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ASSOCIATION OF RESEARCHERS IN CONSTRUCTION MANAGEMENT

International Council
for Research and Innovation
in Building and Construction

W120 - Disasters and the Built Environment

Industry 4.0 and Disaster Resilience in the Built Environment

ARCOM Doctoral Workshop

In association with CIB W120 - Disasters and the Built Environment

Thursday, 25th April 2019
Northumbria University, Newcastle upon Tyne, UK

Workshop Proceedings

Workshop conveners:

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Foreword

Disruptive innovations of the 4th industrial revolution are now starting to make an impact on construction. Although construction has lagged behind some of the other industries in embracing this revolution, recent years have seen a concentrated effort to drive change in construction processes and practices. The 4th industrial revolution is characterised by technologies such as digitisation, optimisation, and customisation of production, automation and adaptation; as well as processes such as human machine interaction; value-added services and businesses, and automatic data exchange and communication. In construction, the applications of Industry 4.0 include 3D printing of building components, autonomous construction vehicles, the use of drones for site and building surveying, advanced offsite manufacturing facilities etc. The application of technologies, processes associated with Industry 4.0 is seen to be already making an impact on construction, and reshaping the future of built environment.

This new digital era of construction, fuelled by Industry 4.0, has significant potential to enhance disaster resilience practices in the built environment. Knowledge on resilience of the built environment including preparedness, response and recovery has advanced significantly over the recent years and we are now in an era where resilience is seen as a key constituent of the built environment. But the recurring and devastating impacts of disasters constantly challenge us to improve our practices and seek ways of achieving greater heights in our quest of achieving a resilient built environment. It is often proposed that the innovations associated with Industry 4.0 joined by IoTs and sensors can be exploited to enhance the ability of the built environment to prepare for and adapt to climate change and withstand and recover rapidly from the impacts of disasters. This integration of cyber physical systems through IoTs needs a holistic view of disaster resilience. Often, the focus is on benefits individual technologies can offer. However, the ability to integrate different aspects of disaster resilience using a range of new technologies promise to deliver wider benefits beyond and above what individual technologies can offer. For instance, an integrated digital twin allows to bring together advanced risk modelling, big data, cloud computing, internet of things, advanced off-site manufacturing, etc. together to deliver a resilient built environment. This requires careful planning and extensive research on the complexities surrounding disaster resilience related aspects and the use of related data.

The ultimate objective of any new innovation, including Industry 4.0, should ideally be to benefit the society. The society that we live today is often disrupted by natural hazard induced disasters, whether it be floods, cyclones, earthquakes, landslides or tsunamis. The challenge that is in front of us is to effectively utilise new innovations driven by digital information to enhance disaster resilience in our buildings, communities, cities and regions. However, unlike earlier industrial revolutions, digital revolution is not easy to control. We must ensure that the fundamental values such as freedom, openness and pluralism are inbuilt in these new technologies. This is an uncharted territory for us. In addition to addressing complexities and challenges of using Industry 4.0 technologies, we also need to have policies and guidelines on the use of information. There should be a balance between innovation and regulation. We are confident that by bringing together researchers, practitioners and policy-makers alike from relevant disciplines we can deliver realistic benefits to transform our disaster resilience practices and policies, and make the built environment we live in more resilient.

Gayan Wedawatta
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Scientific committee

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On Thursday, 25th April 2019 at CCE1 402 (City Campus East), Northumbria University, Newcastle upon Tyne, UK

Agenda

10.30am	Arrival and registration
10.45am - 11.00am	Welcome and Introduction
11.00am - 11.45am	Opening Address: Prof Paul Chan - Delft University of Technology
	Social value, building resilience and the 4th industrial revolution: Concepts, capabilities and challenges
11.45am - 1.05pm	Doctoral Presentations and Discussion
	Elisabeth Marlow - Loughborough University: Measuring the unquantifiable
	Danstan Chiponde - Northumbria University: Exploring mechanisms of failure, learning, and resilience in project-based organisations
	Lilian Smart - University of Huddersfield: Rapid urbanisation - Exploring the role of the built environment in enhancing the urban mental health
	Kashif Shafiq - Glasgow Caledonian University: Development of a framework for identifying the resilience of nature-based solutions against shallow landslides, erosion, and flooding
1.05pm - 2.00pm	Lunch
2.00pm - 2.45pm	Keynote Presentation: Prof Chris Kilsby - Newcastle University
	A Water Digital Twin: Making sense of data, models, processes – rebooting Hydroinformatics?
2.45pm - 3.45pm	Doctoral Presentations and Discussion
	Vinh Nguyen - Northumbria University: Potential of exploiting construction 4.0 associated innovations and technologies in improving disaster resilience in the Vietnamese built environment
	Taiwo Adedeji - Birmingham City University: Application of the flood resilience circle to the city of Birmingham
	Soukaina ElAoud - University of Strathclyde: Integration schema of big data analytics and BIM systems for disaster resilient built environment
3.45pm - 4.30pm	Panel discussion and Closing remarks
4.30pm	Workshop Close

For further details, please visit the workshop website: https://sites.google.com/view/industry-4-disaster-resilience/home

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#DisasterResilience #Built Environment

Opening Address

Prof Paul W Chan, Delft University of Technology

The Fourth Industrial Revolution (Industry 4.0) and Construction Management Research: Concepts, Capabilities and Challenges

