Model for Smart, Self-learning and Adaptive Resilience Building

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Abstract

Purpose – This article's purpose is to develop The Model for Smart, Self-learning and Adaptive Resilience Building (SARB).

Design/Methodology/Approach – Products and patents of methods and systems analysis was carried out in the fields of BIM application, Smart, Self-learning and Adaptive Resilience Building. Based on other researchers' findings, The SARB Model was proposed.

Findings – Analysis of the literature showed that traditional decisions on the informational modelling do not satisfy all the needs of smart building technologies owing to their static nature. The SARB Model was developed to take care of its efficiency from the brief stage to the end of its service life.

Research Limitations/Implications – The SARB Model was developed to take care of its efficiency from the brief stage to the end of its service life. The SARB Model does have some limitations: (1) the processes followed require the collection of much unstructured and semi-structured data from many sources, along with their analyses to support stakeholders in decision-making; (2) stakeholders need to be aware of the broader context of decision-making and (3) the proposal is process-oriented, which can be a disadvantage during the model's implementation.

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Practical Implications – Two directions can be identified for the practical implications of the SARB Model. The initial expectation is the widespread installation of SARB Model within real estate and construction organisations. Furthermore, development of the SARB Model will be used to implement the ERASMUS+ project, "Advancing Skill Creation to ENhance Transformation—ASCENT" Project No. 561712-EPP-1-2015-UK-EPPKA2-CBHE-JP.

Originality/Value – The practical implications of this paper are valuable.

Keywords Smart, Self-learning, Adaptive, Resilience, Building, BIM

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1. Introduction

The rapid development of information and communication technologies (hereafter – ICTs) in the world has opened up broad possibilities for their use in the construction sector. These have an essential impact on this sector, increasing its efficiency and competitiveness and improving the quality of construction and its management. One of the fundamental decisions related to the application of ICT in the construction sector and its rapid implementation in the world regards application of methods relative to digital construction principles and Building Information Modelling (BIM). The use of ICT in Europe's construction sector has grown rapidly in recent years. Numerous digital technologies are now accessible in the areas of construction, planning and management of buildings and they increase the competitiveness of companies.

Many researchers have analysed BIM application capabilities (Scherer and Katranuschkov, 2018; Bosch-Sijtsema *et al.*, 2019; Lu *et al.*, 2017; Habibi, 2017; Kamel and Memari, 2019; Hoseini *et al.*, 2017; Gerrish *et al.*, 2017; Röck *et al.*, 2018). For example, Lu *et al.* (2017) analyzed applications of BIM in supporting green building lifecycle process. Kamel and Memari (2019) reviewed a BIM's application in energy simulation. Gerrish *et al.* (2017) analyzed BIM application to building energy performance visualisation and management. Many researchers also have analyzed the application of multi criteria analysis methods in the BIM area (Guo and Wei, 2016; Oti *et al.*, 2016; Oti and Tizani, 2015; Chen and Pan, 2016; Pavlovskis *et al.*, 2017; Park *et al.*, 2017; Amiri *et al.*, 2017).

There is a big need in the world to extend the use of BIM, to link design and construction with the area of building management. It is important that the building information collected during the first stages of the building's life will be maximised and adapted to the stage of use of the building, since the BIM models are of great value and provide maximum benefits during asset management (Liu and Issa, 2012).

In this case, Model for Smart, Self-learning and Adaptive Resilience Building (SARB) were developed over the course of the ACSENT project No. 561712-EPP-1-2015-UK-EPPKA2-CBHE-JP research. To design and realise a high-quality SARB, it is necessary to take care of its efficiency from the brief stage to the end of its service life. The entire process should be planned and executed with consideration of the goals aspired to by the participating interested parties and the micro, meso and macro environmental levels. To realise the above purposes an original SARB Model and its smart BIM objects was developed by the authors to enable users and the parties involved in the project to analyze a SARB's life cycle, as well as to be able to see its micro, meso and macro environments as one integrated entity.

