

Shaping Worker Safety Behavior: Role Of Safety Culture Perception In Structural Equation Model

Xiaopeng Wang^a, Yongli He^b, Yuyang Xie^a, Fengdong Bi^b, Jidong Wang^c

^a*CNPC Research Institute of Safety and Environmental Protection Technology, Beijing, China*

^b*KunLun Energy Company Limited, Beijing, China*

^c*CNPC Dagang Petrochemical Company, Tianjin, China*

Abstract

To explore the promoting effect of safety culture perception on worker's safety behavior, with safety awareness and motivation and safety knowledge as mediating variables, and safety climate in shifts/departments as a moderating variable, a study was conducted using a sample of 908 valid responses collected from a Chinese energy company. Structural equation modeling was employed to examine the relationships. The research findings indicate that safety culture perception directly promotes worker's safety behavior. Furthermore, safety awareness and motivation and safety knowledge mediate the relationship between safety culture perception and worker's safety behavior. This suggests that safety culture perception indirectly influences worker's safety behavior by enhancing their safety awareness, motivation, and knowledge. Additionally, the study reveals that safety climate in shifts/departments positively moderates the effects of safety culture perception, safety awareness and motivation, and safety knowledge on worker's safety behavior. This means that when safety climate in shifts/departments is improved, it strengthens the positive impact of safety culture perception, safety awareness and motivation, and safety knowledge on worker's safety behavior. The findings of this study provide valuable insights and references for energy companies and other high-risk industries to promote worker's safety behavior.

Keywords: safety culture perception, safety behavior, structural equation modeling (SEM), path analysis

1. Introduction

Production safety directly affects the life safety of employees, the sustainable management of enterprises and the overall stability of society. The occurrence of accidents is highly correlated with workers' unsafe behaviors (Hofmann et al., 1996). This includes ignoring safety procedures, using equipment incorrectly, ignoring hazard signs, and underestimating risks. Although equipment failure and technical problems can also cause accidents, the behavior of workers largely determines whether the operation of a company is safe or not (Yin et al., 2017). Enterprise safety culture is one of the key factors affecting employees' safety behavior, shaping employees' perception and attitude towards safety, and providing guidance for employees' safety behavior. Culture positively affects safety performance, especially safety system culture, which is more significant in high-risk industries or developed countries. Therefore, it is very important to study how to improve employees' safety behavior through the influence of corporate culture on employees' cognition.

At present, the research on safety culture and safety behavior focuses on the construction of cultural system, the concept of safety management and the countermeasures of unsafe behavior. In recent years, some scholars have also discussed the relationship between enterprise safety culture and safety behavior. Martínez-Córcoles et al. (2011) established a structural equation model of leadership behavior, safety culture and nuclear power plant staffs' safety behavior for their research on leadership behavior and nuclear power plant staffs' safety behavior. The results show that leadership behavior not only directly affects safety culture, but also indirectly affects safety behavior through safety culture. The study conducted by Al-Bayati et al. (2021) found that construction safety

culture has a significant impact on safety behavior and safety motivation through the behavior of upper management and safety personnel, while the impact of building construction safety atmosphere is less. The above research indicates that enterprise safety culture has a positive impact on employees' safety behavior. However, the promoting mechanism between employees' perception of enterprise safety culture and their safety behavior in actual production is still unclear. Safety culture perception is the subjective attitude and intuitive judgment of employees to the construction of safety culture and safety system. The perception of safety culture is not only restricted by individual physiological state, safety cognition and other factors, but also affected by irrational factors such as emotion and intuition (Sung et al., 2022). The influence of safety culture perception on safety behavior in different situations is complex and changeable, and the influence relationship and influence mechanism are unclear. Therefore, it is necessary to deeply explore the influence and mechanism of safety culture perception behind the safety behavior of employees in high-risk industries, so as to effectively promote the safety behavior of workers and provide theoretical basis for enterprise risk management.

In summary, this paper verifies the promotion effect of perceived safety culture on safety behavior, and attempts to explore the mediating and moderating role of employee safety awareness, safety common sense, department or team safety atmosphere in this path, so as to establish the promotion mechanism between perceived safety culture and actual safety behavior of employees in enterprises. It provides a theoretical basis for the construction of enterprise safety culture and the improvement of workers' safety behavior in high-risk industries.