The Fourth Industrial Revolution, or Industry 4.0, is a high-tech strategy that originated in Germany, to describe a new wave of technological advancements and applications that follows previous industrial revolutions of mechanisation, electrification and computerisation (see Kagermann *et al.*, 2013). Such a strategy promises efficiency gains, by integrating the value chain, through a combination of technologies and techniques, ranging from automation and robotics, additive manufacturing, sensing, cloud computing, machine learning, big data analytics, Internet of Things (IoT), augmented and virtual reality, and so forth (see World Economic Forum, 2018). Integrating the value chain is, of course, not a new challenge; ever since the many inquiries since the 1940s (and before) into the affairs of the construction industry, questions around how we better integrate across design and construction, and latterly the operations and asset management phases of the building lifecycle have long formed a productive line of research.

In the opening presentation, I argued that there is a risk of sidelining this aspiration of integration if the focus (and hype) remains purely on the technologies and techniques of Industry 4.0 instead of rendering this as a social challenge as well. Even in a country like Japan that is often regarded as a technologically-advanced place, the discourse has moved beyond Industry 4.0 to consider Society 5.0. The underpinning question that belies this shift is to question what technological advancements and integration is for? And the answer is not just making things cheaper and faster, but to effect better outcomes for society. Thus, there is still a long way in harnessing the full potential of Industry 4.0 to construct better societies. And construction as a sector is a usual suspect in lagging behind. Consulting firms like McKinsey Global Institute and PriceWaterhouseCoopers have both indicated a less than 50% chance of robots replacing human labour in the sector by 2030, in part, because construction still relies on craft skills. And we should celebrate the beauty of (at times imperfect) craftwork!

To date, even the ways Industry 4.0 is framed in the academic literature is rather limited. A recent systematic review found that scholars still largely focus on building information modelling (BIM) as a central theme in the fourth revolution (see Oesterreich and Teuteberg, 2016). Even if there is a broadening focus on other technologies, the aspiration still seems to be locked in to developing ‘smart factory’ solutions. But, the original intent of Industry 4.0 is much broader than just developing ‘smart factory’ solutions. Lasi *et al.* (2014), for instance, also talked about other possibilities including the use of Industry 4.0 to adapt to human needs and to improve social responsibility. In a recent critical essay on whether robots are going to take over our jobs published in *Organization Studies*, Fleming (2019) argued for a need to move beyond conversations on the quantity of jobs to discuss how new technologies are going to change the quality of our lives. This perhaps remains the greatest challenge when thinking and talking about the fourth industrial revolution.

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List of Papers

- Measuring the unquantifiable by Elisabeth Marlow, Ksenia Chmutina and Andrew Dainty (Loughborough University)
- Exploring how learning from project-related failure promotes resilience in project-based organisations by Danstan Chiponde, Barry Gledson and David Greenwood (Northumbria University)
- Rapid urbanisation - Exploring the role of the built environment in enhancing the urban mental health by Lilian Smart , Dilanthi Amaratunga and Richard Haigh (University of Huddersfield)
- Development of a framework for identifying the resilience of nature-based solutions against shallow landslides, erosion, and flooding by Kashif Shafiq, Slobodan B. Mickovski, Alejandro Gonzalez Ollauri, Craig S. Thomson (Glasgow Caledonian University)
- Potential of exploiting construction 4.0 associated innovations and technologies in improving disaster resilience in the Vietnamese built environment by Vinh Nguyen, Kanchana Ginige and David Greenwood (Northumbria University)
- Application of the flood resilience circle to the city of Birmingham by Taiwo Adedeji, David Proverbs, Hong Xiao and Victor Oladokun (Birmingham City University)
- Integration schema of big data analytics and BIM systems for disaster resilient built environment by Soukaina ElAoud, Ibrahim Motawa and Yashar Moshfeghi (University of Strathclyde)

MEASURING THE UNQUANTIFIABLE?

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ABSTRACT

Background: 98% of cities are experiencing the effects of a changing socio-ecological environment and increasing risks associated with natural hazards and human-induced threats. A recent Overseas Development Institute’s (ODI) report reviewed 39 resilience frameworks that set out how resilience should be measured and what it comprises, yet only two of those specifically considered cities and few explicitly reciprocate the concept of sustainability.

Purpose and Originality: To date, most resilience literature has been concerned with determining measurement indicators. Instead this paper aims to review five urban resilience frameworks to consider what interpretation of resilience is being measured, their conceptual relationship with sustainability, and commonality between the frameworks' indicators.

Methodology: A thematic analysis[1] has been carried out to compare the intrinsic relationships of the frameworks’ characteristics. Insight into how or whether these frameworks infiltrate into the decision making of the urban environment has been gained through 19 semi-structured interviews from three US cities (NYC, Boston and Chicago).

Findings: Resilience has become quantifiable through indicators, but whether it leads to transformative adaptive capacity of our cities is debatable. The frameworks (or those who use them) still need to address ‘resilient-sustainable’ design and planning in cities. Although resilience in cities is not a one size fits all approach, work towards a more unified framework should be continued and making existing systems more current to 'today's' climate.

Research Implications: Resilience measurement frameworks indicate a relationship with sustainability. Practice acknowledges that existing sustainability measurement frameworks remain the most effective way to integrate theory and practice; this should be enhanced rather than creating new systems to achieve resilient sustainable cities.