This paper is structured as follows: the Introduction; Section 2 presents products and patents of methods and systems analysis; Section 3 describes the Model for Smart, Self-learning and Adaptive Resilience Building (SARB); Section 4 describes the innovativeness of SARB Model; and finally concluding remarks in Section 5.

2. Products and patents of methods and systems analysis

There are a number of Building Management Systems (BMS) that are developed and used in smart buildings. These systems are manufactured and distributed by Carel, Regin, Danfoss, Remak, Honeywell, Siemens Systemar, VTS, Jung and many other companies. However, these systems are not linked to BIM.

Autodesk (U.S.), AVEVA (U.K.), Bentley Systems, Incorporated (U.S.), GRAITEC (France), Intergraph Corporation (U.S.), Data Design System (Norway), IES Ltd. (U.K.), 4M Building Solutions (U.S.), Nemetschek Group (Germany), Trimble Inc., (U.S.) are some of the prominent players and are at the forefront of competition in the Global Building Information Modelling (BIM) Market (Zion Market Research 2017). Most of these companies offer BIM solutions for building design and construction phases, but only a small percentage for exploitation stage. Examples of the proposed similar to SARB Model products are presented in Table 1.

Similar patents have also been analyzed (see Table 2).

Based on the analysis, there is no integrated solution, as proposed by SARB Model, developed worldwide.

3. Model for smart, self-learning and adaptive resilience building (SARB)

The purpose for using SARB is to increasing of the disaster life cycle management of buildings at micro, meso and macro environmental levels. To solve this problem the novel, adaptive to the market Model for Smart, Self-Learning and Adaptive Resilience Buildings

Company	Product	Attributes
Bentley Systems, Incorporated	Asset Performance Software Asset Lifecycle Information Management Software Asset Reliability Software AssetWise Operational Analytics	The proposed products are tied to BIM and are intended for the management and maintenance of the equipment throughout the life cycle of the building. Cloud and IoT technologies are used to manage information flow
Nemetschek Group	Intelligent management of real estate	Company focuses on IT solutions for the administration of complex, commercial real estate portfolios. In addition, it offers software solutions for the management of housing associations and major building administrators as well as comprehensive computer-aided facility management (CAFM)
U.S. Company “Planon”	Facility Management Software	The company develops and installs a building space and workplace management solutions with an integrated BIM model. This solution is intended for effective management of workplaces. The main benefits of the proposed product are the efficient allocation of jobs, allowing employees to move around in the premises more easily and quickly
“FM systems”	FM Management Software	The company offers BIM solutions for managing building spaces, building services, and improvement of building design and construction phases

Table 1. Products Offered

Patent number	Title	Description
CN 104573231 A	BIM-based smart building system and method	The invention provides BIM-based smart building system and method. The system comprises a data acquiring storing module, a data processing module and a data outputting module; the data acquiring storing module is used for acquiring building data including construction data and device data; the data processing module is used for processing the building data to obtain processed data; the data output module is used for outputting the processed data and displaying the processed data through a BIM model. The system has the beneficial effects that (1) the building is displayed by a three-dimensional visual manner; (2) various information for operation maintenance of a building are highly integrated to achieve automatic information management; (3) the Internet of Things is put into use to ensure the data accuracy and timeliness as well as the accurate control for construction devices; and (4) a non-relational database is used to greatly improve the concurrent reading and writing operation of big data. This method and system can create long-term solutions for users and integrate them into day-to-day customer engagement in order to use green energy and create a safe, convenient and comfortable environment
US 20170123386 A1	Method and apparatus for determining information for building information modelling	The present disclosure relates to a sensor network, Machine Type Communication (MTC), Machine-to-Machine (M2M) communication, and technology for Internet of Things (IoT). The present disclosure may be applied to intelligent services based on the above technologies, such as smart home, smart building, smart city, smart car, connected car, health care, digital education, smart retail, security and safety services
US 20160335731 A1	System and method for monitoring and managing information	A system and related method has a database that stores information indicative of a plurality of assets that are used in a building or system. A user interface of the system enables identifying a group of such assets and associating a portion of the assets with the identified group of assets. The assets included in the identified group of assets may collectively be located in different rooms of a building in which the assets are located and/or on different floors of a building in which the assets are located
US 20140371936 A1	System and methods to aggregate instant and forecasted excess renewable energy	Systems and methods dynamically measure, ascertain, and compare a local facility load with local renewable energy generation in substantially real time and determine whether excess energy exists from the local distributed renewable energy resource. Further, systems and methods forecast the available excess energy from the local distributed renewable energy resources for acquisition to third parties. A pulse width modulation (PWM) controller permits delivery of acquired increments of the available excess renewable energy

