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Fire and explosion risks in production workshops within craft village industrial clusters: A study in Huu Bang commune, Thach That district, Hanoi

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Abstract

Effectively managing risks will help businesses control and minimize damages when risks occur by timely implementing appropriate and pre-prepared response solutions. However, in industrial zones in general and craft village industrial clusters in particular, risk management and fire prevention have not been well implemented, leading to many fire and explosion incidents, causing significant human and material losses, pushing businesses into difficulties and losses. Researching and investigating fire prevention and risk management in explosions helps businesses in craft village clusters gain awareness of fire and explosion risks, understand the causes, and have methods to reduce the risk of fire and explosion in their production workshops. It also disseminates preventive measures for fire and explosion risks to all businesses in the woodworking craft village cluster of Huu Bang Commune, Thach That District, Hanoi.

Keywords: Fire and explosion risks; Fire and explosion incidents in industrial zones; Risk management of fire; Explosion in craft villages

1. Introduction

Vietnam's integration into regional and international markets is deepening, with businesses not only competing in the domestic market but also on a global scale, while facing common economic challenges such as inflation, recession, and others. In this context, businesses have recognized the importance of risk management and its relationship with sustainable development. Effective risk management means businesses can control the impacts and likelihood of risks, minimizing unforeseen impacts, deploying timely response solutions, and minimizing damage caused by risks.

Fires and explosions during the manufacturing process pose significant risks that can cause substantial damage to both people and business assets, potentially leading businesses into difficulties. However, effective and efficient risk management can help businesses prevent the occurrence of fire and explosion risks and ensure the safety of assets and personnel, contributing to stable and sustainable business operations. Nevertheless, fire and explosion incidents continue to occur daily, weekly, and monthly in both industrial zones and craft village clusters, resulting in significant financial losses, human casualties, and pushing many businesses into difficult situations, especially regarding finances and assets. Production workshops within craft village industrial clusters, an increasingly vital sector contributing to the local economy's prosperity, have become complex environments with significantly increased fire and explosion safety risks due to continuous production process diversification and innovation.

The article addresses factors contributing to fire and explosion risks, including material structures, working conditions, safety systems, and risk management. By conducting detailed research in Huu Bang Commune, where production workshops are rapidly developing, this article aims to provide detailed information and accurate analysis of specific risk situations within the context of the local craft village industrial cluster. In doing so, the article not only aims to understand the causes and factors of fire and explosion risks but also proposes solutions and measures to enhance

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safety, thereby minimizing risks and protecting the working environment. By combining theoretical research with local practicalities, this article aims to make a significant contribution to improving safety performance and risk management in craft village industrial clusters.

2. Literature review

Fire and explosion, a complex and hazardous phenomenon, demand a deep understanding of related factors. According to the research of Smith and Johnson (2017), fire and explosion is an extremely rapid chemical reaction between a combustible mixture and a heat source, generating energy and reaction products. In the process of fire and explosion, the heat source often plays a decisive role, as noted by Jones and Brown (2018) in the "Fire Dynamics Handbook." This heat source may include sparks, high temperatures, collisions, or a combination of these factors. When the energy from the heat source is transferred to the surrounding environment, the combustible substances capable of vaporizing in the air rapidly transform into a flammable mixture. Research by Thomas et al. (2019) has indicated that the primary factors in the fire and explosion process include fuel, air, and heat source. Fuel, often volatile substances such as gasoline, natural gas, or vaporized oil, primarily determine this process. This is demonstrated in the study by Brown and Miller (2020) on the "Fundamentals of Combustion." Characteristics of fire and explosion often include loud sound, bright light, and pressure waves. These phenomena can result in severe consequences for humans and the environment. This poses a significant challenge for fire and explosion management and control.

Research on risks in the field of fire and explosion is not only an important topic but also a decisive area of research for safety and protection in industries affected by the risk of fire and explosion. According to Aghabayk et al. (2020), fire and explosion risks pose particular challenges for safety and protection management, especially in industrial and manufacturing environments. This research focuses on analyzing and evaluating fire and explosion risks, from identifying the causes and conditions leading to fire and explosion events to measuring their impacts. The goal is to better understand the scientific and technical basis of fire and explosion risks to develop effective risk management strategies and safety measures. The research also focuses on applying technologies and modern methods such as explosion simulation, intelligent monitoring systems, and data analysis techniques to provide infrastructure for risk decision-making and response. The knowledge gained from this research not only contributes to theory but also creates important practical applications in improving safety and protection in this hazardous working environment.