Keywords: Resilience Measurement Frameworks; Sustainability; Cities; Key Performance Indicators

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[1] This paper is supplemented with an appendix for thematic results.

1. INTRODUCTION

Many seek to qualify the meaning of resilience (Carpenter et al. 2001; Folke et al. 2010; Chmutina et al. 2016) and the United Nations (2016, p.22) has defined resilience as “The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management”. If resilience is becoming qualified through this definition, or any other, one might ask: can it be quantified? Or should it? Ayyub (2014) and Michel-Kerjan et al. (2013) suggest there is a need for quantification of resilience to reduce disaster risk and subsequent cost of recovery; but it also takes time to recover from poor decision making of infrastructure and buildings (Rogers et al. 2012; Hammond et al. 1998).

Carpenter et al. (2001, p.2) discuss resilience’s systematic relationship with sustainability and its measurement “by the magnitude of disturbance the system can tolerate and still persist” and consider this as transformative adaptive capacity. Positioning of 'what' terms should be quantified are at a potential juxtaposition. The Overseas Development Institute (2016) analysed 39 resilience frameworks for measurement; three were found to operate at an ‘urban’ scale and only one measured system's ‘capacity’. Considering that the Sendai Framework and Sustainable Development Goal 11 are reciprocating one another on urban development (Peters et al. 2016) and when “Cities consume over two-thirds of the world’s energy and account for more than 70% of global CO2 emissions. And with 90 percent of the world’s urban areas situated on coastlines, cities are at high risk from some of the devastating impacts of climate change, such as rising sea levels and powerful coastal storms” (C40 Cities 2018); why are cities not better represented?

1.1 Sustainability measurement

Expedited by Brundtland's definition of sustainable development (1987) was a generation of measurement systems such as urban ecofootprinting (Rees & Wackernagel 1996) and Strategic Environmental Assessments (UNECE 2003). In 1993, the US Green Building Council (USGBC) was formed and created Leadership in Environmental Design (LEED) as its framework to create sustainable buildings and neighbourhoods. A further 38 established green building frameworks are in use across the globe (World Green Building Council 2017) which have shaped how sustainability as a concept has become a measured entity in practice (Marjaba & Chidiac 2016). Coined phrases such as a ‘triple bottom line’ (Elkington 2001) have created the understanding that sustainability is about Environment, Economy and Social issues, and that impacts can be monitored and evaluated by the common denominator of carbon emissions as indicated in the C40 Cities (2018). LEED remains the most used global framework for sustainable development, and the USGBC reports it is piloting city-based work (USGBC, 2019) and it is considering hazard management with the introduction of RELi credits (Matthews et al. 2014; Champagne & Aktas 2016).

1.2 Resilience measurement

Resilience measurement, by contrast, remains complex and is subject to lively theoretical debate. Levine (2014) and Carpenter et al. (2001) question ‘why’ measure it, where others seek to determine indicators to support its measurement (Cutter et al. 2010; van de Ven et al. 2016). Over two decades, the World Conferences on Disaster Risk Reduction (Yokohama, Kobe and Sendai) had been debating what guidelines to produce for disaster and climate risk management in the context of sustainable development. This finally lead to the UNISDR launching the Sendai Framework for Disaster Resilience (2015) to incorporate ‘resilience’ into decision making and sustainable development (UNISDR 2018), yet, how does this inform practice and city-scale frameworks?

1.3 City Frameworks

For sustainability, C40 Cities is prominent practice for city decision makers. It is a collective group of 96 cities across the world and is actively monitoring and evaluating their performance (C40 Cities 2018). C40 Cities was established in 2005 with a mission of “large cities taking action to address climate change by developing and implementing policies and programs that generate measurable reductions in both greenhouse gas emissions and climate risks.” (C40 Cities, 2019)

For resilience, an initiative called 100 Resilient Cities was launched in 2013 for cities to apply and compete for funding to make their city more resilient. By 2016, there were 63 cities participating and work to support city decision makers started (Berkowitz, 2016). However, despite the prominence of these two city frameworks, there is little comparative evidence on what city measurement frameworks are 'measuring'. ‘What’ is being measured could have significant consequences for risk and sustainability in the urban context of a city as discussed by Hammond (1998), particularly for city planning and building design. Five identified frameworks have been developed within 2010-2018 that explicitly aim to measure resilience of cities. Between these five frameworks there is a total of 90 Key Performance Indicators (KPIs) all used in different contexts. To understand what is being measured, one key document representing each of the framework was reviewed as outlined here and their indicator headings used in table 1:

1. TAMD: An operational framework for Tracking Adaptation and Measuring Development produced by Brooks et al. (2013). It aims to support national and local policy decision makers through the use of scorecards with 9 indicators that have associated credentials. The score is achieved through a ‘yes’, partial or no response.

2. BRE: BRE 12 Cities Assessment Report (BRE 2016)- Derived by case study cities, it has produced a framework that results in a resilience rating to assist municipal authorities, private or public sectors in assessing their current and future resilience demands and capacities. The rating connected to a cost and benefit analysis of hazard impacts compared to the cost of inaction. It measures 3 groups with a total of 12 indicators.

