180. The major factors constituting safety engagement were organizational factors, such as climate, culture, management, and management. Most of the research on safety engagement is on organizational management, but from 2005 onwards, it was confirmed that the proportion of research at the individual level gradually increased. In particular, it was confirmed that research on safety management based on behavior-based safety has increased among the individual-level dimensions. Human behavior is based on attitude. Attitudes can interact with a person's cognition, emotions, and behaviors and form engagement.

Seo et al. (2021) [34] presented cognition, emotion, behavior, and relationship as a framework of categories for forming safety engagement. In this study, it was argued that relationships, along with cognition, emotion, and behavior, at the individual psychological level based on attitude are important topics to form a research model for safety engagement in the workplace. Therefore, it was determined that the relationship between the members, the relationship between the organization and the member, and the relationship with the

external environment are complexly constituted in the formation of engagement in the occupational safety field.

Wu et al. [69] and Li et al. [72] classified safety education provided to employees by organizations as job resources. These studies presented the effectiveness of safety education as a resource to perform duties. Seo et al. [34] suggested that providing safety education can improve employees' organizational commitment. Li et al. [72] suggested that an organizational climate leading to unsafe behavior intended to reduce worktime stress acts as greater stress to the individual than does the stress caused by work intensity. Individual members do not want to engage in unsafe behavior because they desire to be safe while working.

Methods such as device or facility performance analysis, psychological measurement tool development, the Delphi technique, and in-depth interviews have been mainly used as research methods for safety engagement of organizational members. In a recent study, data mining (topic modeling, big data analysis, etc.), a method of finding meaning by analyzing data, was additionally used [21,23,42,51]. Research is being used to construct a model that verifies risks and prepares safety performance improvement plans by composing datasets with accident cases and actual risks. This research method can provide preventive safety measures and is effective in reducing risks in the workplace.

The words with increased frequency included leadership, management, role, supervisor, and manager. In studies after 2005, the role of managers was emphasized, and in particular, it was suggested that the interaction between workers and site managers or safety managers can induce workers to take safety actions in the workplace [4,5,12]. In the field of leadership, prior to 2005, leadership theory based on leader–member exchange theory was studied. However, since 2005, a manager's engagement has been directly related to worker engagement, and various leadership studies, such as transformational, coaching, empowering, and transactional leadership, have been conducted. In addition, a study was conducted to conceptualize safety leadership and to examine the relationship between safety leadership and workplace safety. Peterson was the first to explain the concept of safety leadership and the role of a leader. According to his research, safety leadership is more important than any policy at the level of organizational management, and the safety manager plays a role in conveying to the management what regulations or management measures are appropriate for the field by means of their actions or decisions [12,70]. Safety leadership developed based on transactional leadership and transformational leadership, but as the leader's roles gradually diversified, such as by communication, commitment, coaching, and trust, the underlying theory of safety leadership also diversified.

Among the studies on workers or employees, attitudes and behaviors were the focus; these were mainly conducted to analyze correlations with various factors, such as individual psychological factors, interactions with organizations, organizational trust, and leadership. The scope of safety has been expanded from physical to psychological, emotional, and psychosocial factors, and the scope of research comprises not only on accidents caused by on-site equipment and facilities but also personal psychological dimensions, such as safety psychology, mental damage, relationships between workers, and relationships between workers and organizations. Interdisciplinary studies with safety engineering and disaster management were also conducted in the fields of safety psychology, industrial psychology, and ergonomics.

There was also a change in safety education in the workplace. The purpose of workplace safety education is to improve or form individual attitudes, behaviors, and conformity [13–16,35]. In the past, training was practice-oriented, but theoretical education was also carried out, and theoretical research on safety became active. Safety education in the field of occupational safety is provided either directly by the HR department of a company or by entrusting a local lifelong education institution. Education programs were developed based on the experience of the site manager or safety manager. Safety education plays an important role for individuals to immerse themselves in safety in the workplace.

4.2. Keyword Network Analysis

The meaning of safety in the workplace has changed from safety and achievement, such as safety related to machinery or equipment, reduction in accident rate, cost reduction, and reduction in industrial-accident handling costs, to providing a safe workplace environment for employees. Factors constituting workplace safety include individual factors, such as employees' safety commitment, safety engagement, compliance, behavior, and attitude, and organizational factors, such as the role of management or managers, leadership, organizational trust, safety performance, safety climate, and safety culture [32,33,36,37]. These factors formed a link with each other, and the organizational factor that formed the strongest link with individual factors was leadership. The importance of leadership and the role of management or managers was emphasized to form members' safety commitment, compliance, behavior, and attitude.

As individual factors became more important, the number of studies related to education increased. In relation to safety, the concept of "safety" has also been studied from the viewpoint of behaviorism in relation to competency development, practice, and vocational education. Compared with the studies before 2005, in the studies after 2005, more were related to the individual dimension, and studies were conducted that recognized the individual as being independent [4,5,14–19,24–26]. Individual safe behavior, compliance, and participation are factors of organizational performance, and safety is classified as one way to improve organizational performance. Because accident rates result in costs, such as payment of industrial accident insurance premiums, safety management was practiced in order to reduce costs. Therefore, research on the psychological factors of individuals is limited to the personality or characteristics of the individual and whether or not they have characteristics that cause accidents. However, studies after 2005 have been conducted on the psychological stability provided by safety, interpersonal relationships, burnout, and unsafe behavior caused by psychological stress [38,50,72,73].

The importance of meaning, happiness, engagement, and commitment of an individual at work was emphasized. The importance of organizational support was also emphasized, and trust, relationship formation, and provision of safety education were classified as job resources. In order for organizational members to engage themselves in safety at work, both the psychological environment and the physical environment are important. Because the importance of factors at the individual psychological level has been emphasized since 2005, the importance of safety education that can improve and develop safety compliance, motivation, safety behavior, and safety attitude has also been emphasized [14,15,74,75].