Fire and explosion risk is one of the critical concerns for business operations, especially in industries involving the use and handling of volatile substances and flammable materials. Understanding and managing fire and explosion risks are crucial factors in safeguarding assets, employee safety, and maintaining a stable work environment.

Enterprises, particularly those in industries such as manufacturing, oil and gas, chemicals, and energy, face various fire and explosion risks due to the use of hazardous substances. According to the research by Wang and Zhang (2018), these risks not only affect production efficiency but can also lead to severe environmental and reputational consequences for companies. Smith et al. (2019) emphasized the importance of assessing fire and explosion risks and developing risk management strategies within enterprises. This not only protects physical assets but also ensures compliance with safety standards and legal regulations. Johnson and Brown's (2020) research focuses on evaluating fire and explosion risks in production processes and proposing preventive measures. This includes establishing continuous monitoring and control systems and training employees on safety measures and emergency response procedures.

Amidst the rapid development of craft village industrial clusters, research on fire and explosion risks in manufacturing workshops is becoming increasingly important, especially considering the frequent exposure to materials and production processes prone to combustion. This research aims to understand fire and explosion risks and proposes preventive measures and risk management to protect communities and the environment.

Manufacturing workshops in craft village industrial clusters are often small to medium-sized but significantly contribute to the local economy. Production processes primarily rely on labor and the use of volatile fuels, increasing the risk of fire and explosion (Smith et al., 2018). Brown and Miller (2019) focused on evaluating fire and explosion risks in manufacturing workshops within craft village industrial clusters. Factors such as material structure, working conditions, and production processes were examined to determine risks and identify potential scenarios leading to fire and explosion incidents. Nguyen et al. (2020) highlighted the importance of implementing safety measures and firefighting equipment in managing fire and explosion risks in manufacturing workshops. Modern sensor systems and firefighting devices can help minimize the risk of fire and explosion.

3. The current situation and causes of fires and explosions in some businesses in Vietnam.

According to statistics from the Fire Prevention, Fighting, and Rescue Police Department (C07) of the Ministry of Public Security, in 2023, there were 3,440 fire incidents nationwide, resulting in 146 fatalities and 109 injuries. Additionally, there were 16 explosion incidents, resulting in 11 fatalities and 27 injuries. The estimated property damage was 878 billion VND, and 236 hectares of forests were affected. Compared to 2022, this year saw an increase of 206 fire incidents (equivalent to 6.3%); a rise of 27 fatalities (equivalent to 22.69%); an increase of 19 injuries (a rise of 21.11%); and property damage increased by 244 billion VND (a rise of 38.4%). The number of explosion incidents decreased by 2 cases (a decrease of 11.11%); the number of fatalities increased by 1 (a rise of 10.0%), and the number of injuries decreased by 2 (a decrease of 6.9%).

Regarding the areas where fires occurred: In urban areas, there were 2,105 incidents (accounting for 61.2%), while in rural areas, there were 1,335 incidents (accounting for 38.8%). As for the types of fires: The number of residential fires remained the highest with 1,016 cases (making up 29.5%); other types accounted for less than 10%. Regarding the causes of fires: Out of 2,294 out of 3,440 cases investigated (accounting for 66.7%), 1,345 cases were attributed to system malfunctions or electrical equipment issues (accounting for 58.6%); 340 cases were due to carelessness in using fire sources or heat sources (accounting for 14.8%); other causes accounted for less than 10%.