3. CITY: City Resilience Framework (Da Silva & Moench 2014) – targeted towards policy decision makers, it identifies 52 indicators which are categorised into 12 goals and 4 sectors. These qualities enable cities to carry out an objective assessment of their resilience and measure progress against an initial baseline.

4.MMCRC: Led by the UNISDR to support local government leaders (UNISDR 2010), it produces a 10-point checklist to support the decision making of the ‘local’ area.

5. Resilience.io: A revolution in planning (Resilience.io) (Passmore & Schmidt 2018)- An integrated systems open source platform ‘tool’ to enter in data to understand a system’s ‘performance’ and how to make better decisions regarding resilience and sustainability across spatial scales: City, regional, national, global.

2. METHODOLOGY

KPIs drive decision making, so to understand what is being measured needs practice knowledge as well as a review of the indicators. Building on previous reviews, the frameworks characteristics were initially considered for a direct comparison (table 2-appendix) but when it came to understanding 'what' was being measured, the indicators were too diversified. Each framework defined its own version of resilience, reflecting that it is interpreted in many ways (UNISDR 2010, p.8). A thematic analysis was considered as a more appropriate method because it could highlight some commonality between sustainability and resilience in the frameworks' indicators. The KPIs were reviewed to consider how the measurement relationships were mutually supportive to understand 'what' is being measured and 'why?' in relation to how the measurement frameworks develop from policy into action. This review established themes between the frameworks that were: governance, society, ecosystems, planning and design actions.

Next, to construct whether practice acknowledges the frameworks’ interpretations of resilience as influential in decision making from local policy into city action, semi-structured interviews were carried out. During 2018, a total of 19 semi-structured interviews across a 'power:knowledge' matrix with local governance, lawyer, developer, 'built environment' consultants (LEED APs, architects, civil and structural engineers), regional and city planners who focus on global or local sustainable and resilience practice of cities in Boston, New York and Chicago. Their responses were analysed in NVivo for knowledge of both sustainability and resilience measurement frameworks.

3. THEMATIC ANALYSIS OF MEASUREMENT INDICATORS

Table 2 (in appendix) represents an interpretation of framework KPIs by their designation into five themes of: governance, social, ecosystems, design and planning actions and are thematically discussed as follows:

Theme 1: Governance
What version of resilience is being mobilised by Governance? Four of the five frameworks identify governance indicators but their resilience focus is different. TAMD focuses on climate change, BRE ‘secure and safe’, City looks for more integration through stakeholders, sustainable economy and vulnerability awareness and MMCRC is about disaster risk reduction.

Theme 2: Society
Society is a foundational characteristic of both resilience and sustainability measurement. All the frameworks acknowledge social responsibility to either promote community cohesion and more resilient responses, indicating awareness and responsibility.

Theme 3: Ecosystem
Three frameworks see the ecosystem as a scale of decision making. Resilience.io considers the whole system but other view the system as infrastructure and natural buffers. Does this represent the UN’s resilience definition? And will these indicators lead to transformational adaptive capacity? Maybe not and certainly not if not mobilised by theme 1.

Theme 4: Planning Action
Four out of five frameworks recognise planning actions. TAMD identifies that the planning process needs to change, but the others seem to merely consider that better identification of hazards will automatically lead to more informed decision making. In NYC and Chicago, it is only recently that the planning process is being overhauled because it had stagnated for over fifty years (NYCPlanning 2019; Emanuel 2018).

Theme5: Design Action
This is the least thought about theme, only two frameworks consider design action and both perceive it as 'risk' mitigation. In NYC and Chicago the design codes have stagnated for long periods of time and only recently been revised (Blasio 2009; Buildings 2019; Boston 2017).

3.2 What does practice say about frameworks?

14 interviewees recognised LEED and 4 recognised 100RC. Practice was found not to be affected by the theoretical debate around resilience measurement and considers the safety regulations as most important. Practice recognises that the regulations and policies are out of date and develops its own tools to move things forward. This is the conundrum. It is the design contingent of the interviewees who have started to adopt LEED-RELi, where 'RELi' adds resilience credits into the LEED system.

4. MEASUREMENT DISCUSSION

Whilst measuring resilience is important to convey, each framework has a different measurement method and indicators, and practice says that knowledge needs to be mobilised in planning and design of cities, which reiterates Carpenter et al.'s (2001) and Levine's (2014) positions on measurement of resilience. The outcome of the frameworks beyond their development is not yet known so 'what' interpretation of resilience is being measured needs further assessment. Theme 1 identifies visioning, leadership and stakeholder engagement to achieve an interpretation of resilience but practice is aware that codes of planning and design are outdated. So it has to be asked have the resilience frameworks become a tool to mobilise governance? 100 Resilient Cities (2018, p.2) can report their ‘city’ framework has led to six key areas of change, which are “explication of resilience in city planning; the internal consistency across cities’ various planning documents; the establishment of a Chief Resilience Office or similar cross-sectoral coordinator; a reduction in the strength of the government silos that promote ineffective solutions, duplication and inefficiency; better collaboration across city, state, and national levels of government; and changes to budgetary review procedures or leveraged funds for resilience-building efforts which may ultimately lead to more efficient and effective use of city funds”. From this statement, city planning and institutional change across governance has been the most needed action and a process to engage positive change. Mobilising governance towards managing risks and reducing costs is admirable but not if it deters from sustainable practice and C40 remains a focus for city governance. Sustainable development is a building block for a resilient urban environment, but has it been side-lined, perhaps because funding from 100RC program allowed it to? Given that 100RC has recently withdrawn its funding (Flavelle 2019) so where does that lead the future of this process? What is evident is that we need decision makers who understand the long, medium and short term risks to make progress, or no lessons will be learnt; “the societal and economic impact of a short term approach to the problem could results in inflated problems for future generations” (Champagne & Aktas 2016, p.381).