Table 2.
Patents of Methods and Systems

Patent number	Title	Description
US 20160117917 A1	Physical and Logical Threat Analysis in Access Control Systems Using BIM	An apparatus including a building information model (BIM) of a secured area having a plurality of different portions, the BIM embodied in a memory, a processor that identifies portions of the secured area having different levels of security and a processor that alerts a user of a security weakness based upon an interaction between the security levels and physical characteristics of the secured area defined by the BIM
US 9516281 B1	Systems and methods for automated cloud-based analytics for security surveillance systems with mobile input capture devices	Systems and methods for cloud-based surveillance for a target surveillance area are disclosed. At least two input capture devices and at least one user device are communicatively connected to a cloud-based analytics platform. At least one input capture device is a mobile device with visual sensors. The cloud-based analytics platform automatically analyses received 2-Dimensional (2D) video and/or image inputs for generating 3-Dimensional (3D) surveillance data and providing 3D display for a target surveillance area

Table 2. (*Continued*)

was developed (see Figure 1). The developed SARB Model allow real-time analysis of the building's disaster life cycle, evaluate the needs of users, create neuromatrixes and, based on them, would provide recommendations to building managers, users, builders and designers for resilience.

Different smart BIM objects are constitute the Model of a Smart, Self-learning and Adaptive Resilience Building (see Figure 2):

- Warnings and information subsystem. Subsystem would alert resident to potential issues in his/her area and around their home; warn homeowners when severe weather, such as tornadoes or flash floods; alert friends and contacts if help is needed and pick up alerts from news sources.
- Advisory subsystem. Advisory subsystem would provide immediate tips regarding transport, temporary shelter and food.
- Smart home devices subsystem. Smart home devices like water sensors would send alerts if water levels are rising in homes either through a water leak or even through

