IoT Integrated Fire Prevention and Alert Systems for Garments Industries in Bangladesh

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Abstract

The garments industry in Bangladesh is a significant contributor to the country's economic growth. However, it faces severe challenges in terms of fire safety. Yearly fire-related incidents not only cause harm to individuals but also result in substantial economic losses. This paper addresses the insufficient fire risk assessment in the garments industry and proposes the implementation of an Internet of Things (IoT) integrated fire prevention and alert system. By leveraging IoT devices and their integration into fire safety systems, this solution aims to save lives, protect property, and preserve the environment.

Keywords
IoT; Garments; Safety Systems; Integrated Fire Safety

Introduction
The use of IoT in safety monitoring has been discussed in (Kabir 2021). In various studies, researchers have shown how connected smoke sensors, fire alarm panels, and other smart devices can enhance fire safety (Saeed et al. (2018); Imteaj et al. (2017); Listyorini and Rahim (2018); Victoria Yalli et al. (2021), Rahman et al.(2023)). Therefore, the application of IoT devices in fire safety systems, particularly in garment factories, can save lives. This paper aims to propose an integrated fire safety system for garment factories using IoT devices, based on a risk assessment process. The goal is to find an effective IoT solution that can minimize risks to workers and assets during fire evacuations. Developing a conceptual model for fire safety in workplaces with a large number of employees, such as garment factories, would greatly benefit the industry (Wu et al. 2018). This becomes crucial due to the inadequate safety standards and regulations exposed by previous incidents, which also raised concerns about the responsibilities of factory owners and local authorities (Rae and Provan 2019). Considering the significant contribution of the ready-made garments (RMG) industry to Bangladesh's GDP, substantial improvements in factory safety, particularly fire safety, are necessary.

Technological advancements, like the IoT, have brought significant changes to our lives. In the IoT paradigm, smart devices with unique identification are deployed to collect environmental data. These devices are connected to the Internet using advanced communication technologies to exchange information. The collected data is then processed to make intelligent decisions. IoT devices are widely used in various applications such as smart homes, smart cities, body networks, smart grids, and vehicles.

Revenue from the sale of RMG contributes substantially to Bangladesh's economic development, accounting for approximately 80% of its export revenues. The RMG industry also accounts for around 12% of the country's GDP and employs approximately 4 million people, with women making up around 85% of the workforce. However, the lack of fire safety measures in the workplace remains a major challenge for the industry. Therefore, enforcing safety regulations and implementing stricter monitoring can improve safety performance. However, it would require a substantial shift in the safety culture and approaches within the industry.Garment factories in Bangladesh have experienced numerous fire incidents, resulting in significant loss of life and assets. Even though some factories are modern, insured, and comply with fire safety regulations, they still lack proper fire safety protocols.

2. Background

Fire safety is a vital issue for the RMG sector in Bangladesh. Even though Bangladesh's garment industry has a history of industrial mishaps, the Tazreen Fashions fire in November 2012, which claimed the lives of 112 Bangladeshi garment workers, was the first time that local stakeholders and the international community paid serious attention to this issue.