2. Objectives and hypotheses

2.1. Safety culture perception and safety behavior

Enterprise safety culture has been proved to have a positive impact on enterprise safety performance (Arzahan, 2022), that is, the promotion of safety culture can reduce workers' unsafe behaviors. Employees' perception of corporate safety culture may affect corporate safety performance through a series of potential paths. Employees perceive that an organization's safety culture conveys a concern for safety, which may motivate employees to be more alert and concerned about their own safety (Kalteh, 2022). At the same time, this perception may also increase the safety motivation of employees, making them more willing to adopt safe behaviors, comply with regulations, and actively participate in safety activities. Safety culture perception may also contribute to improving employees' safety knowledge (Yorio, 2019). Employees' perception of an enterprise's safety culture may stimulate their attention to safety training and information, thus improving safety knowledge and common sense, which makes employees more capable of adopting correct safety behaviors and reducing potential safety risks.

In addition, many scholars (Tong et al., 2022; Kalteh et al., 2022) have mentioned in their studies that the safety atmosphere of the smallest organizational structure such as team or department plays a mediating role in enterprise safety management (safety system, safety culture, safety concept, etc.), safety behavior, and employees' participation in enterprise safety construction. The safety atmosphere within the team, including the safety atmosphere of supervisors and colleagues, can mitigate or reverse the adverse impact of risk perception on safety behavior in some cases. Meanwhile, safety environment and safety leadership have a negative moderating effect on the path from unsafe behavior intention to unsafe behavior. Team safety atmosphere also has a positive regulating effect on the safety behavior of the new generation of construction workers, especially in the aspects of work-family balance, perceived work significance and the influence of organizational identity on their behavior. In the following chapters, this paper will continue to discuss whether the mediating effect of safety atmosphere also exists between the perceived degree of safety culture and the promotion path of safety behavior.

2.2. Hypothesis

According to the logical relationship between safety culture perception and safety behavior discussed in the previous section, the following assumptions as shown in Figure 1 have been made:

Hypothesis 1: Safety Culture Perception has a significant positive impact on safety behavior.

Hypothesis 2: Safety Knowledge serves as a chain-mediator in the influence of safety culture perception on safety behavior.

Hypothesis 3: Safety awareness and motivation serve as a chain-mediator in the influence of safety culture perception on safety behavior.

Hypothesis 4: Safety Climate in Shifts/Departments positively moderates the influence of safety awareness and motivation on safety behavior.

Hypothesis 5: Safety Climate in Shifts/Departments positively moderates the influence of safety knowledge on safety behavior.

Hypothesis 6: Safety Climate in Shifts/Departments positively moderates the influence of safety culture perception on safety behavior.

Hypothesis 7: Safety awareness and motivation and Safety Knowledge play multiple mediating roles in the influence of safety culture perception on safety behavior.

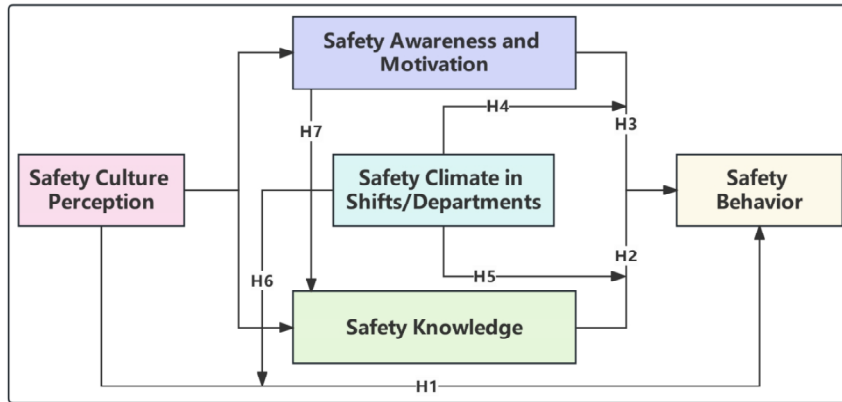


Fig. 1. The hypothesis of the influence path of safety culture perception on safety behavior

3. Methodology

3.1. Research sample

In this study, a stratified random sampling method was adopted to distribute questionnaires online to the employees of 40 tertiary subsidiaries under 26 secondary subsidiaries of a major energy company in China in 28 provincial administrative districts from June to October 2023, and a total of 1,142 questionnaires were collected, with 908 valid questionnaires, representing a validity rate of 79.51%.

The statistics for the valid samples are as follows:

Table 1. Research sample part basic information.

