METHODS FOR FIRE RISK ASSESSMENT IN WAREHOUSES - AN OVERVIEW

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Abstract: The paper discusses the problem of fire risk analysis in warehouses using different techniques for fire risk assessment. The application of different methods for assessing the risk of fire in different types of warehouses was analyzed from the aspect of the materials stored in them: batteries, textiles and chemical products. The aim of the paper is to provide an overview of recent research in the area of fire risk assessment in warehouses. The authors hope that this study can be used as an informative reference for future research in the field of fire protection and risk assessment and provide useful insight into the anatomy of fire risk assessment methods.

Keywords: *Fire Risk Assessment; Warehouse; Fire Protection*

INTRODUCTION

Increased construction and use of warehouses is the main strategy in terms of industrial logistics. Warehouses and storage systems often cover the needs of a wide geographical area and their size is determined accordingly. Due to increased industrial production and distribution, there is a need to build warehouses with increasingly large fire sectors and high-bay storage systems in order to make better use of the space inside the facility (Daganzo, 2005). Although this approach is considered useful in terms of reducing handling costs and better control of stored products, it also brings the problem of increased vulnerability in terms of warehouse hazards and security. In addition to earthquakes and floods, the biggest danger in warehouses is fire (Dinaburg, 2012). Regardless of whether it is a warehouse of smaller or larger capacity, in the event of a fire, which is the worst possible scenario, there is a possibility that the fire will engulf a large number of goods, cause a large amount of material damage, and that due to the combustion process, a large amount of smoke and heat will be produced, which is a large threat to human life and health.

Good and responsible management of fire safety in warehouses is crucial to ensure that fires do not occur or, if they do occur, are likely to be controlled and extinguished quickly, efficiently, and safely. Fire safety management in warehouses also implies that in case of uncontrolled fire growth and development, anyone who happens to be nearby can be safely and quickly evacuated from the fire to a safe location. A warehouse fire risk assessment ensures that all fire safety procedures, fire prevention measures, and fire safety measures in the form of plans, systems, and equipment are in place and functioning properly. (JIN Yu – Xiang, 2020). Fire risk assessment itself is a critical part of a fire prevention program. In this process, the fire risk associated with the possibility of occurrence and the severity of damage caused by fire is assessed and calculated.

REVIEW OF FIRE RISK ASSESSMENT METHODS

Fires in battery warehouses

Storage of lithium-ion batteries (LIB) has always been at increased risk of fire outbreaks due to instability and susceptibility to thermal breakdown. Many scientific papers and studies have analyzed the risk of fire outbreaks in battery warehouses and most of them have focused on the factors that affect fires due to battery heat losses, and very few papers have analyzed the papers on the causes that lead to heat losses. In order to solve this problem, the paper (Xie, 2023) proposed an approach that considers several influential factors for the risk assessment of fire in battery warehouses based on expert assessment and a Bayesian network (Figure 1). The proposed approach uses a Bayesian network model that contains three main groups of parameters: causes of fire, factors influencing the spread of fire, and consequences of fire in order to dynamically analyze the development and consequences of fires in battery warehouses. The results of the analysis showed that the proposed approach is reliable in assessing the risk of fire outbreaks in battery warehouses. In addition, it has been shown that the human factor usually causes open flame fires. It is recommended that in battery warehouses, a high degree of charging of the storage capacity is avoided, and if this is not possible, in addition to the timely response of firefighters, automatic fire extinguishing systems and mechanical ventilation should be installed in the buildings.

