Indoor hazards management using digital technology

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Abstract. Management of indoor hazards constitutes a great challenge for buildings design, construction and operating. The question is how to reduce both buildings vulnerability to indoor hazards and the impact of the latter on occupants and buildings integrity. Indoor hazards could result from different source such as fire, air pollution, water and gas leak, domestic accidents, appliances hazards, intrusion and break-out. Standards are already established for safety buildings design. However, in the operating phase, both occupants and buildings managers are subjected to serious indoor hazards, which could lead to significant human and material damages. The development of the digital technology such as Internet of Things (IoT), communication technology, indoor smart monitoring and Building Information Modeling (BIM) offers a great opportunity to improve indoor safety. This paper presents the indoor hazards and how the smart technology could help in improving the indoor hazard management.

1. Indoor hazards

Hazard concerns any source of danger that has the potential to cause harm and damage to human beings, property and environment. Some of the potential hazards are associated with natural phenomena as flood, earthquakes, climate change, landslides, and storms. This paper concerns indoor hazards, which could be related to technical, environmental and human factors such as fire, pollution, water and gas leak, domestic accidents, appliances hazards, intrusion and breakout. These hazards could cause serious human and material damages. The following sections describe the main indoor hazards.

1.1 Fire hazard

Fire constitutes a major dangerous threat that can affect constructions and cause tremendous losses in life and property damages. Fire in Stephen Court historic building in India caused more than 50 deaths [1]. Fire killed also 72 people in an industrial building in Philippines [2]. Electrical short circuit in Baldia garments factory killed more than 250 people [3]. According to the U.S. National Census of Fatal Occupational Injuries, around 2.5% of indoor injuries in 2017 were caused by fire and explosions [4].

1.2 Indoor air pollution

Indoor air pollution could cause serious disturbance to occupants' comfort, health and productivity. It results from various factors such as combustion appliances, central heating and cooling system, tobacco, building materials, furnishers, household cleaning and maintenance products, excess moisture and outdoor air pollution. Indoor pollutant concentrations could remain for long periods. In Kolkata, toxic fumes diffusion over the ducts of the central air conditioning system in the AMRI hospital killed around 90 persons [5]. Studies conducted by the U.S. Environmental Protection Agency (EPA) stated that poor indoor air quality could cost tens of billions of dollars each year in occupant's productivity and medical care [6].

1.3 Water and gas leak

Water and gas leaks result from pipes or appliances deficiency. Water leak could be characterized by two types: slow leak caused by water that escapes continuously due to poor maintenance, and leak caused by freezing where the water flow may be slow or no flow at all. Water leak generally leads to serious damages for both the construction and furniture; while gas leak could result in fire or occupant intoxication. Ritz Barth, vice chairman of the European Water Partnership (EWP), stated that each year water leak costs Europe around €80 billion [7].

1.4 Domestic accidents

Domestic accidents could result from different factors such as falling objects, falls, cuts, burns, electrical chock, choking, drowning, poisoning by medicines, household or cosmetics products. These accidents concern different categories of occupants, in particular children, old people and people with disabilities.

1.5 Domestic appliances faults

Domestic appliances could present a high risk for occupants and constructions if they are improperly installed or maintained. The most common risk related to domestic appliance are fire, electric shock and gas emissions. They could result from bad installation, poor maintenance, bad usage as well as children inattention and "curiosity".

2. Use of smart technology for indoor hazards management

Since the indoor hazard concerns a multitude of issues, this proposed an integrated system that uses digital technology for the indoor hazards management. The following sections present successively the integrated system, the use of BIM as a platform for indoor hazards management and finally a state of the art concerning the use of smart sensors for indoor safety.

2.1 Integrated indoor hazards management system.

The suggested indoor hazards management system is presented in figure 1. It includes the following layers:

- Information layer, which provides data and information for both occupants and buildings managers concerning buildings' architecture and space organization, sources of indoor hazards and their potential impact on human, constructions, safety, security equipment and procedures.

- Indoor monitoring layer, which allow to follow in real-time the indoor conditions (temperature, air quality, humidity…), equipment functioning, buildings access and vulnerable people activity such as children, elder people and people with disabilities.
- Early hazard detection layer, which offers capacity to early detect indoor hazards and to take early actions to confine the hazards, to alert concerned people, authorities and to organize emergency actions.
- Learning Layer, which allows authorities and communities to learn from hazards events to improve their capacity in indoor hazards management.