Education background	Graduate degree	2.75%
	Bachelor's degree	45.93%
	Associate degree	30.95%
	High school/vocational school diploma	18.61%
	Junior high school education or below	1.76%
Job position	Operational staff	57.82%
	Professional and technical management personnel	31.06%
	Middle management personnel	8.70%
	Company leadership	2.42%
Job category	production process position	52.75%
	human resources/general/accounting position	19.05%
	equipment (including electrical and instrumentation) position	13.55%
	HSE (Health, Safety, and Environment) position	14.65%
Year of service	Under 1 year	9.69%
	2-3 years	20.93%
	4-5 years	15.97%
	6-10 years	19.93%
	Over 10 years	33.48%

In terms of age, the proportions of individuals in the age groups 26-30, 31-35, 41-45, and 51-55 are 11.89%, 25.77%, 13.44%, and 9.25% respectively. The age groups of 22-25 and 36-40 account for 4.63% and 11.04% respectively. The proportion of individuals under 21 and over 55 is relatively low.

Regarding educational background, individuals with a bachelor's degree make up 45.93% of the total, while those with an associate degree account for 30.95%. There are 169 individuals with a high school/vocational school diploma, constituting 18.61% of the total. Those with a junior high school education or below make up 1.76% of the total, while individuals with a graduate degree or above account for 2.75%.

In terms of job positions, the proportion of operational staff is the highest at 57.82%, followed by professional and technical management personnel at 31.06%. The proportion of leadership and middle management personnel is relatively low, at 2.42% and 8.7% respectively. Concerning specific job categories, production process positions account for 52.75%, followed by human resources/general/accounting positions at 19.05%. The number of individuals in equipment (including electrical and instrumentation) positions and HSE positions is relatively small, constituting 13.55% and 14.65% respectively.

In terms of years of service in their positions, employees with over 10 years of experience have the highest proportion at 33.48%. This is followed by employees with 2-3 years and 6-10 years of experience, accounting for 20.93% and 19.93% respectively. The proportion of employees with 1 year or less and 4-5 years of experience is relatively low, at 9.69% and 15.97% respectively.

3.2. Research tool

The questionnaire used in this study was divided into five dimensions, all in the form of a mature Likert 5-point scale, including Safety culture perception, safety awareness and motivation, Safety climate in shifts/departments, safety knowledge and safety behaviour. Safety awareness and motivation were selected from the scale designed by Neal and Griffin (2006). Safety climate in shifts/departments was selected from the scale of Brondino et al. (2006). Safety construction participation and safety behaviour were selected from the scale of Guo et al. (2016). Safety culture perception was selected from Gill and Shergill's (2004) survey on safety culture perception in the civil aviation industry, in which the civil aviation industry-related content was revised to make it suitable for the energy industry. The Cronbach's alpha coefficients of each part and the questionnaire as a whole are shown in the table 2, with a high degree of data consistency.

Table 2. Reliability test for each dimension.

Dimension	Cronbach's α
Safety Culture Perception	0.907
Safety awareness and motivation	0.948
Safety Climate in Shifts/Departments	0.892
Safety Knowledge	0.876
Safety Behavior	0.835

In this study, we aimed to investigate the influence of safety culture perception on worker's safety behavior, considering safety awareness and motivation, as well as safety knowledge, as mediating variables. Additionally, we examined the moderating role of safety climate in shifts/departments. To analyze the relationships among these variables, we employed Structural Equation Modeling (SEM), a method used to establish, estimate, and test causal relationship models. SEM allows for the inclusion of both observable manifest variables and unobservable latent variables.

4. Hypothesis verification and result analysis

4.1. Common method bias, validated factor analysis and discriminant validity tests

Based on the structural equation model and the latent error variable control method, the common method bias was tested. By introducing the common method bias as a latent variable into the model, if the model's fit is significantly better with the inclusion of the method bias latent variable compared to without it, then the common method bias effect has been tested. The results indicate that in the 5-factor model, the chi-squared value (χ^2) is 1362.585, with degrees of freedom (df) = 851. The ratio of chi-squared to degrees of freedom (χ^2/df) is 1.601. The comparative fit index (CFI) is 0.958, the Tucker-Lewis index (TLI) is 0.926, and the root mean square error

of approximation (RMSEA) is 0.034. This suggests that the original data in this study does not exhibit a serious issue of common method bias.