The diversification of resilience indicators in measurement frameworks needs more thought. Work in this direction has already started with ‘Standards in Resilience’ (Thornton Tomasetti, 2019) but this is work lead by practice. Response from the interviews supports the notion that the measurement of resilience has become too fragmented because they use their own tools. Embedding resilience into green building rating systems could lead to quantification of ‘resilience’ in design but planning decisions still need resilience becoming a part of the decision-making process. There are movements towards LEED becoming more 'resilience focused' both with the RELi credits and pilot city framework. The RELi framework being piloted in the LEED rating system with 3 resilience credits (Wilson, 2018) and Champagne & Aktas (2016; p.380) consider that “It is imperative that new buildings, such as those to accommodate the expanding population, are designed to withstand stresses and loads that would be imposed by the future climate, rather than past conditions”.

This thematic analysis highlights that measurement needs further debate particularly if it can lead to creating conflicts in decision making and divert from the issue that planning and design codes need updating (Perelman 2017). Establishing a conceptual link between how sustainability and resilience measurement relate across the frameworks 90 indicators needs more vigorous analysis, but the thematic analysis provided a way to consider what is being measured in the sample of resilience frameworks. It invites a further question of whether there needs to be a united cities framework for sustainability and resilience or whether resilience itself should even be measured through frameworks because of its diversity of application.

5. CONCLUSION

Peters et al. (2016) and the Mitigation Framework Leadership Group (2016) are discussing what interpretation of resilience is being quantified because it has become a theoretical issue. This desire for quantification of resilience is illustrated by the volume of 39 Frameworks in the ODI report (2016). From the thematic analysis, no framework can be recommended as best practice because they need context of applications to truly understand what the indicators measure.

Practice has developed the City framework adopted by the 100Resilient Cities, and practice is leading the LEED developments in cities and RELi. With this movement perhaps resilience measurement knowledge can enhance existing systems rather than diversify both concepts with more indicators.

Turning the tide on resilience (only) measurement will be challenging but if its relationship with sustainability is considered as "development trajectories that combine adaptation and mitigation to realize the goal of sustainable development" (Denton et al. 2014, p.1104) then existing systems can become enhanced and inform better practice and city policy. If practice is recognising existing sustainability measurement systems - then they should be enhanced to create better decision making for all cities.

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Table 1: Five Framework Indicators grouped into themes

Framework Themes	Governance	Society	Ecosystem	Design Action	Planning Action
TAMD (Brooks et al. 2013b)	Climate risk management coordinated across institutions; Knowledge development and Training of climate change issues; Risk spreading mechanisms	Local initiatives to seek funding; Use Informed Responses of Climate Change;		Climate change issues, risks and responses	Climate Change integration into planning documents and processes; Managing uncertainty stakeholder engagement in decision making
BRE (BRE 2016)	Leadership & Government; Security & Safety; Business & Trade; Skills & Innovation	Community & Inclusion; Health & Wellbeing; Mobility & Communication; Sense of Place	Structures & Infrastructure; Systems & Technology; Resources; Environment		
City (Da Silva & Moench 2014)	Effective Leadership; Empowered Stakeholders; Integrated development planning; Sustainable economy; Comprehensive security and rule of law;Minimal human vulnerability; Effective safeguards to human health and life	Collective identity and community support;; Diverse Livelihoods and Employment			Reduced exposure and fragility; Effective provision of critical service; Reliable mobility and communications
MMCRC (UNISDR 2010)	DDR in City Vision or strategic plan Financial planning of resilient activities Ensure effective preparedness and disaster response through city planning	Institutional change to strengthen gaps in resilience capacity; culture of social connectedness	safeguard natural buffers	Risk mitigating infrastructure	hazards and vulnerabilities risk mapped; risk compliant building regulations; Build
Resilience.io (Passmore & Schmidt 2018)		Human scale of resource inputs and outputs	Resource Flows of land use activities- human systems and natural system; Service and Infrastructure Networks		Land use identification and identification of building types