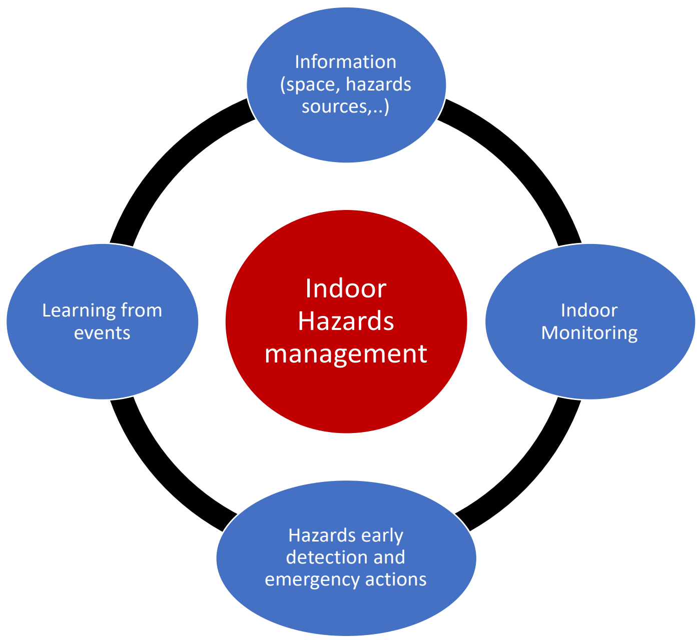

Fig. 1. Integrated system for indoor hazards management

2.2 Use of BIM for indoor hazards management

An important feature of the integrated indoor hazards management system concerns the spatial, temporal and semantic management of buildings components, safety equipment and procedures management as well as the interaction with occupants, buildings managers and emergency services. The BIM technology offers high capacity to meet these requirements [8]. BIM is characterized by its 3D model integration, parameterized constituent and design, its capability in analysis and simulation, database and information synchronization. It provides a 3D full description of the building architecture, space organisation, buildings equipment, emergency access and equipment and construction material. A safety layer could be easily built in the BIM model to gather data and information concerning indoor safety in a 3D graphic environment. The BIM model will provide the building architecture, safety equipment location as well as user manuals, maintenance guides, emergency access and sensors used in safety monitoring as well as real-time readings.

2.3 Smart monitoring

A) Smart sensors

A high number of smart sensors are available for safety monitoring as illustrated in figure 2. The following sections describe the main sensors used in this field.

Indoor comfort: Temperature, humidity, air quality, brightness and noise sensors are used to track the indoor environment. They transmit information at short time interval (few minutes) to the indoor hazards management system. This system can detect easily violation of safety conditions (pollution, fire, etc.) and take the appropriate actions to alert occupants and authorities.

Occupancy and access control**:** Cameras as well as occupancy and contact sensors are used to monitor buildings' access and occupancy and to detect illegal intrusions.

Geolocation: Different technologies are used for outdoor and indoor localisation such as GPS, smartphones, RFID tags, cameras, and electronic bracelets.

Fire detection**:** large variety of sensors are used for fire detection such as optical smoke sensors, video-based smoke and flame sensors, smoke gas sensors, temperature sensors and electrostatic sensors.

Electrical fault**:** Current, voltage and temperature sensors are used to detect electrical faults together with advanced analysis tools for electrical fault diagnosis; automatic electronic switches are used to shut down electrical supply in case of electrical fault.

Water and gas leak: Pressure, flow and air quality sensors are used to detect water and gas leak; flood sensors are used to detect indoor flood; electronic valves are used to stop water and gas supply in case of leak detection.

Devices control**:** A large range of sensors could be used for devices control such as current, tension, flow, pressure, air quality, temperature and RFID. Based on date transmitted by these sensors, both engineering algorithms and Artificial Intelligence could help in early fault detection in domestic devices.

B) Monitoring implementation

The following sections present some examples of monitoring implementation of the digital technology for indoor safety.
Lorincz et al. (2004) suggested to use Wireless Sensor Network (WSN) with handled devices for emergency in CodeBlue building [9].
Lam & Srivastava (2005) presented an Intelligent Workplace, which was used to record and evaluate operational performance of building mechanisms and user comfort. It was used in smart building [10]. Alahmad et al (2011) used advanced integrated real-time monitoring system to track electrical usage in buildings using BIM [11].
Ochoa & Santos (2013) used the theory of "human-centric" with WSN to capture and deliver information to increase the effectiveness of emergency protocol [12].
Marzouk & Abdelaty (2014) proposed an integration between BIM-based models and facility management process using WSN for detecting temperature and humidity in a subway [13].