Table 1 Some recent typical industrial workshop fires and explosions

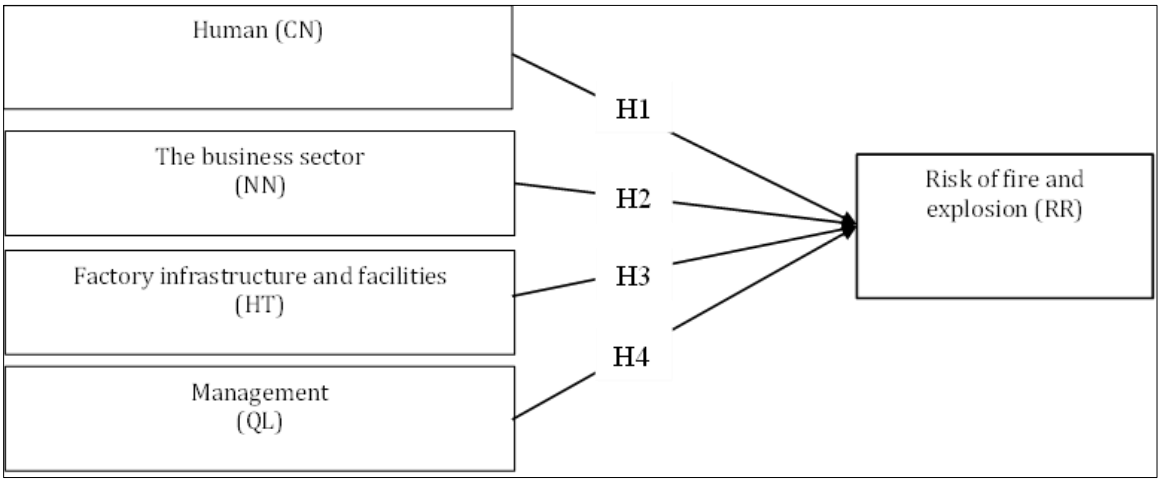
No	Company	Address	Damage value	Time	Reason
1	Duc Thuong confectionery factory	Km19 National Highway 32, Duc Thuong commune, Hoai Duc district, Hanoi City.	Burned down the entire factory and property, killing 8 people and seriously injuring 2 people	29/07/2017	Short circuit, fire due to electric welding
2	Trung Van warehouse	Alley 1 Dai Linh, Trung Van ward, Nam Tu Liem district, Hanoi	900 m2 of factory, 8 people died and hundreds of billions of dong in assets	12/04/2019	Electrical short circuit in the warehouse
3	Rang Dong thermos light bulb joint stock company	87 – 89 Ha Dinh Street, Thanh Xuan Trung Ward, Thanh Xuan District, Hanoi City, Vietnam	150 billion VND, 5% of the company's total assets	28/08/2019	Short circuit in control circuit board
4	CJ FOODS Vietnam Company Limited	Lot EA2-7, Hiep Phuoc Industrial Park, Hiep Phuoc Commune, Nha Be District, Ho Chi Minh City, Vietnam	110 billion and 12,000 m2 of factory burned down	10/11/2020	Fire due to electrical short circuit
5	Luong Tham business household and 7 adjacent wooden furniture production business households	Huu Bang Craft Village Industrial Park, Thach That, Hanoi	More than 1,600 m2 of factory and hundreds of billions of dong	01/12/2020	Short-circuit
6	Nha Be Garment Company	Highway 60, Ward 7, Soc Trang City, Soc Trang	180 billion VND and 10,000 m2 of factory burned down	24/12/2020	Fire caused by electric welding during factory frame repair
7	Production and business households	Mieu village, Huu Bang commune, Thach That district	Nearly 1,000 square meters of factory and many assets were burned	09/04/2022	Short-circuit

No	Company	Address	Damage value	Time	Reason
8	Viet Wood sofo furniture workshop	Craft village, Binh Phu commune, Thach That district, Hanoi	Burned down the entire 400m2 factory and all assets, about 50 billion VND	03/11/2022	Short-circuit

4. Methodology

4.1. Research model

Model of the main causes of fire and explosion risks in the wood processing village sub-industrial cluster



(Source: compiled by author)

Figure 1 Research model

H1: The relationship between business owners and employees in influencing fire and explosion risks at the enterprise is hypothesized as follows: People, including business owners and employees at the enterprise, play a crucial role in identifying and managing hazardous factors in the work environment. Business owners are pivotal in investing in fire prevention and fighting systems, fire protection equipment, and establishing safety policies and regulations to minimize the risk of fire and explosion. However, the role of workers is equally significant, as compliance with safety regulations, participation in fire prevention training, and reporting hazards are vital for ensuring a safe working environment. Worker safety awareness and compliance can effectively detect and prevent fire and explosion hazards at the facility. Therefore, the close cooperation and compliance with safety regulations between business owners and employees are essential to create a safe and productive working environment.