The results of the confirmatory factor analysis (CFA) indicate that the factor loadings of the items related to safety culture perception, safety knowledge, safety awareness and motivation, safety behavior, and shift/department safety climate range from a minimum of 0.651 to a maximum of 0.948. The composite reliabilities (CR) for all five dimensions are above 0.600, and the average variance extracted values (AVE) all exceed 0.500. The results of these studies, shown in table 3, indicate that the quality of confirmatory factor models is reliable.

Table 3. Partial Fit Indicator Test Results

Fit Indicators	χ^2/df	CFI	TLI	RMSEA
Reference Range	<3.000	>0.90	≥ 0.9	<0.08
Actual Values	1.601	0.958	0.926	0.034

Correlation and discriminant validity tests was completed as shown in table 4, the assumed paths between the dimensions demonstrate positive correlations, thus providing preliminary evidence for the hypotheses. Additionally, the results of the inter-variable correlation analysis indicate that all five variables exhibit good discriminant validity.

Table 4. Reliability test for each dimension.

Dimension	Safety Culture Perception	Safety awareness and motivation	Safety Climate in Shifts/Departments	Safety Knowledge	Safety Behavior
Safety Culture Perception	0.816	—	—	—	—
Safety awareness and motivation	0.579**	0.717	—	—	—
Safety Climate in Shifts/Departments	0.527**	0.561**	0.838	—	—
Safety Knowledge	0.667**	0.614**	0.578**	0.765	—
Safety Behavior	0.572***	0.479**	0.706**	0.537**	0.855

Note: * indicates significance level $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$, the same below; the square root of the average variance extracted is shown on the diagonal.

4.2. Structural equation modelling (SEM) analysis (mediating and moderating effect)

Hypotheses 1, 2, 3, and 7 which involves mediating effects were confirmed using the bootstrap method, and the corresponding results are presented in Table 5 below.

Table 5. Reliability test for each dimension.

Effects pathway	Effect type	Standardised path coefficient	95% confidence intervals	Significance level (p-value)
S.C.P→S.B.	Direct effect	0.305	[0.043,0.477]	**
S.C.P→S.A.M.→S.B.	Indirect effect	0.243	[-0.061,0.384]	**
S.C.P→S.K.→S.B.	Indirect effect	0.317	[0.136,0.368]	**
S.C.P→S.A.M.→S.K.→S.B.	Indirect effect	0.170	[-0.078,0.314]	—
S.C.P→S.B.	Total effect	0.588	[0.346,0.708]	**

Note: S.C.P. stands for safety culture perception, S.A.M. stands for safety awareness and motivation, S.K. stands for safety knowledge, S.B. stands for safety behavior, S.C. stands for safety climate in shifts/departments, the same below.

S.C.P → S.B. (Direct Effect): Standardised Path Coefficient of 0.305, 95% Confidence Interval [0.043, 0.477], Significance level is ‘***’. This means that Safety Culture Perception has a significant positive effect on Safety Behaviour. Hypothesis 1 is valid.

S.C.P → S.A.M. → S.B. (Indirect Effect): Standardised Path Coefficient is 0.243, 95% Confidence Interval is [-0.061, 0.384], Significance level is ‘***’. This indicates that the effect of Safety Culture Perception on Safety Behaviour, mediated through Safety Awareness and Motivation (S.C.P.), is not significant. Hypothesis 3 is valid

S.C.P. → S.K. → S.B. (Indirect Effect): standardised path coefficient of 0.317, 95% confidence interval of [0.136, 0.368], Significance level is ‘***’. This indicates a significant positive effect of Safety Culture Perception on Safety Behaviour mediated through Safety Knowledge. Hypothesis 2 is valid

S.C.P. → S.A.M. → S.K. → S.B. (Indirect Effect): The standardized path coefficient is 0.170 with a p-value greater than 0.05, indicating that there is an insignificant effect mediated through the chain of Safety Awareness and Motivation and Safety Knowledge. Therefore, Hypothesis 7 is not supported.

Taken together, the standardised path coefficient for the Total effect is 0.588 with a 95% confidence interval of [0.346, 0.708] and a Significance level of ‘***’. This indicates that the overall effect of Safety Culture Perception on Safety Behaviour is significantly positive.

