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STRENGTHENING LOCAL HEALTHCARE GOVERNANCE THROUGH HYBRID RISK ASSESSMENT: A CASE STUDY FROM SOUTH INDIA

*1S.Sam, 2D.Jebakani

[1] Research Scholar, Department of Mechanical Engineering, Government College of Engineering, Tirunelveli- 627007, Tamil Nadu, India
[2] Professor, Department of Mechanical Engineering, Government College of Engineering, Tirunelveli- 627007, Tamil Nadu, India
*Corresponding authors: samjay680@gmail.com , S.Sam

Abstract: In contemporary healthcare delivery, patient safety is a governance concern as much as it is a clinical one. Operational hazards, human errors, and insufficient compliance with standard operating procedures (SOPs) often undermine the effectiveness of local healthcare systems. This study introduces a governance-oriented hybrid risk assessment framework that integrates Pareto analysis, Analytical Hierarchy Process (AHP), and Complex Proportional Assessment (COPRAS) to systematically evaluate safety risks in healthcare institutions. Data collected from 200 healthcare professionals in a major South Indian hospital highlights key institutional vulnerabilities. The findings reveal that improper medication handling, lapses in infection control practices, and inadequate biomedical waste disposal constitute the most significant risks, while human error remains the predominant cause of safety failures. To ensure validity, Fault Tree Analysis (FTA) was applied as a verification tool. By linking technical risk assessment with healthcare governance, the proposed framework provides local administrators and policymakers with actionable insights to improve patient safety, strengthen institutional accountability, and enhance resilience within healthcare delivery systems.

Keywords: Fireworks; Safe Operating Procedures; Pareto; AHP-COPRAS; FTA.

1. Introduction

With the continuous improvement in technology and science, some latest innovations arise and process industries have to manage many processes and chemicals. Unsafe conditions and handling during the crackers manufacturing process lead to accidents of minor or major (Palaneeswaria 2012). In particular, firework industries have proved to be more susceptible than various industries due to the high amount of explosive mixtures. Accidents at fireworks may have calamitous consequences for the environment, people, facilities and workers. Fireworks is one of the most susceptible industries for severity and frequency of accidents. In India, the fireworks industry retains a devastating position in industrial development because they provide huge employment to human beings (Porchelvi and Devi 2015). Firework products are very famous in our nation because they are widely used to celebrate different festivals. The working peoples are almost illiterate in the fireworks industry because this industry is located in rural regions. Every process in the industry, such as mixing, filling, shell loading, packing, is done manually. Still, employees are not aware of chemical handling because its accident rate is very high compared to various industries (Rajathilagam 2016). Therefore, employees should be trained to understand how to handle the chemicals using Material Safety Data Sheets (MSDS).

In general, the fireworks industry is well-defined to be a hazardous one. Right from the starting stage of production to the storage and transportation of fireworks in the warehouses, the risk to property and life is high. The handling, storage type, and manufacturing process are some of the key factors that endure an explosive event's likeliness and occurrence. Accident explosions during the production of fancy crackers, safety matches and firework products are reported frequently in contextual cases. The explosive accidents happen regularly, resulting in losses of money and materials, injury to workers and heavy losses of human lives.

Risk assessment in the fireworks industry is an essential one to avoid these consequences mentioned above and helps to improve organizational performance, production efficiency, security and safety in a resilient manner. To provide reliable and safe products, every employee should recognize risks outside and within their working environment. Several studies recommend industry be required to implement health and safety practices to prevent people from risks in the surrounding environment. Their outcome will provide appropriate control measures for risk reduction in the working place.

In recent times, fireworks risk management and assessments have received concern at international and national levels. Studied understanding and deep knowledge of the stability and explosive chemical properties are critical to evaluate the relevant hazards and risks and design a safe process (Batti et al., 2013). Discussed explosion causes happened in Italian fireworks industries. She highlighted that the production was not conformed to the inspections and rigorous controls as those need by a proper safety management system (SMS) for vulnerable risk industries (Demichela 2007).

From the above information, it could be understood that there is an urgent need to address the risks in fireworks industry. Apart from incurring economic loss, accidents in fireworks industry claims individual lives and cause severe injuries. So, it is essential to identify and evaluate the risks in fireworks industry. Most of the earlier studies in fireworks industry focus on after impact of the accidents rather than discussing the causes of accidents. However, most of the studies didn't consider the inter-relationships between identified risks in today's complex fireworks industry. Additionally, preceding studies show how the risk assessment framework can help industrial managers optimize risks and implement organizational performance.

The fireworks industry's complexity and relevant risks have improved significantly, resulting in a huge loss of life, equipment, and natural resources. Investigating risks in the fireworks industry to realize the implications of reducing accidents and optimizing resources in fireworks would be the most valuable one. Only limited practical and academic studies exist on how the risk assessment framework explores the inter-relationships between various risks in a fireworks industry. Additionally, the following research questions are addressed in this research work.

a) What are the risks that generate explosion in Indian Fireworks Industry?

b) How can industrial experts evaluate the significance of the identified risks?

c) How do the research outcomes assist industrial experts in accomplishing effective implementation of organizational performance, security and safety?

This study contributes immensely to the literature on fireworks industry. First, this study provides a list of risk factors related to fireworks industry. This list of risk factors will help the industrial management in taking some proactive steps to avoid accidents. Second, this study uses an integrated approach comprising of AHP-COPRAS and Fault tree analysis. The AHP-COPRAS used in this research work builds the inter-relations among explosive risks in a structured way. The risks are prioritized using a radar diagram. This diagram helps industrial experts to realize the complicated relations between the risks for effective organizational performance. Fault tree analysis helps in understanding the logical relationship among the risk factors. The proposed framework was practically applied to a rising Indian fireworks industry. Section 3 gives the details about applying the framework to this industry. Third, this study provides some practical implications that may help the industrial management in addressing the risk factors.

2. Literature Review

The research gaps and highlights in the literature regarding risk assessment in fireworks and various industrial sectors, AHP-COPRAS and FTA methods are presented individually.