Table 2- Framework Comparison

Code	Search description	TA MD	BRE	City	MM CRC	Resilience.io
Framework Aim	What is the framework setting out to do? what does it want to achieve?	Yes	Yes	Yes	Yes	Yes
Resilience definition	What is the theoretical definition of resilience- is it defined?	No	Yes	Yes	Yes	No
Resilience working terms	What actions are undertaken under the word 'resilience'- is there a working definition?	No	Yes	Yes	Yes	Yes
Resilience policy	Sendai or other named documentation	Yes	Yes	No	Yes	No
Framework characteristics	Conceptual (Type1) or Prescriptive (type 2)	1	2	2	1	1
Measurement Indicator	What is the process being outlined?	9	5	12	10	5
Measurement Process	Do indicators use measurement indicators?	Yes	Yes	Yes	Yes	Yes
Measurement Unit	Is sense of place recognized as a term?	No	No	No	No	No
Sense of Place	Is it reflected in risk characteristics?	No	Yes	No	No	No
Risk	How is risk being managed?	No	Yes	No	Yes	No
Risk Management	Is sustainability defined? If so how?	No	Yes	No	Yes	No
Sustainability definition	Is there a working definition? and associated words with sustainability?	No	No	No	No	No
Sustainability working terms	SDG or other named documentation	No	No	No	Yes	No
Sustainability policy	Are stakeholders mentioned?	Yes	No	No	Yes	Yes
Governance Ownership	Are stakeholders identified explicitly?	No	No	No	Yes	No
Stakeholder management	Who has responsibility for the decision?	Yes	Yes	No	Yes	No
Stakeholder who?	Who?	No	Yes	Yes	Yes	Yes
Measurable Outcome?		1	4	1	1	No

EXPLORING HOW LEARNING FROM PROJECT-RELATED FAILURE PROMOTES RESILIENCE IN PROJECT-BASED ORGANISATIONS.

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ABSTRACT

Background: In addition to the rare but very visceral, natural catastrophes observed in the natural environment, disasters can also be defined as events of complete failure that produce unfortunate consequences. They occur regularly in the built environment, both during the production and operation of its physical assets.

Purpose and Originality: This work explores disaster resilience from the perspective of organisational responses to severe project-related failures. It identifies a range of notable project disasters, then considers if and how, learning can aid in achieving resilience by those project-based organisations (PBOs) encountering such failure during the delivery of their projects.

Methodology: Qualitative literature review was adopted in establishing the existing knowledge from the related fields of failure, learning, and knowledge management within PBOs.

Findings: It was established that Abilities, Motivation and Opportunity (AMO) of PBOs assists in times of response and recovery when encountering project failures, which are (AMO) developed through learning from past disasters and failures.

Research Implications: The negative perception of project failure should be reframed and approaches to learning from failure should be absorbed into organisational practice so that knowledge resulting from prior lessons can be applied to aid organisational resilience in future disasters.

Keywords: Failure, Organisational-learning, Organisational-resilience, Project-based organisations (PBOs).

1. INTRODUCTION

According to the ACF-International (2014) report, circa 2 billion people are exposed to both manmade and natural related disasters. Recently, Hallegatte et al., (2018) estimated that USD 520 billion is spent annually on those affected by global disasters, and echoed the need to 'build back better' since such disasters and costs are associated with the infrastructure sector. Evidently, the impact of disasters on the infrastructure sector is only worsening. This may be associated to Voss and Wagner's (2010) observation that most future disasters arise from the failures to learn from past ones. Accordingly, Stead and Smallman (1999) noted that failure to learn is the precursor to a crisis. To counter that, learning from disasters and failures is being encouraged by many sectors such as finance, oil and aviation (Stead and Smallman, 1999; Pidgeon and O'Leary, 2000; Choularton, 2001; Syed, 2015). Hence, since disasters also occur in the construction sector, the main aim of the present work is to explore how learning from project-related failure promotes resilience in Project-Based Organisations. The objective is therefore to consider how PBOs' resilience in disaster management and response can be improved by learning from past failures. This is promoted via the application of the 'ability, motivation and opportunity' (AMO) model. Notably, unlike previous research which focused only on the latter element of capability, this research takes a wider view by also considering 'ability', 'motivation' and 'opportunity' as a form of resilience based on lessons from man-made failures and disasters.

2. DISASTER AND FAILURE IN PERSPECTIVE

The term 'disaster' is usually associated with large crises such as floods, hurricanes and earthquakes (Voss and Wagner, 2010). However, besides the natural catastrophes, disasters can also be considered as events of failure with unfortunate consequences, such as those regularly observed during the production of built environment assets. For example, Choularton (2001, p. 61) defined a disaster as: "an amalgam of the results of an event or series of events, whose impact is disruptive, destructive and/or negative in nature, and whose magnitude is sufficient to be labelled disastrous". Thus disasters are considered both to be natural, and man-made (Choularton, 2001).

The Disaster Circle, Causes and Relation with Failures

Stead and Smallman (1999) established the five key stages in the disaster circle as being: pre-conditioning; trigger; crisis; recovery, and; learning. This is triggered by both natural-, and human-, related factors such as organisational culture (rigid institutional beliefs, norms and practices), infrastructural (outdated, new products) and failure to notice a series of events that may cause a disaster (Stead and Smallman, 1999). Unfortunately, as much as there are natural and manmade causes to disasters, some natural disasters arise as a consequence of human related failures (Tainter and Taylor, 2014). These can come about from trying to satiate organisations' desire (often through technology advancements) to produce faster and large quantities which overwhelms their system (Choularton, 2001). This may be fuelled by high demand for built environment infrastructure due to increased population, urbanization, climate change, globalization and socio-political phenomena (Bosher and Dainty, 2011; Word Economic Forum, 2017). Hence, in trying to solve a problem further risks of a disaster are generated by man (Stead and Smallman, 1999; Tainter and Taylor, 2014). For instance in, solving the energy challenge, nuclear power plants were developed and have unfortunately experienced failures leading to disasters (Voss and Wagner, 2010). Similar comparisons can also be made with aviation. Yet, these disasters offered lessons leading to safer aviation (Syed, 2015).