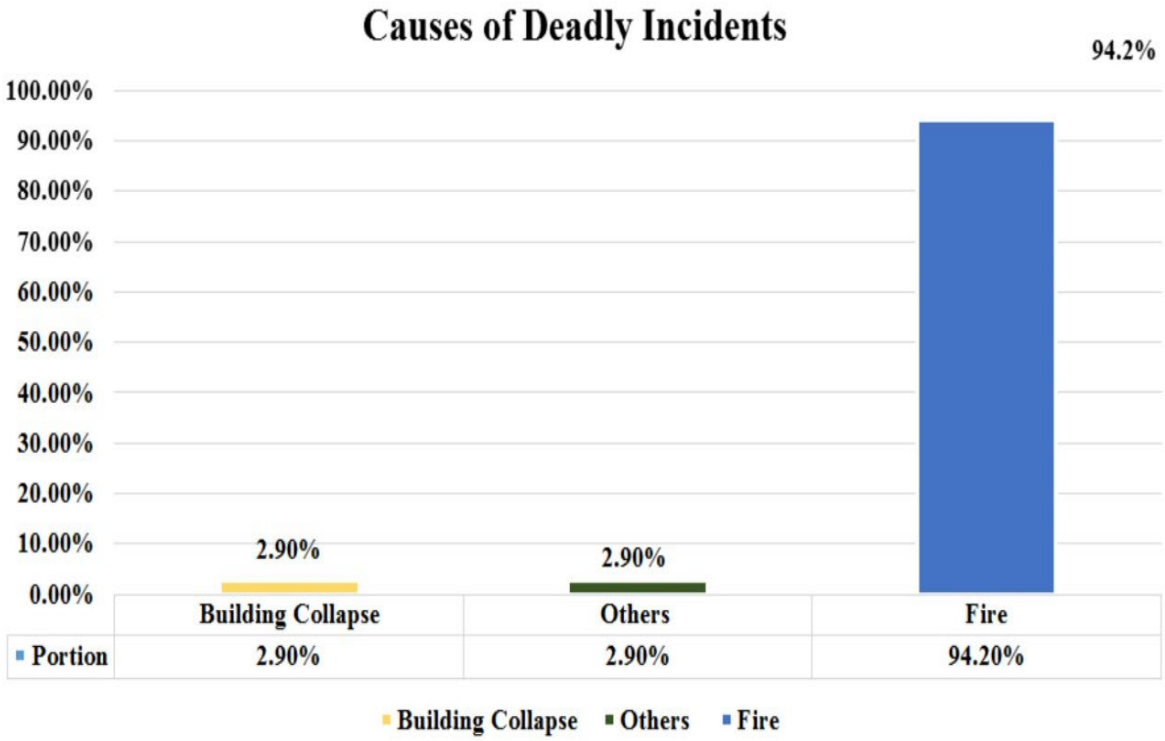

Figure 1. Causes of deadly incidents in the RMG sector of Bangladesh (Hossain, 2016)

As of January 2013, the Bangladeshi government has signed a statement of commitment to fire safety in the workplace with workers' organizations and employers' organizations. A few months after that, the Rana Plaza building collapsed, resulting in the deaths of 1,132 people and the injuries of over 2,500 others in April 2013 (Y. Kamal 2021). Because of this tragedy, the fashion industry's influence and desire for sustainable reform have become emblematic.