To mitigate the influence of multicollinearity, the study employed a process of variable centering for the independent, dependent, and moderating variables. Table 6 presents the examination results of the moderating effects of safety climate in shifts/departments. Model 1 represents the regression analysis results after incorporating Age, Job Positions, Education, and Work Experience as inputs. Model 2 and Model 3 depict the regression analysis results after introducing safety culture perception and its interaction effect with safety climate in shifts/departments. Similarly, Model 4 and Model 5 illustrate the regression analysis results after considering safety awareness and motivation along with its interaction effect with safety climate in shifts/departments. Lastly, Model 6 and Model 7 exhibit the regression analysis results after incorporating safety knowledge and its interaction effect with safety climate in shifts/departments.

In Model 3, the interaction effect between safety culture perception and safety climate in shifts/departments positively influences safety behavior, with a significant B-value of 0.160. This supports Hypothesis 6, indicating that as safety climate in shifts/departments improves, the positive influence of safety culture perception on safety behavior becomes stronger. Therefore, safety climate in shifts/departments positively moderates the impact of safety culture perception on safety behavior.

Likewise, in Model 5, the interaction effect between safety awareness and motivation and safety climate in shifts/departments positively influences safety behavior, with a significant B value of 0.106. This supports Hypothesis 4, suggesting that safety climate in shifts/departments enhances the positive influence of safety awareness and motivation on safety behavior. In other words, safety climate in shifts/departments positively moderates the impact of safety awareness and motivation on safety behavior.

Similarly, in Model 7, the interaction effect between safety knowledge and safety climate in shifts/departments positively influences safety behavior, with a significant B-value of 0.098. This supports Hypothesis 5, indicating that safety climate in shifts/departments strengthens the positive influence of safety knowledge on safety behavior. Therefore, safety climate in shifts/departments positively moderates the impact of organizational identification on safety behavior.

Table 6. Reliability test for each dimension.

Variables	Model						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Age	0.020	0.015	0.038	0.034	0.045	0.012	0.026
Job Positions	0.025	-0.038	-0.022	0.011	0.024	0.063	0.071
Education	-0.009	0.019	0.017	0.006	0.003	0.010	0.008
Work Experience	0.088	0.034	0.042	0.024	0.030	0.051	0.056
S.C.P.	—	0.266 ***	0.219 ***	—	—	—	—
S.A.M.	—	—	—	0.322 ***	0.324 ***	—	—
S.K.	—	—	—	—	—	0.525 ***	0.460 **
S.C.	—	0.523 ***	0.606 **	0.545 ***	0.529 **	0.393***	0.413 **
S.C.P. × S.C.	—	—	0.160**	—	—	—	—
S.A.M. × S.C.	—	—	—	—	0.106**	—	—
S.K. × S.C.	—	—	—	—	—	—	0.098*
Regression Model Significance (F)	1.434	70.265	72.433	76.680	67.712	94.772	81.365

Note: The above are all Beta values.

5. Discussion

The findings of this study provide valuable insights into how organizations can effectively apply safety culture perception to reduce workers' unsafe behavior. By enhancing employees' perception of safety culture, organizations can effectively promote safer work practices and reduce the occurrence of unsafe behavior. Moreover, the results emphasize the importance of not only improving employees' understanding and awareness of safety culture but also fostering their motivation and willingness to prioritize safety. Organizations can achieve this by implementing comprehensive safety training programs, promoting open communication channels, and encouraging employee involvement in safety initiatives. By enhancing safety awareness and motivation, organizations can further strengthen the positive impact of safety culture perception on workers' safety behavior. Additionally, a positive safety climate refers to shared perceptions, attitudes, and behaviors related to safety within a specific unit or department. The research findings suggest that when the safety climate within shifts or departments is supportive and promotes a strong safety culture, it can amplify the effects of safety culture perception, safety awareness and motivation, and safety knowledge on workers' safety behavior. To create a positive safety climate, organizations should encourage teamwork, promote safety as a shared responsibility, and recognize and reward safe behavior. By fostering a positive safety climate, organizations can maximize the impact of safety culture perception on workers' safety behavior.

In conclusion, this study provides practical implications for organizations aiming to reduce workers' unsafe behavior. By focusing on safety culture perception, organizations can enhance workers' perception of safety, which directly promotes safety behavior. Furthermore, organizations should prioritize safety awareness and motivation, as well as safety knowledge, as mediating factors in this relationship. By implementing training programs, promoting open communication, and fostering employee involvement, organizations can enhance safety awareness and motivation. Lastly, organizations should strive to create a positive safety climate within shifts or departments to maximize the impact of safety culture perception, safety awareness and motivation, and safety knowledge on workers' safety behavior. By implementing these strategies, organizations can effectively reduce workers' unsafe behavior and create a safer work environment. Further research can explore the specific interventions and strategies that organizations can adopt to enhance safety culture perception and promote safety behavior among workers.