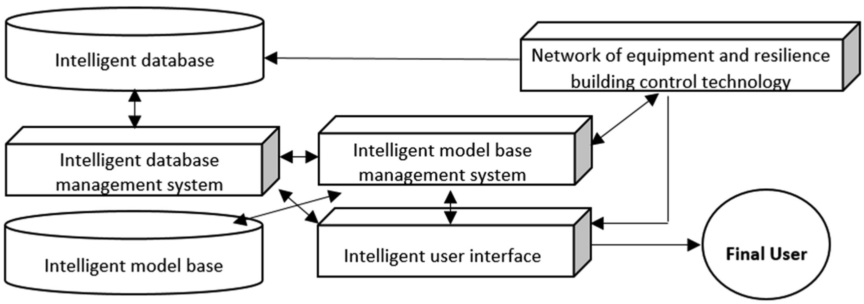

Figure 1. Architecture of the SARB Model

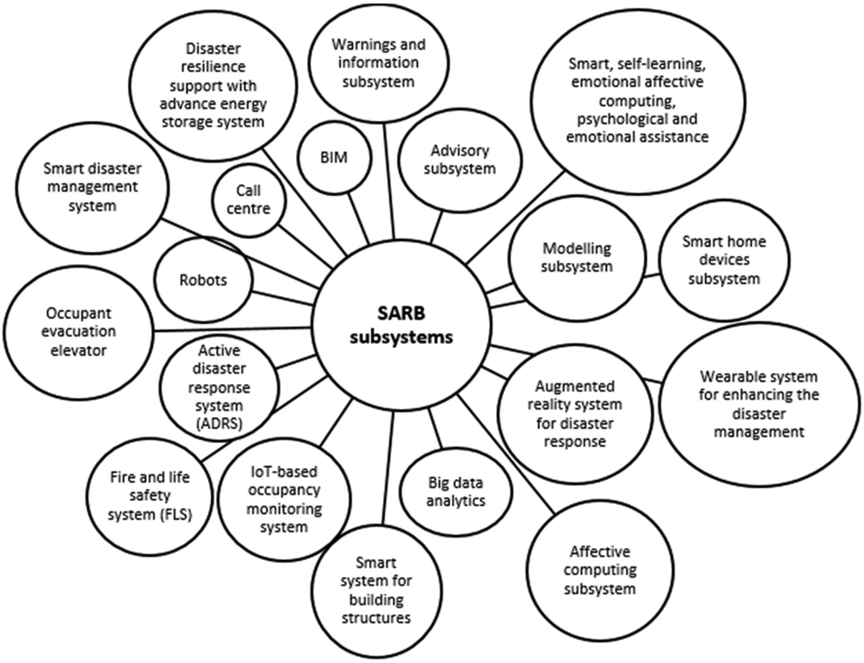

Figure 2.
Smart BIM Objects

a natural disaster. Those installed in vacation homes could keep his/her updated if those spaces have weathered potential water damage from a hurricane or not.

- Big data analytics. Big data analytics would accumulate data from various sensors and informational resources, analyze, determine different disaster management dependencies.
- Modelling subsystem. Modelling subsystem models disaster management phases and personal activities (prevention, mitigation strategy, preparedness, local emergency planning committees, preparedness measures, response, recovery). Modelling subsystem would provide multiple criteria analysis of different alternatives (saving and protecting human life; relieving suffering; protecting the health and safety; safeguarding the environment; protecting property; maintaining or restoring critical activities; promoting and facilitating self-help in affected communities; the recovery of the community (including the humanitarian assistance, economic, infrastructure and environmental impacts); recovery effort).
- Smart, self-learning, emotional affective computing, psychological and emotional assistance. This system would support the morale of the affected inhabitants and select in real time the most suitable film, music, lighting and the like for its users.
- Wearable system for enhancing the disaster management.
- Augmented reality system for disaster response. Its use in the context of disaster management is to represent different invisible disaster-relevant information (humans hidden by debris, simulations of damages and measures) and overlay it with the image of reality.

- Affective computing subsystem. Affective computing in disaster management is the study and development of systems and devices that can recognise, interpret, process and simulate human affects. The systems interpret the emotional state of humans and adapt its behaviour to them, giving an appropriate response to those emotions. In addition, the affective computing can detect the different emotions in the text.
- Robots. Robots substitute for humans and replicate human actions. Robots can be used in any disaster management situation (finding survivors in unstable ruins, etc.) and for any purpose. Robots attempt to replicate walking, lifting, speech, cognition and basically anything a human can do.
- Smart system for building structures. Smart system for building structures is defined as system that can automatically adjust structural characteristics, in response to the change in external disturbance and environments, toward structural safety and serviceability as well as the extension of structural service life. Increased safety – Sensors that detect whether concrete and other building infrastructure is successfully holding a load can increase safety and decrease the likelihood that a building or facility would collapse or otherwise become damaged. System modeling explosions and building collapse.
- IoT-based occupancy monitoring system. System estimate the occupancy in buildings to be used in emergency response. The Wi-Fi-based approach uses an intrusion detection tool to analyse Hypertext Transfer Protocol traffic and identify mobile devices that are connected.
- Fire and life safety system (FLS). System consists of the fire alarms, sensors, sprinklers, smoke purge and exhaust fans. The FLS typically connects to the local fire department and alarms. Traditionally, these systems were in separate conduits and cabling went from the control panel to the devices.
- Active disaster response system (ADRS). ADRS can actuate embedded controllers to perform emergency tasks to respond to the alerts. Examples of emergency tasks include opening doors and windows and cutting off power lines and gas valves. In addition, ADRS can maintain a temporary network by utilizing the embedded controllers; hence, victims trapped inside a building are still able to post emergency messages if the original network is disconnected.
- Occupant evacuation elevator. Elevator is applied for emergency evacuation, which would provide a faster and a safer evacuation program.
- Smart disaster management system. System simulate all the possible scenarios of emergency in the building and then, through the decision-making capability of the system, select the fastest and safest strategy of evacuation.
- Disaster resilience support with advance energy storage system.
- BIM.
- Call centre.