2.1 Risk assessment in fireworks and various industrial sectors

Reviewed the hazards and consequences in fireworks industries and discusses the accident causes and fireworks effects on air quality. From the results, it was found that recognizing the possible human error and performing risk assessment will prevent/protect accidents in future perspective (Ajith et al., 2019). They were studied lessons understood from previous accidents in the establishments of fireworks and aimed to investigate the management, organizational, and technical aspects crucial in safety management systems to control major risks. The outcomes suggested for enhancing the safety of management via proper audit, particular training activities, good practices and guidelines (Pirone et al., 2016). They were assessing the health risk related to activities of fireworks in Central London. The findings showed that metals with high concentration attributable to fireworks burning emissions at night time compared with daytime (Hamad et al., 2016). Performed the safety and risk assessment on manufacturing firecrackers in the Philippines and suggested implementing hazard control techniques such as personal protective equipment, administrative and engineering controls, and work practices (Bondal 2016). Conducted risk assessment to handle, manufacture, and safe storage of flash compositions using "What-If Analysis." The findings show that the major causes for the explosion in these working places are friction and impact (Sivapirakasam et al., 2009). The sustainability of the Indian fireworks industry was studied and examined the challenges faced by the Chinese manufacturer's entry and also difficulties handled by employees in the working environment. Finally, they provided some valuable guidelines to diminish the damage lead by the working environment and prevent employees' health (Muthuramalingam and Ilango 2017). Table 1 shows the number of non-fatal and fatal accidents reported in this industry for the past decade

Table 1. Details of previous accidents

Year	2020	2019	2018	2017	2016	2015	2014	2013
No of accidents (Fatal)	48	85	50	40	62	60	18	35
No of accidents (Non-Fatal)	1198	826	1545	1838	954	1098	131	1908

The risks that create accidents were investigated in the textile industry and found that accidents are mainly due to dust, high noise, the unwillingness of workers, and poor lighting and ventilation (Bathrinath et al., 2020). The usage of smart personal protective equipment was reviewed and surveyed Russian mining industry. From the results, 30% of employees supported the usage of smart PPE, which is an optimistic outcome of the surveys (Nikulin et al., 2019). While analysing the ergonomic risk factors affecting the production efficiency of the leather industry and they concluded that fatigue, outdated machinery, operational setup and vibration are the major risks (Karuppiah et al., 2020). Highlighting the employee perspective regarding job satisfaction in the fancy crackers manufacturing industry and examining employee satisfaction factors. Offering compensation, empowering employees and company activities are the most influential ones (Vijayaragavan 2014). Human error in the healthcare industry was examined and found that working conditions, number of simultaneous goals and adequacy of organization support turn out to be crucial (Bhalaji et al., 2020). Table 2 shows explosive risks in the fireworks industry.

Most of the authors used traditional and conventional methods. These methods have some key limitations are they don't consider the inter-relationship among risk factors. In reality, there are relationships between risk factors, and one factor might impact others. In this study, the AHP-COPRAS was utilised to characterise such inter-relationships. The inter-relationships between risk factors can be captured using this strategy. As well as this method helps in uncertainties and inter-relations between risk factors for decision-makers.

2.2 AHP-COPRAS

AHP method is used to investigate green and lean practices in Indian small and medium scale enterprises (SMEs). The research findings are expected to help practitioners and policymakers concentrate on key issues to facilitate green and lean manufacturing (Thanki et al., 2016). The implementation of green manufacturing and its barriers were examined with the help of the analytic hierarchy process and determined that financial constraints, lack of new technology, processes and materials, and lack of environmental knowledge are the most influential barriers (Govindan et al., 2014). COPRAS method was used for Urbanistic assessment based on geographic information system (GIS) in Kaunas city. The outcomes of this research will help city planning specialists and town planning authorities to localize and establish problems of buildings in the urban territory, substantiate the decisions and strengthen the integrated approach (Zagarskas et al., 2007). A case study was conducted for risk assessment in an excavation project in Shiraz city using the COPRAS method. From the results, the industry needs more attention to the risks such as incomplete emergency plans, ground subsidence, shortage of managerial experience, unfavorable geographical conditions and construction safety (Valipour et al., 2017).

The Integrated AHP-COPRAS method is used for the selection of maintenance strategy under a Fuzzy environment. From the results, it was observed that maintenance strategy selection is a crucial issue because of its vital roles in manufacturing and production. Therefore, the accuracy in choosing the most suitable strategy is one of the key maintenance goals (Fouladgar et al., 2012). A company supplier was chosen at both national and international level using hybrid MCDM method like AHP-COPRAS. The findings depicted that the proposed hybrid MCDM method will also guide various multi-national companies effectively choosing their suppliers in decision-making (Zolfani et al., 2012).

2.3 Fault Tree Analysis (FTA)

With the help of FTA, they assessed the risks of natural and oil gas pipelines owing to natural hazards and discovered that intermediate occurrences of corrosion in the sea and on land, failure of gas and oil transportation pipelines, and excessive salt and acid content are the most significant dangers (Badida et al., 2019). Additionally, the outcomes are expected to be useful to the industrial managers when decision-making is relevant to the risk management of gas and oil pipelines. Risk assessment of gas and dust explosion in coal mines using fault tree analysis and their outcomes provide valuable guidelines for enhancing the safety management efficiency feasibly and scientifically (Shi et al., 2018). FTA is used for risk analysis in cyber-security to find the vulnerability of a cyber-security system. From the outcomes, the industry needs to address the following risks as characteristics of E-Commerce, user authentication problems and credit transactions for the implementation of cyber-security (de Gusmao et al., 2018).