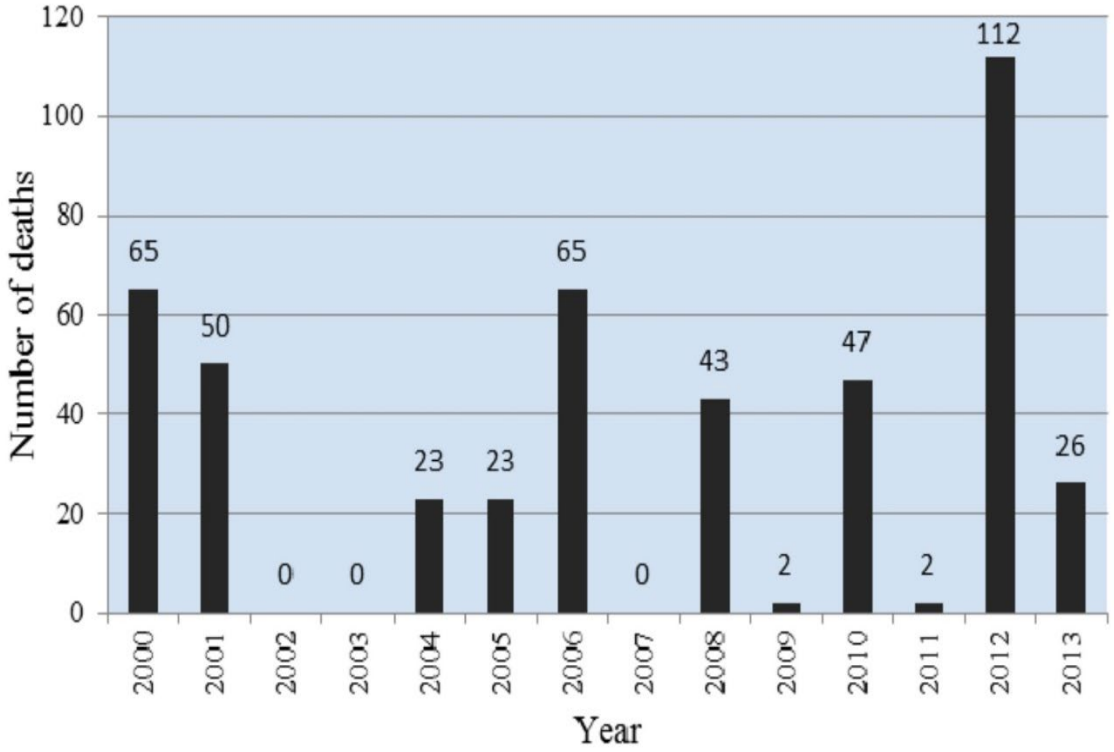

Figure 2. Number of deaths due to fire in RMG factories from 2000 to 2013 (Hossain 2016)

Concerns about the obligations of American and European corporations and governments that employ workers in Bangladesh and other low-wage marketplaces throughout the world have been raised by the collapse of the Bangladeshi garment industry. Companies frequently reduce manufacturing costs in an attempt to lower customer pricing. While effective fire prevention measures are applied in conforming factories, workers' concerns about the safety of their workplace are greater in non-compliant companies, and factory management takes fewer precautions in these facilities. Effective precautions are implemented to control fires in the compliant factories. However, the safety of their workplace is greater in the non-compliant garment industry because factory management takes fewer precautions in these facilities.

3. Risk Mitigation

Fire safety in garment factories can be achieved collectively. The risk of fire-related death can be reduced by implementing the following measures in industries such as garment factories.

3.1 Proper factory building plans

The factory facilities should be designed in such a way that employees can move freely throughout the manufacturing facility. The safety and workability of the production equipment and the provision of congenial working conditions for the personnel are drafted on different assignments of operation and supervision. As mentioned in (Vaishnavi 2021), "the factory building is the primary tool to carry on production and the one into which all other production tools and mechanisms must fit." When designing a manufacturing building, it is necessary to consider the requirements and importance of a fire prevention system. This has now become a requirement in the current environment. Fire protection systems range from conventional fire extinguishers to automatic IoT-based fire detectors and fire protection equipment in industrial settings (Kantarci and Mouftah 2014).

Table 1. Casualties and Damages in the RMG sector of Bangladesh from 2000 to 2013 (Hossain 2016)

Year	Nr. of accidents	Damages (in million BDT)	Property saved (in million BDT)	Nr. of injured	Nr. of deaths
2000	99	13.27	18.66	145	65
2001	67	15.16	18.40	176	50
2002	78	7.66	35.33	NA	NA
2003	102	4.81	21.89	NA	NA
2004	108	19.63	24.44	50	23
2005	76	88.51	118.09	130	23
2006	73	42.86	341.59	536	65
2007	326	4.16	58.36	NA	NA
2008	89	46.66	186.83	209	43
2009	293	99.11	377.99	150	2
2010	222	74.53	337.06	153	47
2011	175	16.69	121.08	64	2
2012	97	98.00	166.65	459	112
2013	28	9.0	NA	312	26
Total	1833	54.01	1826.43	2384	458

3.2 Efficient IoT-based Fire sensors

IoT-based solutions have revolutionized the mechanism in which real-world systems are interconnected via the Internet. A real-time detection and warning system has been added to the use of IoT-based technologies, which is currently being explored further (Liu et al. 2017)

3.3 Proper Monitoring

The main requirements for fire prevention system monitoring and notification are found in NFPA 101, Section 9.6.4.2 (Cote and Harrington 2012), which states that fire prevention systems necessary for any use must be equipped to automatically transmit warning of a fire alarm or other emergency to the fire brigade and the municipal fire department (if provided). In the event of a fire, timing is crucial. Therefore, a monitored fire alarm is a fail-proof system that reacts faster than the human brain does in the event of a fire.

3.4 Strict regulation

In general, fire safety legislation exists in practically every country, and standards such as ISO 13943 are widely used. Some are comprehensive and full, whilst others are incredibly simple, if not primitive in their presentation. The roots of nearly all of these laws are as diverse as the number of nations in which they are currently in operation.

When considering fire safety rules, ordinances, standards, and other similar legislation, we must take into account the vast number of factors and interests that are involved, many of which are beneficial, but many of which are antagonistic (Jun et al. 2014). It is recommended that every nation establish national fire safety objectives. The objectives of the following section must be quantifiable and derived from the Swedish Rescue Services Agency and co-financed by the European Commission, Civil Protection Unit under the Community Action Program in the field of civil protection (2000-2004).