H2: The influence of the business line of an enterprise on the risk of fire and explosion is hypothesized as follows: The business line of an enterprise can significantly affects the risk of fire and explosion at the enterprise due to the unique factors associated with each industry. Industries such as chemical, petroleum, and electronics manufacturing are prone to higher risks of fire and explosion due to the use and storage of flammable substances. Conversely, service and information technology occupations are generally less at risk due to the absence of hazardous materials or work processes. Understanding and assessing the specific risks of each business line are crucial for establishing appropriate fire prevention and safety measures, thereby minimizing the risk of fire and explosion and ensuring the safety of employees.

H3: The hypothesis regarding the physical infrastructure in the craft village industrial park cluster is as follows: The physical infrastructure in the craft village industrial sub-zone significantly impacts the risk of fire and explosion at businesses. An unstable electrical system or electronic devices that are not regularly maintained can create a risk of fire or short circuit, leading to serious consequences. Problems in transport infrastructure and service management can also increase response time during emergencies. Therefore, ensuring proper design, construction, and maintenance of physical infrastructure is essential to minimize the risk of fire and explosion and create a safe and sustainable working environment.

H4: The role of management, propaganda, guidance, training, and fire prevention training of local authorities in minimizing fire and explosion risks at businesses is hypothesized as follows: Management, propaganda, guidance, training, and fire prevention training from local authorities play a crucial role in minimizing fire and explosion risks at businesses. Strict regulations and effective propaganda programs can improve awareness and attitudes towards fire safety. Additionally, investing in education and training programs has a positive impact on reducing fire-related incidents at businesses. The fire risk management model promoted by local authorities contributes to a safer working environment and sustainable development of the business community, while government support and supervision ensure compliance with regulations and fire safety measures.

4.2. Data

To collect data, the authors utilized a Questionnaire, conducted phone calls, face-to-face interviews, and in some cases, sent surveys via email. A total of 260 survey forms were distributed, out of which 251 valid responses were received. The subjects interviewed in depth were business owners with furniture manufacturing workshops in Huu Bang commune, Thach That district, Hanoi. This study applied measurement scales previously established by other research and adjusted them to fit the research context in Hanoi, Vietnam. All measurement scales were in Likert 5-point scale format, with 1 representing strongly disagree and 5 representing strongly agree.

5. Result

5.1. Check the reliability of the scale

The results in table 2 show that all Cronbach's Alpha coefficients of the groups of observed variables are greater than 0.6. In general, the research components ensure the reliability to perform the necessary analysis of the study. All correlation coefficients of the total variables are greater than 0.3 and excluding any variable will reduce the reliability of the scale. Thus, the observed variables ensure enough reliability to conduct further analysis.

Table 2 Results of assessing the reliability of the scale

Item	Item-test correlation	Item-rest correlation	Average interitem covariance	Alpha
CN1	0.47500	0.4102	0.507633	0.8781
CN2	0.40500	0.3529	0.513215	0.8791
CN3	0.42250	0.3644	0.511475	0.8790
CN4	0.33630	0.5774	0.514916	0.8807
CN5	0.47850	0.4258	0.509953	0.8777
CN6	0.48380	0.4355	0.510696	0.8776
CN7	0.44950	0.5786	0.507974	0.8790
CN	0.59650	0.5625	0.509649	0.8759
NN1	0.37130	0.6158	0.514009	0.8799
NN2	0.51410	0.4583	0.507425	0.8769
NN3	0.40460	0.6494	0.512744	0.8792
NN4	0.38680	0.6329	0.513635	0.8795
NN5	0.42640	0.6678	0.511222	0.8789
NN6	0.48630	0.7273	0.508215	0.8776
NN	0.57430	0.5388	0.510197	0.8762
HT1	0.33630	0.5774	0.514916	0.8807
HT2	0.50850	0.4416	0.505257	0.8774
HT3	0.51410	0.4583	0.507425	0.8769

HT4	0.38390	0.6063	0.510574	0.8811
HT	0.80800	0.7927	0.507302	0.8736
QL1	0.42640	0.6678	0.511222	0.8789
QL2	0.38390	0.6063	0.510574	0.8811
QL3	0.50430	0.4364	0.505294	0.8775
QL4	0.53670	0.4711	0.503733	0.8766
QL	0.71470	0.6872	0.505645	0.8735
RR1	0.47850	0.4258	0.509953	0.8777
RR2	0.48630	0.4273	0.508215	0.8776
RR3	0.52010	0.4528	0.504449	0.8771
RR4	0.53670	0.4711	0.503733	0.8766
RR	0.8184	0.8015	0.504593	0.8723
Test scale			0.509195	0.8814

Source: Author's compilation from calculation results

According to the analysis results in Table 2, the Cronbach's Alpha coefficients are all greater than 0.6. The Cronbach's Alpha coefficients of the variables People (consisting of 7 observations), Business sectors (comprising 6 observations), Physical infrastructure (including 8 indicators), Management practices (4 indicators), and Fire and explosion risks (consisting of 4 indicators) are 0.8759, 0.8762, 0.8736, 0.8735, and 0.8723, respectively. Therefore, all observed variables are accepted and will be used in the subsequent factor analysis.