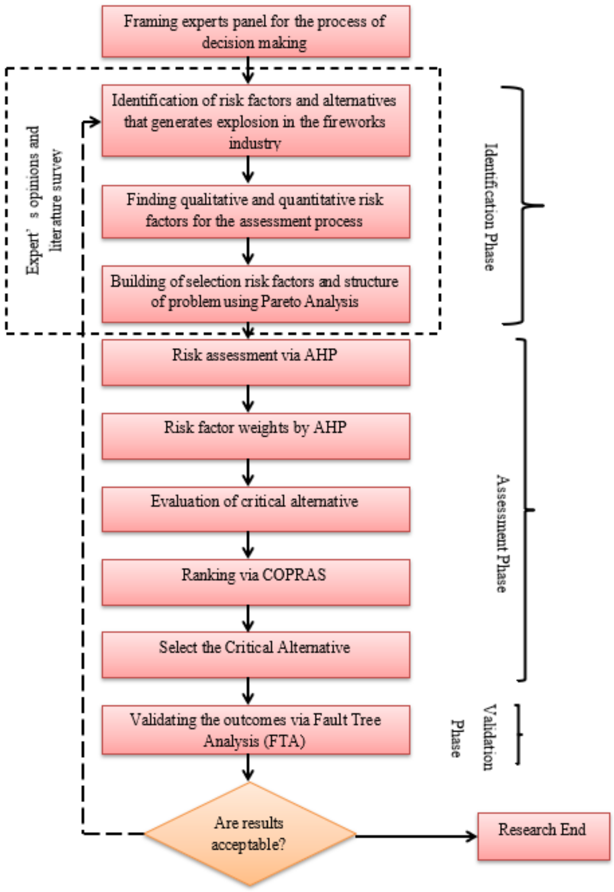

Fig 1. Proposed Framework of this research work

Table 1. Risk Factors that generates explosion in Fireworks industry

Notation	Risks	Brief Description	References
FI1	Impact	Impact risk arises mainly due to shock or high force applied over a short period when two or more surfaces collide with each other.	Lin (2016)
FI2	Static electricity	Risk made from the contact of two surfaces and have separated and worn, and at least either surface has a higher resistance to electric current.	Azhagurajan et al., (2020)
FI3	Friction	Risk resulting from when two hands relative to each other during chemical handling, the friction between the two hands transforms work to heat.	Sun et al., (2017); Lin et al., (2019).
FI4	Lightening	Risk arises from a lot of aluminum dust is present in loading and mixing shed, at the time of lightening it suddenly made fire.	Xiaolong et al., (2015)
FI5	Spontaneous combustion	This risk is mainly due to freshly preparing the charcoal, which occurs self-heating and catches fire.	Li and An (2016)
FI6	Unstable (slow decomposition)	Risk can be happened because handling the chemicals more delayed i.e., more than 1 hour	Mahilang et al., (2020)
FI7	Hygroscopic reaction	An exothermic or hygroscopic reaction occurs when raw materials are held in warehouses for an extended period.	Wielogorska and Winterton (2020)
FI8	Changes in Temperature	Based on the balance between energy leaving and entering the earth.	Lai and Brimblecombe (2020)
FI9	Rising Humidity	It occurs at higher temperatures and a higher amount of water it makes the air can hold.	Africa et al., (2020)
FI10	Lighting and Ventilation	It is the deliberate use of light to accomplish aesthetic or practical effects. Ventilation is used to control air motion, humidity and indoor temperature in the working environment.	Chang et al., (2016); Retama et al., (2019).
FI11	Welfare Amenities	Employees are always enlightened in their working environment if they are provided by welfare facilities such as restroom, first aid, canteen facility, drinking water, parking etc.	Sengupta et al., (2016)
FI12	Improper Housekeeping	Poor arrangement of tools, rooms and equipment may hamper the housekeeping.	Ragheb (2020)

FI13	Safe disposal of fireworks wastes	This risk is mainly due to the unusual disposal of waste materials.	Duan et al., (2020)
FI14	Lack of personal protective equipment (PPE)	It affects the employee's health such as injury, worn and accident.	High and Brywczynski (2019)
FI15	Lack of training for newly joined employees	Many youthful employees are in a working environment they didn't know about safety and chemical handling.	Ding and Ding (2020)
FI16	Overtime or working hours	This risk influences capability to focus on safety norms at the time of working.	Kaur and Kaul (2017)
FI17	Provision of fire fighting facilities	Fire fighting facilities can extinguish or control fires, protecting them from emerging into big ones.	Henshaw and Perwich (2016)
FI18	Poor knowledge about handling chemicals	Chemical safety includes mixing and handling instructions, as well as essential PPE for personnel.	Singh et al., (2019)
FI19	Safety Counselling	It can motivate an employee to handle the problem or stress in the workplace.	Swuste et al., (2019)
FI20	Adequate means of escape in case of fire	A safe route is provided for employees to escape from working place without the necessity of outsiders.	Van Coile et al., (2019)
FI21	Storage arrangement of scraps and tools	A proper arrangement can be avoided by protecting hazard storage conditions, careless and overcrowded.	Campbell (2020)
FI22	Safe access in working place	Implies enough space for safe access and movement if necessary make ensures stairs, corridors and floors are free of obstacles.	Wang et al., (2018)
FI23	Safety environment regarding building layout	The layout of buildings should be made at least minimum distances for safety.	Hale (2003)
FI24	Process isolations with a high fire risk	It is a set of technologies to prevent each process from other processes.	Rajeshkumar et al., (2012)
FI25	Conditions of passage and floors	It is designed to protect the chemical containers dragged or throw away.	Chow (1993)

2.5 Highlights and Research Gaps

Fireworks are major contributors to the Indian economy and are vital for the well-being of many unskilled employees. Today fireworks management has difficulty managing explosives and also both a global and local issue. Regarding these issues, several studies have concentrated on risks that generate explosions in the fireworks industry. Reviewed the fireworks hazards and their consequences related to the environment and several gases that contaminate the surrounding environment when the crackers explode (Vijayakumar et al., 2021). Prioritize the risks to enhance security and safety in fireworks industries using a decision tree classifier (Indumathi et al., 2021). For the past decade in Sivakasi, discussed the accident's causes and preventive measures during the lighting of the fireworks crackers (Rajathilagam et al., 2012). The chemical affects employees' health, the risk faced by the worker, and the conclusion of some control measures for reducing risk (Nandhagopal et al., 2020).

A research gap occurs in exploring risks related to explosives, interactions or dynamics between these risks, and no research papers on determining most influential explosive risks in the fireworks industry by using MCDM methods. Such exploration can assist industrial managers in formulating risk and mitigation strategies for actual industrial cases. This research work uses an AHP-COPRAS method for assessing the contextual inter-relationships between various risks in the fireworks industry.