- ❖ Involve all parties who have an interest.
- ❖ It is recommended that fire indicators be developed.

- ❖ National and local governments are encouraged to implement community fire safety initiatives.
- ❖ The tasks will be divided among the parties involved and will include, in addition to legislation and tactics, information, education, and exercises, among others.
- ❖ It is advised that the fire departments take the initiative in their respective communities. It is recommended that they divert their attention away from intervention and instead contemplate the big picture of the scenario in which they find themselves. It is recommended that national agencies provide support for such initiatives.
- ❖ It is proposed that national methods for data collection to be established. It is necessary to place greater emphasis on fire prevention and fire safety operations in such systems. Statistics are a valuable tool, but systems for collecting and disseminating findings from fire investigations are advised as a complementary tool. It will be necessary for the local authorities to gather and assess some of these facts. It is proposed that additional research to be done on this topic.
- ❖ Improvements in the exchange of information between countries (statistics, facts and other information). It is recommended that this be started with more modest goals than those of the current study. A network and meetings can be used to achieve this goal.
- ❖ It is proposed that lessons learned through response activities be applied to the prevention of many types of everyday mishaps. It is advised that we take steps in that direction.
- ❖ It is recommended that a voluntary network of national organizations be established.

3.5 Local Authority

Inspections, evacuation planning, and other critical emergency procedures are all required as part of every fire protection plan. Fire prevention systems assist users in staying organized when preparing emergency response procedures. From inspecting smoke detectors and sprinkler systems to maintaining personal protective equipment, fire prevention systems assist users in staying organized. The local authority is responsible for several important aspects of fire prevention regulation, including inspections of buildings to assess fire risk, administration of alarm systems, evacuation route planning, and other activities. The authorities are the fire safety department, Bangladesh Garment Manufacturers and Exporters Association (BGMEA), Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA), Accord and Alliances, local government, government labor department, ministry of business etc.

3.6 Adequate training

To avoid fire hazards and respond quickly in the event of a fire, workers need to be trained appropriately. If the proper instruction is not received, a tiny thing can rapidly become a large thing with serious implications. As a result, a fire puts everyone in the building at risk. Their working hours, location, or unfamiliarity with equipment may also put them at a greater risk of injury or death. Fire safety training teaches employees how to identify fire dangers, conduct a fire safety risk assessment, keep their workplaces safe, respond if a fire occurs and deal with emergencies.

3.7 Smart Fire Alarm System

Smart monitoring devices are composed of frameworks for sensing modules and communication modules, and they are designed to collect data from their surroundings and store the results on web servers. They are intended to provide consumers with an early warning of a crisis so that they can take appropriate action (Giandi and Sarno , 2018).

3.8 Improved Environmental Practices

In addition to better working conditions, new initiatives are much needed in the context of fire safety in industries. The fire safety risk assessment assists in determining what actions need to be taken at a workplace to prevent a fire and keep people safe from hazards. The assessment looks at:

- ❖ Emergency exits and routes.
- ❖ Fire warning and detection systems.
- ❖ Hazardous compounds should be removed from the environment or safely stored.
- ❖ Emergency fire evacuation procedures.
- ❖ The needs of those who are vulnerable to fire can communicate with other employees on the premises.
- ❖ Fire safety training for all members of the staff.

4. Integrated System with IoT

The proposed solution is based on IoT devices and related fire safety apps. Since it is an integrated system, it includes mobile apps, fire detection sensors, and an alarm system. In addition, it involves local authorities and local fire service departments and also an environment that can prevent fire-related deaths.