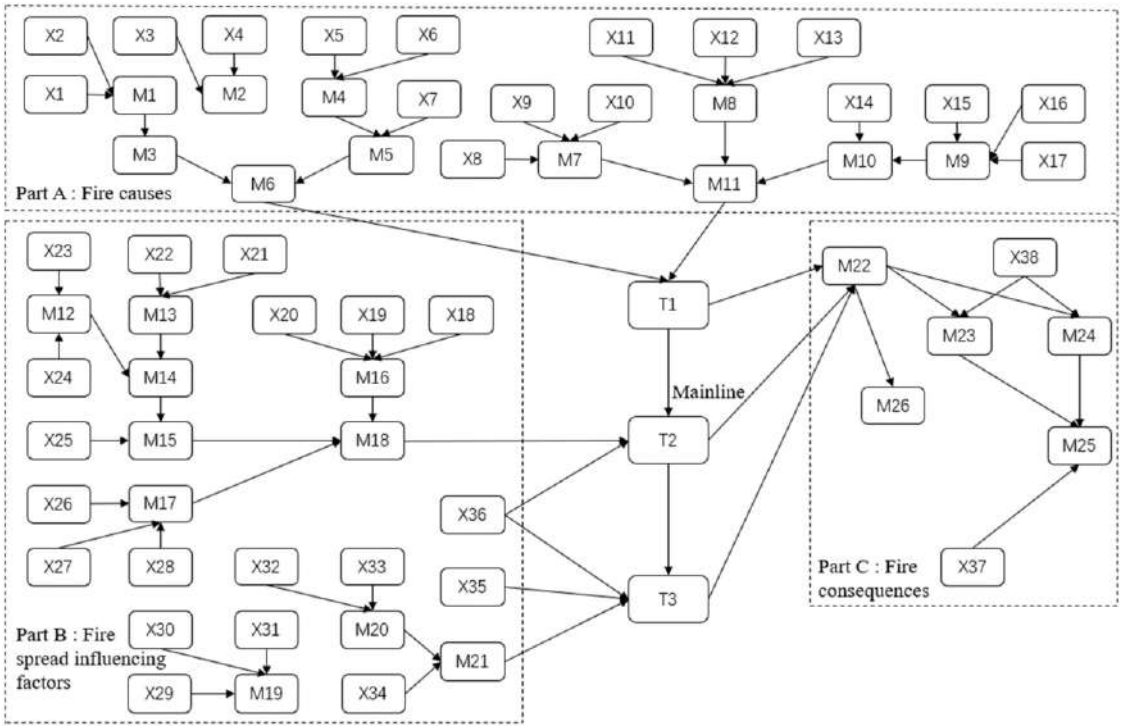

Figure 1. The block diagram of the BN model (Xie, 2023)

Proper transport and storage of batteries are important processes during the life of batteries. For this reason, it is important to create a procedure for assessing the risk of battery fires during transport and storage in order to prevent fires. The proposed procedure (Huang, 2022) presents an improved fire risk assessment method for lithium-ion batteries during transportation and storage by combining the event tree method (FTA) and the fuzzy logic method by performing 8 possible failure paths and 9 basic events. A case study of battery transportation by ship confirmed

that the proposed method can accurately assess fire risk and locate possible problems. By analyzing their importance structure to the largest event, the weights of each failure path are set to 0.128, which is used to calculate the HRN synthesis. In order to quantitatively assess the hazard risk of battery transportation and storage, probability, severity, and hazard control number are proposed as evaluation indices.

Fires in textile warehouses

It is known that cotton belongs to substances that are prone to self-heating and self-ignition during storage and that fires in buildings where cotton is stored are not rare. Research on fire risk assessment in cotton warehouses is limited. In the paper (Ding, 2019), the authors focus on fire risk assessment in a cotton warehouse and explore a strategy to control fire risk. Bow tie models (Figure 2) and Bayesian networks were established in order to investigate the relationship between the causes of accidents, safety barriers and possible consequences. The results obtained based on research showing that the first safety barrier (detecting and extinguishing a fire before the arrival of the fire brigade) is more controllable and more effective than the second safety barrier (extinguishing the fire after the arrival of the fire brigade). Based on the collected probability data, the probability and risk of a normal accident are greater than that of a major accident and a severe accident when safety barriers fail; when the first safety barrier fails, the probabilities and risks of major and severe accidents increase by more than 2000 times. Critical events for the occurrence of fire are open flames and sparks during cotton storage, and critical events for detection and extinguishing before the arrival of the fire brigade are supervision of the warehouse by an employee, regular inspection, and installation of automatic fire alarm and extinguishing systems.