Marzouk et al. (2015) presented an interesting example concerning a multifunctional building (offices, laboratories, lecture hall) in Riyadh City. This example included comparison of sensors records and the thermal simulation for a building using as-build BIM model. Each space was defined according to its function and based on the function the settings were adjusted. After the building was located on the map in its accurate location using Google Earth, the weather file was attached to the 3D model and the solar path was defined based on the building orientation. The critical spaces were identified due to their affection with external environmental changes. Energy analysis was used to monitor the efficiency of the building regarded energy usage and carbon emissions [14].

Cheung & Lin (2016) used Safety Monitor System to monitor hazard gases emission in a building located in northern Taiwan. Furthermore; this system could be used for additional functions such as humidity and temperature measurements [15].
Cheng et al. (2017) indicated that an integrated system must adopt a BIM-based interface that interacts with Bluetooth, wireless networks and other sensors to provide the following data (a) Environmental Perception, (b) Fire sense, (c) Locating/Evacuation Rescue, (d) Fire location and (e) Global information [16].

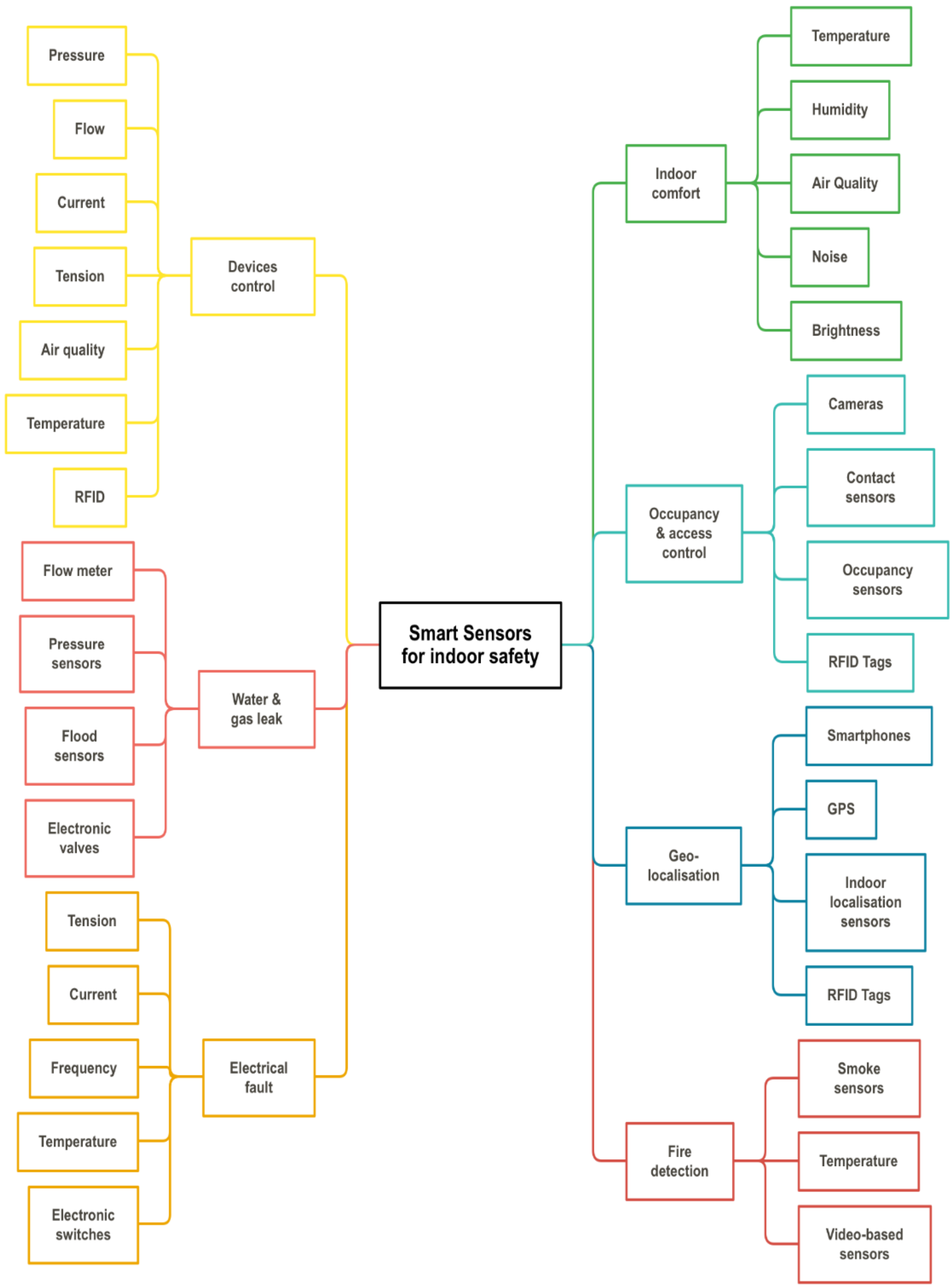

Fig.2. Sensors used for indoor safety

3. Conclusions

Indoor hazards management constitutes a great challenge for both occupants' and constructions safety. Standards are used in buildings design for safety purposes. However, in the daily life, occupants are subjected to a wide range of indoor hazards such as fire, pollution, water and gas leak, domestic accidents, appliances faults, intrusion and breakout. Indoor hazards concern more particularly low-income occupants living in poor quality buildings. This paper presented how the digital technology could help in meeting the challenges of indoor hazards. A literature review showed the availability of a wide range of sensors and technologies to improve indoor safety. However, they are generally used in a segmented way. Since the indoor safety concerns a multitude of issues and technologies, this paper proposed an integrated approach that uses the BIM technology together with smart sensors and advanced communication technology to set up a holistic safety system for indoor safety. Work is under progress to implement this approach in some buildings.

References

1. Business Line. (2012). Fire breaks out in Stephen Court building. Retrieved from Business Line: https://www.thehindubusinessline.com/economy/Fire-breaks-out-in-Stephen-Court-building/article20424284.ece.