3. Methodology

Figure 1 shows the proposed research framework. The detailed description of AHP and COPRAS is the integrated AHP-COPRAS method that examines the relationship between risks and alternatives in fireworks. This integrated method can capture inter-relationship between risks and identify the direct and indirect relations of several alternatives. Additionally, Fault Tree Analysis (FTA) is used to verify the obtained AHP-COPRAS results.

3.1 Recognition of risk for risk assessment

3.1.1 Chosen of risks in Fireworks Industry

A detailed survey was finalized by academic experts and professionals from Indian Fireworks Industry to recognize and find inter-relationships between the explosive risks. The questionnaires (refer to Appendix A) were primarily sent to 250 industrial experts via email to identify the risks in fireworks. These industrial experts were from the majority of the Indian Fireworks industry, situated in the Southern region of Tamil Nadu. The respondents and industry were selected based on skill, experience in decision making, reputation, product type and market share. In this research work, the response was collected from 200 respondents; 50, from the department of production, 30, from the department of logistics, 20, from the academic experts, 70 from the department of supply chain and 30, from the department ICT. The average working experience of the industrial experts was 15 years in their relevant designation.

A Y/N-based set of recognized risks was primarily given to the decision-makers to recognize the critical risks in fireworks. Next, a linguistic scale was provided to the respondents to assess the significance of the risks (Table 3). Pareto analysis was conducted to separate the "vital few" and the "useful many" risks in fireworks by ranking the frequency of occurrence. Pareto analysis is a widely used tool to recognize the crucial factors in different streams such as total quality management, supply chain management, enterprise resource planning and food safety assurance system due to its easiness of adoption (Wong et al., 2021; Bajaj et al., 2021). Decision-makers and industrial managers frequently use Pareto analysis to direct focus to the continuous enhancement opportunity by highlighting the risks in contradiction of the useful many or vital few causes. The avg.weight was considered for choosing the 20 most important risks in fireworks.

Among the 25 risks suggested in this research work, the no of feedback values for the first two recognized risks were 20 for impact and 18 for static electricity. Likewise, the least significant recognized risks were 1 for process isolations with high fire risk and condition of passage and floors with the feedback values of 1, respectively.

3.1.2 Recognition of most vital risks

Twenty most vital risks in the context of their fireworks were examined further based on the pareto analysis. These risks were Impact (FI1), static electricity (FI2), friction (FI3), lightening (FI4), spontaneous combustion (FI5), unstable (slow decomposition) (FI6), hygroscopic reaction (FI7), changes in temperature (FI8), rising humidity (FI9), lighting and ventilation (FI10), welfare amenities (FI11), improper housekeeping (FI12), safe disposal of fireworks wastes (FI13), lack of personal protective equipment (FI14), lack of training for newly joined employees (FI15), overtime or working hours (FI16), provision of fire fighting facilities (FI17), poor knowledge about handling chemicals (FI18), safety counselling (FI19) and adequate means of escape in case of fire (FI20).

3.2 Analytic Hierarchy Process (AHP)

3.2.1 AHP overview

The AHP is a multi-criteria decision-making (MCDM) method initiated by (Satty 1980). It assists decision-makers in handling intricate problems with subjective and multiple contradictory criteria (projects ranking, investment or location selection, etc.). The AHP bottom line is the concept of relative weights to prioritize alternatives or decision criteria (Solangi et al., 2021). AHP method is a practical and effective approach that can consider unstructured and complex decisions (Bakir and Atalik 2021). The AHP is suggested in this research work to face intangible and tangible risks that generate explosions in the fireworks industry. The methodology selection is based on the problem characteristics, drawbacks of other methodologies and consideration of the advantages (Qarnain et al., 2020). The decision-maker judges the significance of every risk in pair-wise comparisons. The AHP outcome is weighing of each decision alternative or prioritised ranking.

Basically, there are three major steps for considering decision-making problems by AHP: Building hierarchies, synthesis of priorities and comparative judgment, briefly as follows.

Step 1: Constructing a pair-wise comparison matrix (H) based on industrial experts opinions. Experts provided the ratings using a linguistic scale it is shown in Table 3.

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1m} \\ h_{21} & h_{22} & \cdots & h_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ h_{m1} & d_{m2} & \cdots & h_{mm} \end{bmatrix} \quad (1)$$

Where m is the matrix order.

Table 3. Linguistic scales for both AHP and COPRAS

Intensity of weight	Description
Inverse comparison reciprocals	Reciprocals
1	Equally significant
2,4,6,8	Intermediate weights
9	Extremely significant
7	Very strongly significant
5	Strongly significant
3	Moderately significant

Step 2: Creating matrix for Normalization (H_1)

$$H_1 = \begin{bmatrix} h'_{11} & h'_{12} & \cdots & h'_{1m} \\ h'_{21} & h'_{22} & \cdots & h'_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ h'_{m1} & h'_{m2} & \cdots & h'_{mm} \end{bmatrix} \text{ and } h'_{ji} = \frac{h_{ij}}{\sum_{j-1}^{m} h_{ij}} \text{ for j, i = 1, 2, 3, …, m} \quad (2)$$

Step 3: Calculation of risk factors.

$$U = \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{bmatrix}, \; u_j = \frac{\sum_{j=1}^{m} h_{ji}}{m} \text{ and } U' = HU = \begin{bmatrix} U'_1 \\ U'_2 \\ \vdots \\ U'_3 \end{bmatrix} \tag{3}$$

Based on the risk factor weights from AHP method, we determine the critical alternative with the assistance of COPRAS method.

3.2.2 Consistency check for pair-wise comparison matrix

As per the following steps the consistency ratio was computed (Sarkar and Biswas 2021):

1) Compute the relative weights or eigenvector and λ_{max} for every matrix of order m.

2) Using the equation (4) calculate consistency index for every matrix order m.

$$CI = (\lambda_{mas} - m)/(m-1) \tag{4}$$

3) Using the equation (5) the consistency ratio is computed.

$$CR = \frac{CI}{RI} \tag{5}$$

3.3 COPRAS method

To assess the overall efficiency of an alternative, it is vital to recognize the most influential risk, assess alternatives, evaluate information regarding these risks, create a method for assessing the risk to meet the needs of decision-makers. With this situation, the decision analysis is concerned in which a decision-maker has to select among various alternatives by focussing a specific set of usually contradictory risks. The Complex Proportional Assessment (COPRAS) method was first initiated by (Zavadskas and Kaklauskas 1996). Most of the risks for assessing alternatives managing vague features and risk values can't be expressed accurately in routine life situations. This method is used to evaluate minimizing and maximizing index values, and the effect of minimizing and maximizing the index of attributes on the result assessment is considered individually. Accordingly, this method has the following features.