5.2. Exploratory factor analysis (EFA)

The study conducted an Exploratory Factor Analysis (EFA) simultaneously for all measurement indicators of variables in the research model. This analysis was performed based on the results of the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test presented in Table 5, which indicated that the data used for factor analysis were suitable. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was found to be .842, which is greater than the recommended threshold of 0.6, signifying adequacy of sampling. Additionally, the Chi-Square value of Bartlett's test was 3469.969 with a significance level (p-value) of sig = 0.000, which is less than 0.05, indicating that the correlation matrix is significantly different from an identity matrix.

Table 3 Testing the appropriateness of factor analysis

Kaiser – Meyer – Olkin Measure of Sampling Adequacy		**0.842**
Bartlett's Test of Sphericity	Appro Chi – Square	3469.969
	Df	154
	Sig	0.000

Source: Author's compilation from calculation results

There are 5 factors extracted based on the criterion of eigenvalue greater than 1, so these 5 factors best summarize the information of 25 observed variables included in EFA. The total variance extracted by these 6 factors are 72.01% > 50%, thus, the 5 extracted factors explain 72.01% of the data variation of the 25 observed variables participating in EFA.

Table 4 Exploratory factor analysis

Factor	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**
Factor1	4.46244	0.58451	0.2185	0.2185
Factor2	3.87792	0.89547	0.1951	0.4136

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor3	3.98246	2.05657	0.1593	0.5729
Factor4	1.92588	0.17315	0.077	0.6499
Factor5	1.75274	0.35827	0.0701	0.7201
Factor6	0.99446	0.34348	0.0558	0.7758
Factor7	0.95099	0.1964	0.042	0.8179
Factor8	0.85458	0.20584	0.0342	0.8521
Factor9	0.64874	0.02997	0.0259	0.878
Factor10	0.61877	0.05917	0.0248	0.9028
Factor11	0.5596	0.02665	0.0224	0.9251
Factor12	0.53295	0.14972	0.0213	0.9465
Factor13	0.38323	0.03372	0.0153	0.9618
Factor14	0.34951	0.06806	0.014	0.9758
Factor15	0.28145	0.10764	0.0113	0.987
Factor16	0.17381	0.02797	0.007	0.994
Factor17	0.14584	0.1412	0.0058	0.9998
Factor18	0.00463	0.00463	0.0002	1
Factor19	0	0	0	1
Factor20	0	0	0	1
Factor21	0	0	0	1
Factor22	0	0	0	1
Factor23	0	0	0	1
Factor24	0	0	0	1
Factor25	0	.	0	1

Source: Author's compilation from calculation results

Table 5 Factor rotation matrix

Variable	Factor1	Factor2	Factor3	Factor4	Factor5
CN1	0.6926				
CN2	0.8373				
CN3	0.6714				
CN4	0.9618				
CN5	0.9425				
CN6	0.7856				
CN7	0.8107				
NN1		0.5785			
NN2		0.8540			
NN3		0.5614			
NN4		0.7118			

Variable	Factor1	Factor2	Factor3	Factor4	Factor5
NN5		0.9045			
NN6		0.9462			
HT1			0.9618		
HT2			0.8201		
HT3			0.8540		
HT4			0.9721		
QL1				0.9045	
QL2				0.9721	
QL3				0.9052	
QL4				0.8917	
RR1					0.9425
RR2					0.9462
RR3					0.9096
RR4					0.8917

Source: Author's compilation from calculation results

The results of the rotated matrix show that the 25 observed variables are classified into 5 factors, all observed variables have Factor Loading coefficients greater than 0.5 and there are no longer any bad variables.