5. Conclusions

We derived the main factors constituting safety engagement in the workplace included in people's daily living space and analyzed their characteristics. We found documents to be analyzed by means of a systematic literature review and performed text mining by generating unstructured data. In this study, we used text frequency analysis and keyword network analysis to derive the components of safety engagement in the workplace and explored the relationship between these factors. Idris et al. [76] reported that providing a physically and psychologically safe environment at work increases individual happiness and can also contribute to organizational performance improvement. Bronkhorst [77] also emphasized the importance of the work environment. In this study, we integrated both physical and psychosocial environments and analyzed the relationship with the safe behavior of members. Job autonomy, peer support, and manager support were viewed as job resources, and we also emphasized the importance of leadership in manager support.

Research conducted so far has mainly been in engineering fields, such as safety engineering, disaster prevention, public health, occupational safety, and occupational health, but recently, convergence studies in fields such as lifelong education, vocational education, and workplace learning have been conducted [12,14,77,78]. Safety is being studied as a field of lifelong education or workplace learning, and it has been confirmed that safety education improves safety motivation, compliance, behavior, and attitude of members. Interdisci-

plinary studies are being conducted because realistic education programs and platforms need to be established and operated to increase the effectiveness of safety education. The purpose of safety education research in the field of workplace learning and vocational education is not to provide simple practice or experiential education. The purpose is to understand the characteristics of the learner and provide education appropriate to the situation so that the learner can embrace the knowledge to prepare for and respond to general and dangerous situations in the field. Research is being conducted to prepare an academic framework for sharing theories, experiences, and knowledge when designing educational programs.

We classified safety engagement factors derived from text mining into cognition, emotions, behaviors, and relationships. In the cognitive aspect, safety participation factors can induce safety attitudes and behavioral commitment by acquiring academic and practical knowledge about safety through workplace learning, vocational education, sharing experiences among workers, safety education provided by the organization, interaction and communication between learners, and the ability to share through experiences and accumulate knowledge.

The emotional aspect can be classified into factors such as self-efficacy, goal orientation, sense of duty, safety awareness, and safety motivation. These factors occur at the individual level and can also be categorized as an employee's job resource. Safety compliance is a concept included in safety behavior corresponding to the safety performance of the organization, and it means acting in accordance with safety regulations. Emotional immersion can form members' safety attitudes and safety compliance and ultimately induce members' safety behavior. Workplace safety commitment in terms of behavior comes from the improvement of workers' behavior. In order for members to focus on safety, they must have the ability to avoid or respond to physical and mental hazards.

In the relational aspect, various relationships, such as worker–worker, worker–site manager, manager–site manager, and manager–management were confirmed. In order to achieve organizational safety and achievement, an antagonistic relationship was formed between workers and managers, which negatively affected workers' unsafe behavior due to stress in the work environment [18,31,73,75]. The leadership of managers and management can induce workers' voluntary and active safe behavior and can contribute to the formation of an organizational atmosphere and culture.

Through this study, we drew several implications. First, the meaning of the workplace is that it acts on people as a living space rather than a place to work. As it has been found that not only organizational factors, but also individual factors, play an important role in immersion in the workplace, there is a need to conduct specific research on the psychological level of safety. However, despite the growing importance of such study, the number of studies was small in quantity. In order to grow quantitative and qualitative research related to workplace safety engagement, more specific research should be conducted. Second, safety-related studies in the workplace mainly dealt with the risks faced by blue-collar workers, such as those at construction and manufacturing sites. However, in recent research, not only physical factors, but also psychological factors, personal feelings of happiness, etc., are considered, and multidimensional factors are being considered as important. Therefore, additional consideration of the study subjects is necessary. Elaboration of models for workplace safety engagement studies must be intuitively easy to understand. In this study, by establishing a framework for developing a research model of workplace safety engagement and deriving major subelements, we intended to suggest a direction to increase engagement formation at the organizational level and at the individual level.

Nevertheless, this study has several limitations. First, academic research on workplace safety engagement has been actively conducted since the 2000s, so the amount of research literature was not large overall. Because the literature included when constructing text data was limited to academic papers, it will be somewhat difficult to generalize to an entire workplace safety engagement research trend. In addition, although it was attempted to secure the objectivity of the research through text mining, it is difficult to say that the

subjectivity of the individual researcher is completely excluded. In a follow-up study, we intend to conduct an in-depth analysis of the influence and relationship of key concepts constituting workplace safety engagement. It is expected that the discussion will be expanded through additional analysis, such as path analysis and social network analysis, to increase the objectivity of effectiveness, causality, and measurement tools.

This study is not simply a study of what constitutes safety commitment. This study was performed to establish basic data for the development of a research model for safety engagement in the workplace. The safety engagement research trend was analyzed, the main components were derived to establish a framework of the research model, the components were derived, and an interrelationship analysis was performed. The current work is different from previous studies in that it analyzed various cognitive, emotional, behavioral, and relational factors by analyzing the factors of workplace safety engagement. In particular, the existing level of participation in safety on the level of individual commitment to cognitive, emotional, and behavioral factors was investigated, the influence relationship was analyzed, and this study also examined the relationship between workers, managers, and managers.

We will comprehensively diagnose the maturity level of safety participation in the workplace and suggest future-oriented directions for safety engagement in the workplace. We also intend to proceed with a follow-up study based on the results derived from this study to develop a workplace safety engagement research model, establishing a framework for cognition, emotion, behavior, and relationships. In the follow-up study, research will be conducted to develop a big-data-based research model through topic modeling and network analysis.

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