- Independent attributes.
- It is a balanced method.
- The attributes with qualitative values are transformed into attributes with quantitative values.

In this method, the decision matrix is framed based on the opinions from industrial experts in Equation (6).

$$Y = \begin{bmatrix} h_{11} & \cdots & h_{1i} & \cdots & h_{1m} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ h_{j1} & \cdots & h_{ij} & \cdots & h_{jm} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ h_{n1} & \cdots & h_{ni} & \cdots & h_{nm} \end{bmatrix}_{n\times m}; \quad j = 1,...,n, \quad i = 1,...,m \tag{6}$$

In the equation (6), h_{ij} is the decision matrix element for j^{th} the alternative in i^{th} attribute. On the other hand, industrial experts provide the risk factor weight $[u_1, u_2, ..., u_m]$.

3.3.1 COPRAS method description

The Normalized Decision Matrix

Equation (7) is used to normalize the obtained decision matrix.

$$h^*_{ij} = \frac{h_{ij}}{\sum_{j=1}^{n} h_{ij}}; \quad i = 1,...,m \tag{7}$$

Here, h_{ij}^{*} specifies the normalized value of decision matrix of j^{th} alternative in i^{th} attribute.

The Weighted Normalized Decision Matrix

Equation (8) is used to find the weighted normalized decision matrix values.

$$\hat{h}_{ij} = h_{ij}^{*}.U_i ; \quad j = 1,...,n, \ i = 1,...,m \tag{8}$$

In equation (8), U_i is the risk factor weight $[u_1, u_2, ..., u_m]$.

The minimizing and maximizing indexes

Given the positive or negative attributes type, the minimizing and maximizing indexes of every attribute are attained by equations (9) and (10).

$$D_{+j} = \sum_{i=1}^{k} \hat{h}_{ij} ; \quad j = 1,...,n, \tag{9}$$

$$D_{-j} = \sum_{i=k+1}^{m} \hat{h}_{ij} ; \quad j = 1,...,n, \tag{10}$$

Where k specifies the no of positive attributes and m-k specifies the no of negative attributes and D_j indicates the minimizing and maximizing indexes of j^{th} attribute, as per the type of it.

The value of relative significance

Equations (11) and (12) are used to calculate the relative significance value of every alternative.

$$B_j = D_{+j} + \frac{\min_j D_{-j} \sum_{j=1}^{n} D_{-i}}{D_{-j} \sum_{j=1}^{n} \frac{\min_j D_{-i}}{D_{-i}}} \tag{11}$$

$$B_j = D_{+j} + \frac{\sum_{j=1}^{n} D_{-i}}{D_{-j} \sum_{j=1}^{n} \frac{1}{D_{-i}}} \tag{12}$$

Alternatives Final Ranking

The alternatives with relative significance values are prioritized in descending order, and value with the highest one has the highest rank.

3.4 Fault Tree Analysis

Watson (1961) first developed the Fault Tree Analysis (FTA). It is a valuable analytic tool for the safety and reliability of intricate systems. FTA represents the logical relationship between sub-system and component failures and how they combine to cause system failures (Shu et al., 2021). FTA aims to focus on estimating the likelihood of a particular accident, determining the combinations of equipment failures, operating conditions and human errors that contribute to an incident, and identifying remedial measures and their impact.

3.4.1 Procedure of Fault Tree Analysis

It has 4 steps following as

- Uniquely identify all gates and basic events
- Resolve all gates into sets of basic events
- Remove duplicate events within sets
- Delete all supersets (sets that contain other sets)

Step1:

From Figure 3 the gates are identified with letters and the basic events with numbers.

Gates=A, B, C, D, E, F

Basic events=1, 2, 2, 3, 4, 5, 6 (2 appears twice)

Step2:

This step 2 is done in a matrix format by using or-gate & and-gate rules.

Basic Events (Alternatives)

1. Temperature Increase
2. Human Error
3. Management Pressure
4. Improper Tool
5. Scratch Nail
6. Exothermic Reaction

These six alternatives are identified from literature and individual opinions from industrial experts to improve organizational performance, safety, and security.

Step3:

Cut sets have a repeated basic event. So we remove these repeated events.

Step4:

There are many supersets. So these supersets are deleted. And remaining sets are the minimal cut sets.

4. Proposed Framework Application

The proposed framework was used to examined and evaluate the risks that generates explosion in Indian Fireworks industry. The case industry, herein termed ABC, is a leading fireworks industry in India and began its operation in the year 1920 as fancy cracker manufacturers. The case industry is one of the well-known fireworks products manufacturers in the nation and exports products to 150 countries. Over the years, the industry hasn't only manufactured fireworks products but also contributed to the development of socio-economic of India. This industry manufactures over 100 products under 8 major categories such as sparklers, ground wheels, pin wheels, flowers pots, rockets, chakkars, fancy and novelty items. This industry is operated under ISO 14000 and ISO 9000 certification.

In the recent years, ABC has handled various challenges in fireworks industry because of the risks involved. The case industry is committed to implementing the best appropriate strategic policy to reduce the risks in fireworks. Therefore, they need to determine the most influential risks and alternatives in fireworks and need to understand the relationship between them to enhance its business efficiency in the trade market. The proposed AHP-COPRAS method is adopted to determine the relationship between risk factors in fireworks industry. Figure 2 depicts the graphical representation of the case study.