Impact of Project Failure/Disaster and Learning Opportunity

Love et al (2011) notes that economic, environmental, social loses and fatalities are associated with failures and disasters. Negative emotions and resignations also arise among team members depleting earlier lessons and causes unnecessary costs through hiring and training new employees (Shepherd et al., 2013; Walsh and Cunningham, 2017). Baumard and Starbuck (2005) also noted that some failures require extensive changes in containing them, a situation which Tainter and Taylor (2014) referred to as a ‘learning crisis’. Conversely, Choularton, (2001) argues that not all effects of a disaster are negative since they provide lessons and an opportunity to develop new products, innovation and insights in managing disasters (Voss and Wagner, 2010). Accordingly, Pidgeon (1998) considered how lessons from failures can be used in enhancing safety. Voss and Wagner (2010) also advised treating all disasters with the same level of attention regardless of size, to avoid bigger disasters. Further, organisations and sectors can also learn from each other based on the concept of 'isomorphism' because different systems with similar components are vulnerable to similar failures (for details see Stead and Smallman, 1999). However, it is advisable to ensure that both, past problem solving forms (learning from failures) and future discoveries (Voss and Wagner, 2010) are used. Accordingly, the innovations arising in 'industry 4.0' can help in disaster identification, mitigation, analysis and recovery.

Examples of Disasters' Effect and Lessons Learnt

Learning from failures by PBO's is important. This is because they are part of the construction sector which delivers the much needed infrastructure (which also poses as a disaster risk in case of failure) by many other sectors and when disasters occur, its services are vital in the recovery process (Bosher and Dainty, 2011; Word Economic Forum, 2017). For instance, the Summerland fire disaster in 1974 caused by the failure of following regulations by the contractor and flawed design lead to the revision of the design and building processes (Turner, 1976). The Ronan Point Apartment collapse in 1968 also lead to changes in building codes in the UK, Canada and United States (Pearson and Delatte, 2005). More recently, outside of the construction sector, the Samsung Note 7 battery explosion failure did not follow the necessary tests to verify the batteries due to time constraints imposed by management (Yun et al., 2018) leading to restructuring and adopting other technologies for batteries (open innovation strategy) (Ibid). Other examples of disasters are given in Table 1 and notably lessons can be drawn from disasters in other industrial sectors. Such disasters in Table 1 are also sources of lessons in training ACE professionals in mitigating failures and disaster risk management. Hence such lessons also add to the wider case of resilient communities by developing technical, ethical and professional abilities (Delatte, 2003; Pearson and Delatte, 2005; Bosher and Dainty, 2011).

Table 1: Disasters and Lessons learnt (Pidgeon, 1998; Holloway, 1999; Spurrier, 2009)

Case and Disaster	Causes	Failure Features	Lessons Learnt
Tacoma Narrows Bridge (1940) – wind broke the cables supporting the bridge.	Flawed design techniques and verified; Relied on untested theory and design.	Face saving, Rigidities in perception and belief in organisational settings.	Aerodynamic forces in bridges; Wind tunnels introduced for testing.
Space Challenger Shuttle (1986) - shuttle broke apart after launch.	Faulty design; Ignored the problem with the rings and engineers' advice.	Rigid perception & belief in organisational settings; Failed to detect eminent failure.	Redesigning rocket boosters. Introduced group decision making, ethics.
Chernobyl Nuclear Power Plant (1986) – Explosion of a nuclear power plant.	Flawed and dangerous reactor, administrative failings, exhausted operatives.	Rigidities in perception and belief in organisational settings. Poor communication and between shits, tired team.	Awareness of radiation effects, treatment, reviewing of emergency response to such disasters.

Disaster Resilience through Learning - The AMO Resilience Mechanism

Resilience is considered as the capacity to prevent disruptions, recover from unpredictable disruptions, and reduce their impact by adaptation and anticipating change (Voss and Wagner, 2010; Tainter and Taylor, 2014). Past research also reveals that learning from disasters is, in itself, a form of resilience. For instance, Pelling (2007) suggested sharing lessons learned from others to enhance disaster assessment and identification. Accordingly, Stead and Smallman (1999) advised that learning from disasters should take the following forms; a) organisation specific learning b) isomorphic learning and (c) iconic learning[1]. Additionally, Bartsch et al (2013) observed that the main three mechanisms in managing knowledge sharing, and essentially in learning, is by better developing the members' ability, motivation and opportunity (AMO) in preparation for learning. Thus, instead of a single dimension of resilience with emphasis on 'ability' (Berkes, 2007; Tainter and Taylor, 2014) 'motivation' and 'opportunity' were also considered as appropriate constructs for this research. Importantly, Khang and Moe (2008) observed that competencies or ability are not good enough for project success without motivation among team members. Hence from Table 2 it can be argued that if disaster resilience is to be achieved by PBOs, the success resides in ensuring that they develop the; 'Ability' (ability to detect, cope and manage disasters); 'Motivation' (team members' discretional response to disasters and learning from it); and 'Opportunity' (identify weaknesses and build upon them by developing innovative solutions). Overall, this leads to a resilient society by revising standards, policies, designs and regulations in the light of disasters, resulting in resilient infrastructure being provided (Hallegatte et al., 2018).