5.3. Regression analysis

The results of the regression analysis in Table 6 indicate that the adjusted R-squared value of the model is 0.6887. Therefore, it can be concluded that the independent and control variables in the research model explain 68.87% of the variance in fire and explosion risk.

The F-test result of the model has a significance value of sig = 0.0000. Thus, this relationship ensures reliability at a significance level of 5%. This demonstrates that the research model is consistent with reality. Consequently, it can be concluded that the independent variables impact the fire and explosion risk, and the multiple linear regression model is appropriate for the dataset and can be utilized.

Moreover, the results of the multicollinearity test for the model show that the variance inflation factor (VIF) = 1.81 < 10. Therefore, it can be concluded that there is no multicollinearity phenomenon in the model.

Table 6 Regression analysis result

RR	Coef.	Std. Err.	t	P>t
CN	0.2604631	0.0368994	7.06	0.000
NN	0.1478272	0.0361355	4.09	0.000
HT	0.0905358	0.0670294	1.35	0.008
QL	0.7067662	0.0477855	14.79	0.000
_cons	-0.071024	0.1939292	-0.37	0.715
Adj R-squared	0.6887		Prob > F	0.0000
F(4, 245)	138.69		VIF	1.81

Source: Author's compilation from calculation results

As per the regression analysis outcomes, the variable denoting human involvement (CN) exhibits a significant impact on the likelihood of fire and explosion (RR), displaying a Beta coefficient of 0.2604631 and a p-value of 0.000 (< 0.05). Consequently, there exists ample evidence to uphold the postulation posited by H1 at a confidence level of 95%. This suggests that the human factor (CN) exerts a positive influence on the propensity for fire and explosion (RR).

Furthermore, the business sector demonstrates a discernible effect on fire and explosion risk (RR), as evidenced by a Beta coefficient of 0.1478272 and a p-value of 0.000 (< 0.05). Thus, there is substantive support for embracing hypothesis H2 at a confidence level of 95%. Consequently, it can be affirmed that the business sector exerts a favorable impact on fire and explosion risk (RR).

Analogously, both infrastructure (HT) and management (QL) factors manifest a constructive influence on fire and explosion risk (RR), thereby warranting the acceptance of hypotheses H3 and H4.

The relationship between the dependent variable and the independent variables can be generalized through a standardized regression equation as follows

RR = -0.0710 + 0.2604*CN + 0.1478*NN + 0.0905*HT + 0.7067*QL

The analysis conducted reveals that within the spectrum of factors influencing fire and explosion hazards within an organizational context, management practices emerge as a pivotal determinant. Management practices encompass a multifaceted approach involving the formulation and enforcement of safety policies, procedures, and guidelines. Additionally, they entail vigilant oversight to ensure adherence to safety regulations. Instances of inadequate implementation of management practices may precipitate severe ramifications. Insufficiently defined safety protocols and guidelines can leave employees ill-equipped to navigate fire and explosion risks. Furthermore, lapses in regulatory compliance can precipitate serious repercussions and unforeseen accidents.

Effective management practices also entail comprehensive employee training and supervision, fostering adept risk identification and mitigation capabilities. By prioritizing safety management and preemptive measures, organizations can substantially mitigate fire and explosion hazards, fostering a secure and conducive work environment.

Although other factors such as human factors, infrastructure, and business sectors wield significance, the direct influence of management practices in shaping the implementation of preventive measures and control mechanisms for fire and explosion risks within an organizational framework is unmistakable.

6. Conclusion

Identifying and managing fire and explosion risks constitute a crucial managerial task in the operational activities of businesses in general, and enterprises in the woodworking craft village of Huu Bang commune in particular. It is imperative to ensure fire prevention and control measures are in place, mitigating the occurrence of workplace fires and explosions, and promptly detecting and addressing any incidents to minimize property damage. This approach facilitates business continuity by enabling proactive engagement in production and commercial endeavors. To achieve this objective, business owners must prioritize fire prevention efforts, accurately identify potential fire and explosion risks, and effectively implement risk management activities to preempt any potential losses from fire and explosion incidents.

Moreover, business owners must foster a culture of fire prevention and firefighting, adhere to legal regulations concerning fire prevention, participate in specialized training courses organized by relevant authorities, and proactively develop firefighting plans for their production and business facilities.

Fire prevention and effective risk management contribute to ensuring social security, fostering sustainable development of the industry and economy, safeguarding the living environment, and promoting societal prosperity.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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