2. Galvez, D. (2018). Fire hits industrial building in Valenzuela City. Retrieved from Inquirer.net: https://newsinfo.inquirer.net/1061938/fire-hits-industrial-building-in-valenzuela-city.
3. Tunio, H. (2012). Baldia factory fire: Short circuit, all of Karachi to blame for tragedy, says tribunal. Retrieved from The Express Tribune: https://tribune.com.pk/story/474798/baldia-factory-fire-short-circuit-all-of-karachi-to-blame-for-tragedy-says-tribunal/.
4. Bureau of Labor Statistics. (2018). National Census of Fatal Occupational Injuries in 2017. United States of America: United States of America, Department of Labor.
5. Dutta, A. (2011). At least 89 killed in Kolkata hospital fire. Retrieved from Livemint: https://www.livemint.com/Politics/tZcRjGyGk5F5HH2eVMKcqN/At-least-89-killed-in-Kolkata-hospital-fire.html
6. United States Environmental Protection Agency (1997). An Office Building Occupant's Guide to Indoor Air Quality. Washington, DC: EPA.
7. Moriwaki, A. (2015). Water, Water, Leaking Everywhere. Retrieved from theBIMhub: https://thebimhub.com/2015/07/03/water-water-leaking-everywhere/#.XE49MlwzbIV.
8. Bowden, S., Dorr, A., Thorpe, T., & Anumba, C. (2006). Mobile ICT support for construction process improvement. Automation in Construction, 664-676.
9. Lorincz, K., Malan, D., R.F, T., Jones, F., Nawoj, A., Clavel, A., Welsh, M. (2004). Sensor Networks for Emergency Response: Challenges and Opportunities. IEEE Pervasive Computing, 16-23.
10. Lam, K., & Srivastava, V. (2005). Living in the Intelligent Workplace Structuring and Managing Building Operation Information. Proceedings of the Fifth International Conference for Enhanced Building Operations. ESL.

11. Alahmad, M., Nader, W., Brumbaugh, A., Cho, Y., Ci, S., Sharif, H., Neal, J. (2011). The "BIM's 4D+" dimension: Real time energy monitoring. IEEE GCC Conference and Exhibition (GCC), 589-592.
12. Ochoa, S., & Santos, R. (2013). Human-centric wireless sensor networks to improve information availability during urban search and rescue activities. Information Fusion.
13. Marzouk, M., & Abdelaty, A. (2014). BIM-based framework for managing performance of subway stations. Automation in Construction, 70-77.
14. Marzouk, M., Abdelbasset, I., & Al-Gahtani, K. (2015). Tracking Indoor Air Quality of Buildings Using BIM. 5th International/11th Construction Specialty Conference. Columbia: CSCE.
15. Cheung, W.-F., & Lin, Y.-C. (2016). Development of BIM-based Safety Monitoring System Integrated with WSN Technology. 601-608.
16. Cheng, M.-Y., Chiu, K.-C., Hsieh, Y.-M., Yang, I.-T., Chou, J.-S., & Wu, Y.-W. (2017). BIM integrated smart monitoring technique for building fire prevention and disaster relief. Automation in Construction, 14-30.