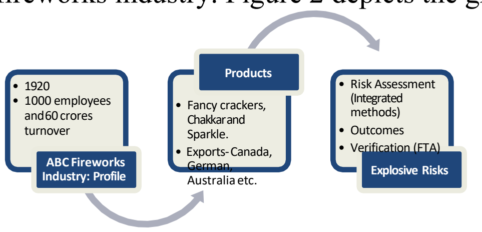

Fig 2. Graphical representation of the case study

The data was gathered via minor questionnaire (Refer Appendix B) from six industrial experts using the linguistic scale shown in Table 3. Four experts were selected from the case industry and two academic experts were chosen based on their intensity and experience. Six respondents were chosen based on the techniques of purposive sampling; where respondents chosen based on intensity and experience on this topic. The minor questionnaire was finished by one-to-one interview during this process. Lastly, the industrial expert's opinions and data gathered were analysed using the developed AHP-COPRAS method. In addition to this, FTA method is used to validate the obtained AHP-COPRAS results. The crisp procedure of the proposed method is defined below:

5. Result and Discussions

5.1 Outcomes of AHP-CORPAS

The radar diagram is built and the findings of the research are detailed below. As per Fig 3, hygroscopic reaction (FI7), Friction (FI3), safe disposal of fireworks wastes (FI13), Housekeeping (FI19) and

Adequate means of escape in case of fire (FI20) are the most influential explosive risks in the fireworks industry. The least influential risks are lightening (FI4) and Lack of personal protective equipment (FI14).

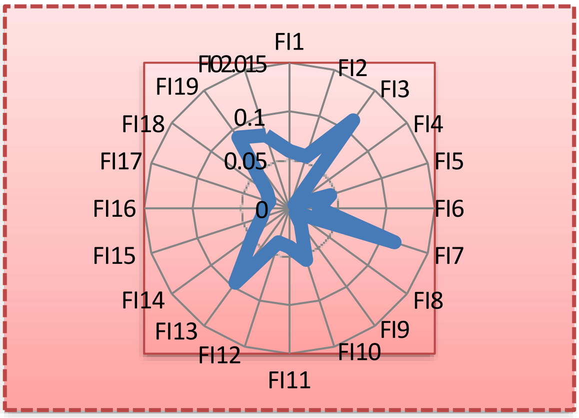

Fig 3. Radar Diagram for risk factor weights

All the top five risks are vital for managers in the industry for formulating strategies regarding risk mitigation to minimize the risks in the fireworks industry. The hygroscopic reaction takes the first one in the radar diagram, which refers to the water affinity of the chemicals. In other words, it is the phenomenon of holding and attracting molecules of water by either adsorption or absorption from the nearby environment, which is usually at room or normal temperature (Gangwar et al., 2017). In this case, some highly hygroscopic chemicals absorb moisture from the air and either react with it or decomposes. This is an undesirable reaction and often these reactions are exothermic, i.e., excess heat is evolved during this reaction (Ma et al., 2019). This excess heat liberated becomes a major safety problem. Therefore, using only distilled water and raw material should be in the purest form for controlling this risk. Friction is the second most influential risk with a weight of 0.112. It is a force that repels the relative motion among materials or two objects (Cao et al., 2020). Deformations, surface roughness and molecular adhesion, are the major cause of this resistive force. In the fireworks industry, some chemicals readily undergo exothermic reactions even under slight friction. During handling, chemicals are subjected to mechanical effects, which frequently give rise to friction forces (Sun et al., 2017). To avoid this risk, the floor should be covered by a rubber sheet and also material should be non-ferrous for mitigating the risk. Additionally, employees should be strongly advised to wear rubber gloves for mixing the chemicals. Next to friction, the safe disposal of fireworks waste is the third influential one in the case industry. Waste material in fireworks that present unusual problems in disposal (Bunn 2019). To overcome this scenario needs special waste handling techniques. In the case industry, daily wastes are gathered and scorched in an open pit. The machinery, process buildings and laboratories should be cleaned and swept earlier or at the end of every shift if necessary. The waste explosives and sweepings should be stored and properly gathered in a safe place. Therefore the industry should recruit a competent person for monitoring the safe disposal of wastes. The storage place should be supervised and controlled by a competent person and at a place permitted by the licensing authority (Duan et al., 2020). Hence, remnants and wastes should be removed from the industry, carefully gathered and destroyed by scorching under competent person monitoring and taking due precautions. As well as oiled waste, oiled rags or any articles related to spontaneous ignition should not be taken into any storehouse or magazine used for explosives storage. As per the radar diagram, housekeeping is the crucial risk that involves the systematic arrangement of equipment, tools, operations, supplies and storage facilities. Proper housekeeping empowers to get high production efficiency, personal relation and enhance employee's morale (Sridhar et al., 2013). In other words, housekeeping helps the management prevent and control accidents in the working environment (Eisenberg and Levanon 2013). Every employee's worked in the fireworks industry should be imparted training regarding safety by a competent person monthly during transportation, explosives storage, handling, manufacture, records and documents of such training shall be maintained. The safety officer, competent and qualified persons, the occupier should conduct training and workshops regarding safety to build the safety awareness and skill for their own and their sub-ordinates and record the same. Adequate means of escape in fire is one of the most influential risks in the fireworks industry based on the radar diagram. Poor located, unavailable exit facilities, obstructed or inadequate, can lead to a major life loss and injury caused to building inhabitants if an emergency should happen (Hagiwara and Tanaka 1994). In case the emergency may have low catastrophic, the resultant panic will be catastrophic if the employees find they are incapable of leaving. Therefore exit way should be a safe and better one. The buildings of high risky processes such as filling and mixing should have a blast wall of 20 centimeters of RCC ahead of doors at a space of 2 to 3 meters or 30 centimeters thick constructed of cement and brick (Langdon-Thomas 1963). The blast wall should be 0.4 meters broader than the door's opening on mutual sides and have an altitude of 3 meters. Therefore all buildings in the fireworks industry have at least three doors on two sides and have a free way of access to the working environment. As well as passage and floor ways should be made clear to avoid tripping accidents and easy to get out. Table 4 recaps the five most influential risks, rankings and their preventive measures.