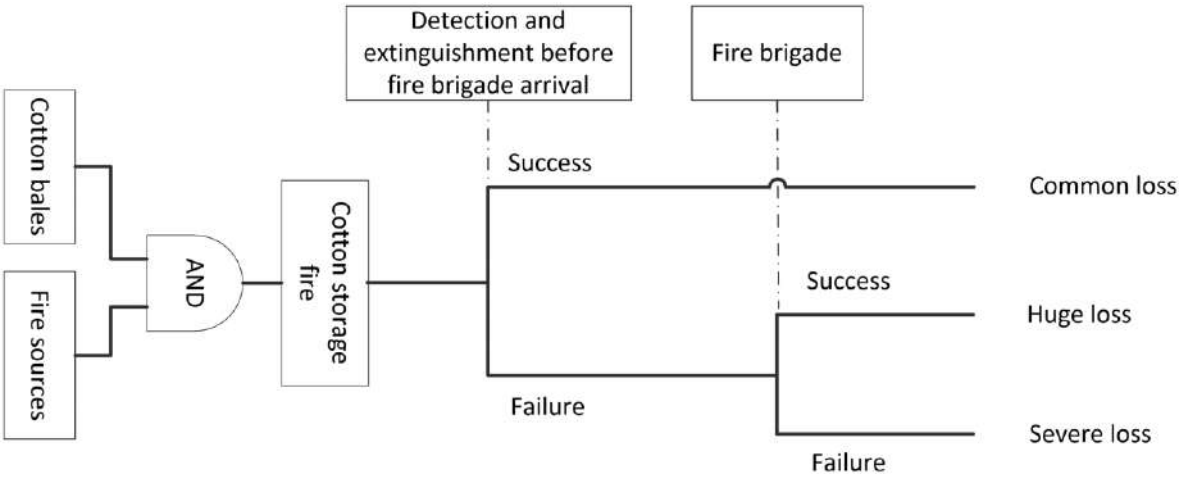

Figure 2. Generic Bow-tie model for cotton storage fire risk assessment (Ding, 2019)

Fires in industrial buildings

Fire safety is one of the main issues affecting the overall life cycle of industrial facilities. A better overview of the risk management of industrial facilities is realized through a risk management plan that reveals the relationships between all safety factors that are present during the exploitation of the facility itself. Due to the complexity of the industrial building system, the paper (Dârmon, 2020) discusses a probabilistic approach to assessing the risks and consequences associated with fire. The method of event trees was used to estimate the frequency of fires in an

industrial building and its consequences. In addition to requirements for the safety of employees' lives, criteria are set for the assessment of probability risks, taking into account the goals of property protection and business continuity. The above fire risk assessment approach can be considered as an optimization technique for sustainable production and better management of fire protection systems in industrial facilities.

Fires in chemical product warehouses

Fires at storage tanks for chemical products are very complex due to the difficulty of extinguishing them and the ease with which the fire spreads to nearby elements of the storage. The study (Ramezanifar, 2023) aimed to introduce a procedure based on Set of pairs analysis (SPA) based on Fault Tree Analysis (FTA), established through experts to identify and assess the fire risk of storage tanks. In a quantitative FTA system, sometimes only enough data is available to calculate the failure probability of the system to be studied. To illustrate the applicability of the proposed approach, a methanol storage tank fire fault tree was derived and Basic Events (BE) were analyzed. According to the obtained results, the fire accident was calculated at 48 BE, and the value of the probability of fire occurrence was calculated. In addition, this study lists the most important causes that led to the fire. The proposed approach established in this study can assist decision-makers in determining where to take preventive or appropriate measures on a storage tank system. Furthermore, parameter tuning can be performed for different systems with limited manipulation.

CONCLUSION

This paper presented a comprehensive review of the literature on fire risk assessment methodologies in warehouses based on selected references from the field of fire protection.

Based on the above references, the following conclusions can be drawn:

- Fire in warehouses represents a serious danger in both developing and developed countries and represents a significant threat to life, structure, property, and environmental safety.

- The fire protection measures currently in place lead to an unquantifiable level of fire protection in warehouses, providing minimal fire risk mitigation strategies and not taking into account contemporary fire risk issues.

- Implementing key measures that include improving fire safety features in warehouses, proper regulation and enforcement of building code provisions, increasing awareness and proper use of technology and resources are of great importance to reduce the risk of fire in warehouses.

- Research and training needs necessary to improve warehouse fire safety include implementation and development of cost-effective fire suppression systems, characterization of new materials, development of performance-based codes, and understanding of fire hazards.

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