The SARB Model aim is to create a unique technology that can provide user-friendly personalised conditions for building users by analysing user behaviour with neuro-analytical systems. Intelligent sensor systems and digital modelling tools that help you find rational multicriteria challenges are the key to maximising disaster life cycle of the buildings. By using innovative research methods, different smart BIM objects could collect data from various sensors and sources of information, analyse, identify various dependencies and supplement these data with BIM throughout the smart, self-learning and adaptive resilience building disaster life cycle process.

4. Innovativeness of SARB model

Traditional decisions on the informational modelling do not satisfy all the needs of smart building technologies owing to their static nature. Current BIM systems lack information needed for developing a virtual environment capable of interactions with users (Heidari *et al.*, 2014). The effort to eliminate the shortcomings of the traditional BIM requires a dynamic BIM that is relevant during the planning and exploitation stages in the life cycles of smart buildings (Volkov and Batov, 2015). This would permit a continual integration of progressive objects into a construction project and the maintenance of smart building elements with needed information (Zhang *et al.*, 2015).

Innovative, scientific research SARB Model could accumulate data from various sensors and information resources, analyse, determine various dependencies and supplement the BIM with such data over the entire course of the disaster life cycle of a smart building. All this information would enrich objects with knowledge about themselves and, at the same time, develop "intelligent" building elements, which can "respond" to requests and "submit" their existing information into a desirable form – graphically or digitally. This would permit the accumulation and use of knowledge about these elements over the entire disaster life cycle and provide recommendations to the target groups.

The products and patents of methods and systems analysis was performed to substantiate this idea. This analysis showed that the SARB Model would be more advanced than the other models developed in the world. The distinguished features of innovativeness are the following:

- The model would accumulate biometric and physiological user data, integrate these for analysis with other data, determine various dependencies and supplement the BIM with these data over the entire process of the smart, self-learning and adaptive resilience building life process.
- Neuromatrixes would be developed permitting a comprehensive analysis of smart, self-learning and adaptive resilience building from quantitative, qualitative and neuro perspectives; the ability to compile and analyse thousands of alternatives for selecting the most rational one according to user needs and the establishment of the investment value of a building. No neuromatrix-based systems have been developed in the world capable of performing an analysis of a smart, self-learning and adaptive resilience building and providing recommendations.

5. Conclusions

Analysis of the literature showed that traditional decisions on the informational modelling do not satisfy all the needs of smart building technologies owing to their static nature. There is also no integrated solution, as proposed by SARB Model, developed worldwide.

In this case, the Model for Smart, Self-learning and Adaptive Resilience Building (SARB) was developed to take care of its efficiency from the brief stage to the end of its service life. Developed SARB Model enable users and the parties involved in the project to analyze a SARB's life cycle, as well as to be able to see its micro, meso and macro environments as one integrated entity.

The proposed SARB Model could accumulate biometric and physiological user data, integrate these for analysis with other data, determine various dependencies and supplement the BIM with these data over the entire process of the smart, self-learning and adaptive resilience building life process. The SARB Model would allow real-time analysis of the building's disaster life cycle, evaluate the needs of users, create neuromatrixes and, based on them, would provide recommendations to building managers, users, builders and designers.

Although the results are encouraging, the SARB Model developed in this study does have some limitations. Among them, the ones requiring highlighting are the following: (1) the processes followed require the collection of much unstructured and semi-structured data from many sources, along with their analyses to support stakeholders in decision-making; (2) stakeholders need to be aware of the broader context of decision-making; and (3) the proposal is process-oriented, which can be a disadvantage during the system's implementation.

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