6. Conclusion

Two key factors, namely safety awareness and motivation, and safety knowledge, have been identified as partial mediators in the relationship between perceived safety culture and safety behavior. Safety awareness and motivation refer to individuals' understanding of the importance of safety and their willingness to engage in safe practices. On the other hand, safety knowledge pertains to the level of understanding and familiarity individuals possess regarding safety procedures and protocols.

Furthermore, Both safety awareness and motivation, as well as safety knowledge, play significant roles in mediating the impact of perceived safety culture on safety behavior. However, the mediating effect of safety awareness and motivation is slightly more influential than that of safety knowledge. This suggests that while knowledge is important, the motivation and willingness to prioritize safety are critical factors in driving safety behavior.

Moreover, the findings indicate that safety climate within shifts or departments can act as a moderator, amplifying the impact of safety culture perception, safety awareness and motivation, and safety knowledge on safety behavior. A positive safety climate within shifts or departments refers to the shared perceptions, attitudes, and behaviors related to safety among employees working in the same unit. When the safety climate is supportive and promotes a strong safety culture, it can further enhance the positive effects of safety culture perception, safety awareness and motivation, and safety knowledge on safety behavior.

In conclusion, the perception of safety culture has a significant positive effect on safety behavior within organizations. By improving employees' perception of safety culture, organizations can enhance their safety behavior. Safety awareness and motivation, as well as safety knowledge, play important mediating roles in this relationship, with safety awareness and motivation having a slightly greater influence. Additionally, a positive safety climate within shifts or departments can act as a moderator, strengthening the impact of safety culture perception, safety awareness and motivation, and safety knowledge on safety behavior. These findings highlight the importance of fostering a strong safety culture and promoting safety awareness, motivation, and knowledge to improve safety behavior in organizations.

References

- Al-Bayati, A.J. 2012. Impact of construction safety culture and construction safety climate on safety behavior and safety motivation. *Safety*, 50(9): 1847-1856.
- Arzahan, I.S.N., Ismail, Z., Yasin, S.M. 2022. Safety culture, safety climate, and safety performance in healthcare facilities: a systematic review. *Safety science*, 147: 105624.
- Brondino, M., Silva, S.A., Pasini, M. 2012. Multilevel approach to organizational and group safety climate and safety performance: Co-workers as the missing link. *Safety science*, 50(9): 1847-1856.
- Gill, G.K., Shergill, G.S. 2004. Perceptions of safety management and safety culture in the aviation industry in New Zealand. *Journal of Air Transport Management*, 10(4): 231-237.
- Guo, B.H.W., You, T.W., González, V.A. 2016. Predicting safety behavior in the construction industry: Development and test of an integrative model. *Safety science*, 84: 1-11.
- Hofmann, D.A., Stetzer, A. 1996. A cross-level investigation of factors influencing unsafe behaviors and accidents. *Personnel psychology*, 49(2): 307-339.
- Kalteh, H.O., Salehi, M., Mokarami, H. 2022. The mediator role of safety motivation and knowledge between safety culture and safety performance: The results of a sociotechnical and macroergonomics approach. *Work*, 72(2): 707-717.
- Martínez-Córcoles, M., Gracia, F. 2011. Tomás I, et al. Leadership and employees' perceived safety behaviors in a nuclear power plant: A structural equation model. *Safety science*, 49(8-9): 1118-1129.
- Neal, A., Griffin, M.A. 2006. A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. *Journal of applied psychology*, 91(4): 946.
- Sung, H., Kim, J.U., Lee, D. et al. 2022. Radiation risk perception and its associated factors among residents living near nuclear power plants: A nationwide survey in Korea. *Nuclear Engineering and Technology*, 54(4): 1295-1300.
- Tong, R., Wang, X., Wang, L., et al. 2022. A dual perspective on work stress and its effect on unsafe behaviors: The mediating role of fatigue and the moderating role of safety climate. *Process Safety and Environmental Protection*, 165: 929-940.
- Yin, W., Fu, G., Yang, C., et al. 2017. Fatal gas explosion accidents on Chinese coal mines and the characteristics of unsafe behaviors: 2000-2014. *Safety science*, 92: 173-179.
- Yorio, P.L., Edwards, J., Hoeneveld, D. 2019. Safety culture across cultures. *Safety science*, 120: 402-410.