Table 4. Five vital risks, their priorities and preventive measures

Risk	Priority	Preventive measures
Hygroscopic reaction (FI7)	1	Use only distilled water
Friction (FI3)	2	Floor should be covered by rubber sheet
Safe disposal of fireworks wastes (FI13)	3	Hire competent person for monitoring the safe disposal
Improper Housekeeping (FI12)	4	Need to implement 5S concept
Adequate means of escape in case of fire (FI20)	5	Put signage board for safe exit

The least influential risk in the fireworks industry is lightening with the weight of 0.006, which creates fire and heat in the mixing and loading shed. In this shed, a lot of aluminum dust is present, automatically creating fire and exploding (Jing 2010). A lightening arrester should be provided for controlling this risk. Lack of PPE followed by lightening is the second least influential risk in the fireworks industry. PPE is designed to prevent and protect the worker's body from infection or injury (Akbar-Khanzadeh et al., 1995). PPE is required when there are risks present. The purpose of PPE is to diminish employee exposure to risks when administrative and engineering controls are effective or not feasible to control these risks to low levels (Guseva Canu et al., 2013). Every worker in the fireworks industry should know all the necessary things regarding accident prevention and also the management should also provide proper tools that will not posture the issue. Working rooms are being not to be jammed and tools arrangements are very neat. For accident prevention, PPE is the last line of defense. So, workers need to wear PPE to prevent and protect their life in case of accidents.

Overall, to reduce the risks, the industry should follow health and safety procedures as indicated in Factories Act (1948). The government must take the necessary steps in assessing the policy and procedures of industrial safety.

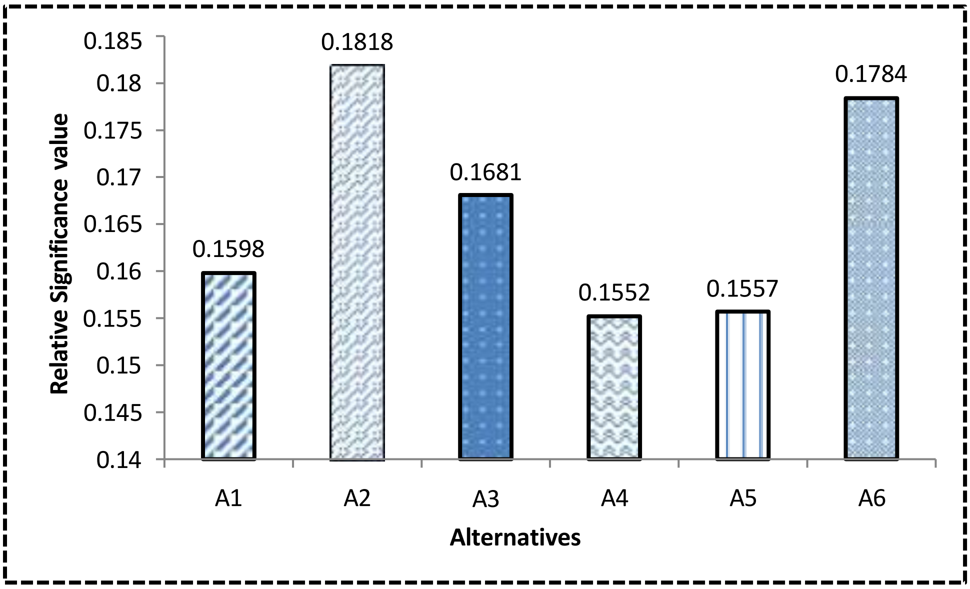

Fig 4. Alternatives Ranking

Human Error (A2) is the critical alternative in the fireworks industry, based on Figure 4. It is mainly due to overtime, working conditions, poor safety counseling, and awareness about accidents. In the fireworks industry, pleasurable working conditions continuously bring cheers in the working place and thus, workers are being engaged in their works happily (Abdollahpour et al., 2013). Employees are working without bored and any feeling of tired in the daytime. But they are engaged in overtime after their actual working time; surely, they will feel drowsiness (Chang and Woo 2017). During their overtime work, they are not capable of focusing on safety norms. Employees engaged in high-risk works such as filling and mixing usually work early morning between 5.00 am to 11.00 am. Better counseling is based on knowledge and communication skills, primarily by voice, by which one person's emotion can be communal with another person (Ghahramani and Khalkhali 2015). Safety counseling can give a worker comfort and reassurance by giving him the courage to handle confidence or issue that he is dogging a sequence of proper action. It includes an employee's change physic itself via a change in values and basic goals. Therefore, the fireworks industry should recruit a safety counselor to advise the employees if individual family problems and mental health influence them. It will assist the employee to work focus on their task and to avoid accidents. In addition to this, employees should be aware of bringing the successful, safe environment and how to control the accidents in the fireworks industry. The management should conduct training about major causes for the accidents and how to manage the chemicals safely. Finally, the management should be adopted some of the safety approaches such as counselling, training etc.
This research work has recognized five major risks as the most important: hygroscopic reaction, friction, safe disposal of fireworks wastes, improper housekeeping, and adequate means of escape in case of fire. The research findings differ significantly from fireworks risk ranking in various industrial segments. Recognized and investigated accidents cause risks in fireworks industries using factor analysis technic. They have found that supporting aids for safety, environmental conditions, and lack of awareness about accidents are the most dominant (Rajathilagam and Azhaguraj 2015). Evaluated risks in the fireworks manufacturing industries have determined that thermal effects, moisture, and improper handling turn out to be the most influential (Surianarayanan et al., 2008). Explored risks that created an explosion in the fireworks industry and concluded that the workforce lacks knowledge about handling chemicals and no proper education is the crucial one (Pandey et al., 2019).

5.2 Outcomes of FTA
In FTA, cut sets are a list of failure event which leads to the top event. Minimal cut sets are a list of minimal necessary and sufficient conditions for the occurrence of the top event. The alternatives were found out based on industrial expert's opinions and literature to cause an accident. Based on the numbers

and types of failures in the minimal cut sets, a person or team may recommend improvements that will make the top event less likely.

For instance,

Cut set 2: 2, 6

Cut set 5: 1, 2, 3

Both cuts set 2 and 5 shows basic event 2. Basic event 2 is human error. So the human error has occurred in both wet and dry mixing chemical rooms. Therefore, the industry should consider Alternative 2 to improve organizational performance in the fireworks industry.