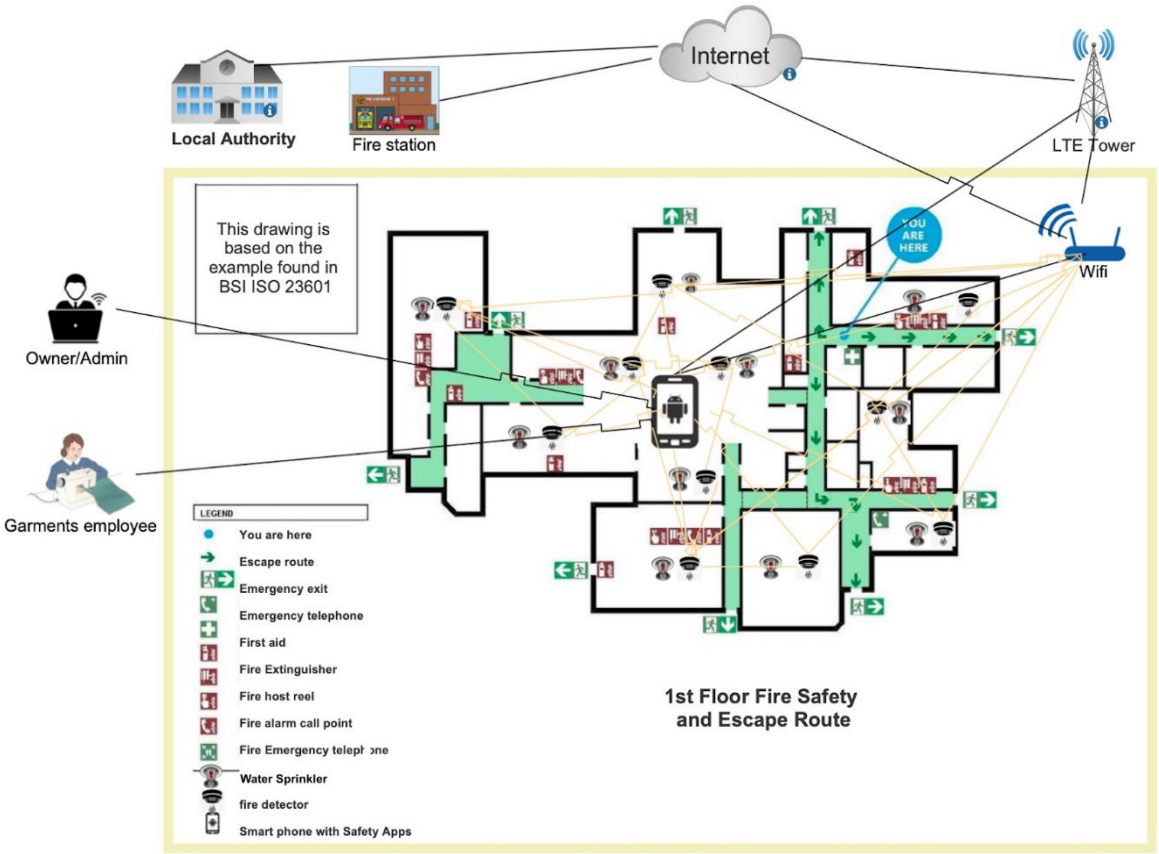

Figure 3. IoT Integrated Fire Prevention and Alert System (floor plan adopted from (IndiaMART, 2023)

4.1 System overview

The proposed system is shown in Figure: 3. In this system, all the sensors are interconnected via wired or wireless connections with backup battery power and also with a central router. The sensors can transmit data to the fire safety mobile application as well as the central router. The mobile application has several features. It has the ability to send or receive fire security data from nearby mobile app users, central routers, or data from a long-term evolution (LTE) network. The app has a built-in floor plan that includes an escape route, and an emergency exit door, and has the ability to generate a safe possible escape direction, notifying the fire service department and local authorities, as well as the owner and its staff.

4.1.1 IoT Devices

IoT-enabled fire safety system not only notifies us but can also play a vital role in keeping us safe in the workplace. A connected fire detector sensor is a device that is linked to another over the internet or cloud. Connected sensors share information concerning themselves, their surrounding environment, and their users (Jianfeng et al. 2009).

The fire prevention and alert system presented in this study is based on IoT and fuzzy logic, which identifies any fire that occurs in the vicinity. It is possible to share data between sensor nodes in a network that is connected to a database from the main system using IoT technology (Hanafi et al., 2020). The proposed system adopted the technology from Hanafi et al. (2020) that uses Arduino as the primary controller, which has the capability of transmitting notifications in real-time to the built-in fire detection system. Safe From Fire (SFF) is a self-contained smart fire extinguisher system that is combined with several sensors, actuators, and a microcontroller unit to provide self-control (MCU) (Mobin et al. 2016).