5.3 Validation of results

The final stage of this research work is to verify the outcomes. The outcomes need to be valid and reliable for case industry. With the support of industry experts, the outcome's reliability was assessed. In this regard, we sent our outcomes to the industrial experts. Moreover, 200 industrial experts (both Male and Female) working for not less than 5 years from the fireworks industry were asked to express their opinions about the importance of outcomes and frameworks via discussion with other experts. Also, industrial experts put the rating for outcomes and frameworks in questionnaires via a five-point linguistic scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree and 5-strongly agree). The verification is acquired from industrial experts by sending the outcomes of this research for clarification and verifying the results with existing literature. After verification, outcomes are presented to the fireworks industry.

6. Implications to practices and theory

The prioritization and recognition of risks that generate explosions are a major concern for risk management in the Indian fireworks industry. The findings of this research work can guide managers in the industry to mitigate, assess and diminish the recognized risks in the fireworks industry.

6.1 Theoretical implications

The result of this research work gives some theoretical contributions to the present literature on fireworks. Addressing the negatively related risks and examining the inter-relations between risk and alternatives generates an explosion in the fireworks industry. Recognizing the crucial risks and alternatives of the fireworks industry via gathering the industrial expert's opinions and literature review. Developing a systematic and effective procedure of the present method ponders both the influence and strength of the risk factors. Growing the aware of a more effective method that recognizes the critical risks and alternatives to the case while considering the relationships of identified risk factors present in the fireworks. Proposing an integrated and comprehensive framework based on AHP-COPRAS and FTA methods to examine the identified risk factors. Assessing the risks in the case industry so that the industrial experts and managers can concentrate their effort to accomplish the production efficiency and organizational performance more efficiently. Giving preventive measures to managers in the industry for the risk management advancement by finding risks that impact each other. Giving supporting info to the industrial experts and managers to take environment-friendly decisions and financially sound at the time of risk happening.

6.2 Practical implications

The most influential risks found in this research have vital implications for diminishing risks and improving organizational performance, safety and security in the fireworks industry. Making industrial managers and employees have knowledgeable and skilled about risks and preventive measures regarding the explosion and also can assist in reducing risk in the case industry throughout the year. Sharing of knowledge about risks is significant in accomplishing organizational performance in a rising nation like India. This research work is expected to help industrial managers reduce risk and ensure production efficiency, organizational performance, and turnover. Managers can accelerate to implement the preventive measures for effective organizational performance. This research reveals that hygroscopic reaction is a threatening factor to sustain global and local competition and can result in proper or equipment damage, demise and loss of resources (Lin et al., 2019). Therefore, industrial managers can execute preventive measures and techniques in their operating system. If they can initiate preventive measures in their system, it will surely be fruitful to increase the organizational performance, safety, and security of the fireworks industry. This research work recognized major risks and alternatives and prioritized the successful pathways to improve organizational performance and safety in the Indian fireworks industry. The present research work cheers global and local stakeholders to implement organizational performance in the case industry by advancing security and understanding in a rising economy context. Shareholders put pressure on the case industry to improve safety using preventive measures to reduce adverse economic, social, and environmental effects. In addition, this research work serves as a benchmark study for several researchers to explore explosive risks in an Indian context.

7. Conclusions, Limitations and Scope for future work

An integrated AHP-COPRAS method is developed to find the inter-relationships between the recognized risks in this research work. Additionally, this research provides an important contribution to fireworks risk management and for creating strategies for risk mitigation to reduce identified risks. The outcomes found the inter-relationship and structure between the risks in the case industry. The results depicted that five risks are the most influential one. It was also clear from the results that hygroscopic reaction took the top position in the radar diagram, hindering safety and organizational performance. This risk has a high impact on turnover and production efficiency in the fireworks industry. Subsequently, lightening was prioritized as the least one in the radar diagram, which had a solid contribution to the contextual case. Other vital risks are friction, safe disposal of fireworks wastes, improper housekeeping and adequate means of escape in case of fire. The outcomes are helpful to recognized risks in the case industry. On the other hand, human error (A2) is the critical alternative that has occurred due to the lack of awareness on the safety systems. Additionally, to validate the obtained integrated method results, Fault Tree Analysis (FTA) was used in this research. Both integrated and FTA methods provided similar outcomes. The finding of the research work helps the fireworks industry in improving safety, diminishing cost, controlling risks and focussing on developing proficiency.

Further, eventually suggesting preventive measures and creating strategic decisions may assist experts in diminishing all risks and also improve organizational performance. The proposed integrated method can be used to analyze the interaction between risks, which can help industrial managers in risk-based decision-making to make the industry more secure and resilient. The proposed method and framework can evaluate the risks of various industries such as leather, polymer, apparel, textile, chemical, and create an effective framework for the expert's collaboration from various fields of knowledge.

A generic AHP-COPRAS method is presented for risk assessment in the fireworks industry. In this research work, the explosive case from India is chosen considerably to check the method and framework. The framework and methods would work for various nations as well. This framework is also expected to be beneficial and applicable to any national context to improve production efficiency. Additionally, this proposed framework can be executed in various industrial fields of various regions. At first, expert comments on explosive risks in a particular industry can be gathered by distributing the risks recognized in this paper to the industrial managers. Then, a Pareto analysis can be conducted to determine the vital risks related to the industry. Finally, industrial managers can use the integrated method to determine the inter-relationships between the recognized risks and alternatives for the policy-making towards the organizational performance. However, applying the framework in various contextual cases will generate various results because the risk is characterized by the geographic, natural, political, social, and economic factors in which the industry is operating.

This research work possesses some limitations. These limitations will give sufficient scope for future studies. For a case, this work focuses mainly on the risk factors from the operational perspective. However, emphasis has not been given on organizational perspective. Hence, in future, while evaluating risk factors in fireworks industry, organizational aspects have to be considered. Also, this study primarily focuses on only Indian fireworks industry while will not reflect complete scenario of an emerging economies. So, a cross-country study has to be carried out to get complete picture. Further, in this work, an integrated approach of AHP-COPRAS and FTA has been used. This work was completely based on expert feedback, which might lead to unbalanced and biased results. Various MCDM methods can be applied in future perspectives, such as SWARA-CRITIC, Fuzzy AHP- Fuzzy COPRAS and Fuzzy AHP – Fuzzy TOPSIS.

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