All of the input data acquired from the MQ-2 smoke sensor, the thermocoupling-K temperature sensor, and the flame sensor will be analyzed by the system, which will use fuzzy logic to do so. Fuzzy logic was used to process the results from all of the sensors at the same time. The output of the fuzzy logic algorithm is separated into three categories: danger, warning, and safe circumstances (Hanafi et al. 2020). Then, using IoT technology, the NodeMCU, which is responsible for transmitting signals and remote information, will send the current circumstances to a cloud server, as well as to local sensors and mobile apps, among other places.

4.1.2 Smart Water Sprinkler

The smart Water sprinkler system will be activated when the temperature of a room reaches 57°C. A scanning infrared pyrometer should be activated immediately if it detects a fire. A 50mm-deep wall-box incorporating a movable infrared sensor is used to detect the warmest place. Then, pumps are installed in the unit to disperse the mist. The pump has a vertical blade that spans water around 32 square meters at a rate of 5.6 litres per minute. Using mist droplets, it is possible to extinguish pan flames and access hard-to-reach areas of a production building. During a fire, the system can minimize heat. The water mist reduces the oxygen concentration in a hazard zone, which allows workers in danger to navigate burning facilities. With the battery backup, the new smart water sprinkler system will work even if the building's energy is cut off or unavailable. It operates faster, more reliably and causes less water damage to the property.

4.1.3 IoT-enabled fire detector

Temperature sensors are currently set up to detect normal temperature ranges. However, if we use special heatproof sensors together with other sensors, we can detect the temperature of a fire. This would allow firefighters to adjust their equipment and tactics according to the severity of the fire. Knowing the precise location of a fire in a building is extremely valuable. IoT sensors can not only determine where a fire started but also track its spread and speed. This information will be transmitted to fire crews simultaneously with the emergency call. The safety system will provide crucial data to the local fire department's computer systems, enabling them to organize an appropriate response. Additionally, a voice alarm system could guide people to the safest evacuation routes based on the fire's path.

4.1.4 Fire Safety Mobile App

The proposed fire safety app offers various features to ensure workplace safety. It helps identify potential risks and prevents false alarms by monitoring smoke detection signals. One of its key functions is guiding workers and employees to safe evacuation routes in case of a fire. The app displays the most suitable exit paths and may suggest waiting in a safe area until the rescue team arrives. If a passage or exit door is blocked or smoke-filled, alternative exits such as door D/E are recommended as the safest option. If all doors are affected, the app suggests finding a

window or another secure location to wait for the rescue team, while also sending the user's location to the authorities. Additionally, the app guides fire safety regulations during these critical situations.

Apart from its features, the fire safety app offers multiple connectivity options. It will be available for download on both the Google Play Store and the Apple App Store. The app ensures a safe working environment by verifying the presence and proper functioning of fire suppression equipment, along with strict adherence to fire safety regulations (Wang et al. 2020). It can directly receive notifications from fire detection sensors using Wi-Fi or Bluetooth, and it can also send fire alerts to nearby app users through these connections. Furthermore, the app can send fire notifications to a cloud server, notifying relevant authorities. In an emergency, the app sends SMS messages or pre-recorded voice calls to various stakeholders, including garment workers, owners, local authorities, and the fire service department. It can also send alarm messages to an assigned email address when a smoke detector is triggered in a garment factory. The primary goal is to keep all stakeholders informed about the situation.

4.2 Fail-safe System

If any of the sensors stop working, the nearby sensors can detect this and inform the system administrator. The system itself can recognize sensors that are experiencing problems by communicating with them. In case there is an obstacle on the escape route or emergency door, the sensors can detect it and inform both the system administrator and the local authorities. If the cloud application server of the app is not working, it can still communicate with other nearby mobile phones through Bluetooth or Wi-Fi connection.

5. Conclusion

There are many casualties and damages to both people and property in Bangladesh as a result of fire incidents. However, we can minimize or prevent such losses by employing technology, implementing fire prevention policies, raising awareness about fire safety, providing training, promoting moral ethics, and enforcing rules and regulations through relevant authorities. To address this issue, a system that combines the IoT with fire prevention and alert capabilities is being proposed. The primary objective of this system is to save lives and prevent property damage. Currently, this integrated system is in the conceptual stage, but efforts are underway to transform these ideas into a fully operational system. The goal is for the software version of this system to effectively reduce fire-related losses in garment factories throughout Bangladesh.

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Biographies

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