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[1] Isomorphic learning is learning from the experiences of other organisations while iconic learning is the general and broad way of learning such as being aware of a disastrous event (Stead and Smallman 1999).

Table 2: AMO Based Resilience through the Life Cycle of Failure/Disaster: Adapted from Turner (1976) and Stead and Smallman (1999).

Disaster Life Cycle	Associated Challenges.	Resilience through AMO.
Pre-conditions – Factors leading to failure.	Incubation; unnoticed events. Institutional and industry practices.	Ability to detect and mitigate disasters, cultural and behavioural change; new technology for detecting and mitigating disaster (industry 4.0).
Trigger – Explicit latent failure.	Blinded by existing cultural norms, beliefs & company's practices.	Right skills through experience to detect specific failures and avoiding state of normalcy supported by industry 4.0 were humans are limited.
Crisis – On set of a crisis or disaster	Blame and scapegoats, punishment, conflict among stakeholders.	Emotional intelligence, managing and containing the disaster, stakeholder management, outlined procedures, innovative technology and solutions.
Recovery.	Treating symptoms, blame, scapegoats, and failures legitimization.	Accepting limitations, adjustment in response to the crisis, communication, supportive environment, open management practices.
Learning.	Single loop learning, adaptive learning.	Change in policies, standards, procedures rules, institutionalization of learning from disaster.

Barriers to Learning from Disasters

Besides organisational culture (Stead and Smallman 1999), over 40 years ago Turner (1976) listed the following barriers to learning: rigid perception and belief in organisational settings; the 'decoy problem' (actors' response to the disasters distracts analysing the real cause); a disregard of non-members view; information difficulties; involvement of strangers; failures to comply with existing regulations; and minimizing emergent dangers. Smith and Elliott (2007) also observed that scapegoating, hypocrisy and self-deception as barriers also known to perpetuate the occurrence of disasters (Stead and Smallman 1999). Accordingly, Pidgeon and O’Leary (2000) summed the barriers as being information difficulty (complex, vague, varying interpretation), blame and organisational politics related (parochial interest, secrecy, faulty reporting, normalisation of errors). The confusion caused by the disaster also constrains learning, referred to as 'learning crisis' by Tainter and Taylor (2014). Others include biased media coverage and group think (Smith and Elliott, 2007).

3. METHODOLOGY

The study is based on literature review with a narrative approach being adopted since systematic literature review (SLR); (a) is more suitable for research questions answering the ‘can it work' question (Bryman, 2012) and (b) is not suitable in research with many terse terms due to challenges in formulating the key search word (Ahola, 2018). For instance, structuring the 'key words' for SLR search would require the inclusion of terms as diverse as ‘disaster’, ‘failure’, ‘learning’, ‘resilience’, ‘ability’, ‘motivation’ and ‘opportunity’.

4. DISCUSSION

Failure is typically perceived negatively due to its undesired consequences, yet it also offers learning opportunities (Choularton, 2001; Voss and Wagner, 2010). Consequently learning from failure and disaster can develops capabilities (per the AMO model) which allow for better response and management of disasters that then lead to improved ‘organisational resilience’ (Smith and Elliott, 2007). This is done by highlighting weaknesses, challenging existing beliefs and the inherent assumptions of teams and their members. To achieve that, PBOs may also consider the following issues:

There are no small failures/disasters – If that is not done, cultural norms and beliefs among team members that overlook failures are natured and the small failures culminate into catastrophes (Stead and Smallman, 1999; Voss and Wagner, 2010). Besides that, learning from small disasters has less pressure (Voss and Wagner, 2010).

Social Capital - Enhances learning by eliminating barriers due to closeness and intimacy through frequent interactions (Bartsch et al., 2013), ideal for collecting and sharing information on disasters informally and informally (Voss and Wagner, 2010).

Learning from others - Isomorphic learning - learning from each other as organisations - needs to be developed for accelerated learning so that early and appropriate response to disaster can be taken (Stead and Smallman, 1999). Vicarious learning through simulations, which helps in assessing preparedness and less cheaper especially in the face of failure, is encouraged (Stehlik, 2014). Further, triple-loop learning based on the work of Argris and Schon (1996, cited in Voss and Wagner, 2010) is recommended. This is achieved through deeper cultural change with predefined disaster management and response actions (Smith and Elliott, 2007; Voss and Wagner, 2010).

Importantly, Choularton (2001) also observed that once a risk is averted, other risks are created. Essentially, new challenges arise and society is exposed to other types of disasters because existing achievements are outstripped by further developments (Spurrier, 2009).This is in line with Handy (1994) who likened the success paradox to the sigmoid curve that successive life circles must be linked for sustained success. The same inference is made to PBOs' resilience as shown in Figure 1 where the AMO resilience of PBOs develops from AA to CC. However, due to changes within and outside the organisation and new disasters, the PBO ends up at DD. To avoid that, continuous learning and learning from others (PBOs and sectors failures) is encouraged by introducing a new ‘curve’ and subsequent ones at BB (curves 2 and 3). Innovations and discoveries (Voss and Wagner, 2010) essentially, industry 4.0 for detection, analysis and information sharing on disasters should be adopted. Besides that, institutional, cultural, professional practices and regulations should be reviewed, or new ones introduced to move to the next ‘curve’. Overall, AMO resilience developed overtime should be reviewed and developed continuously.

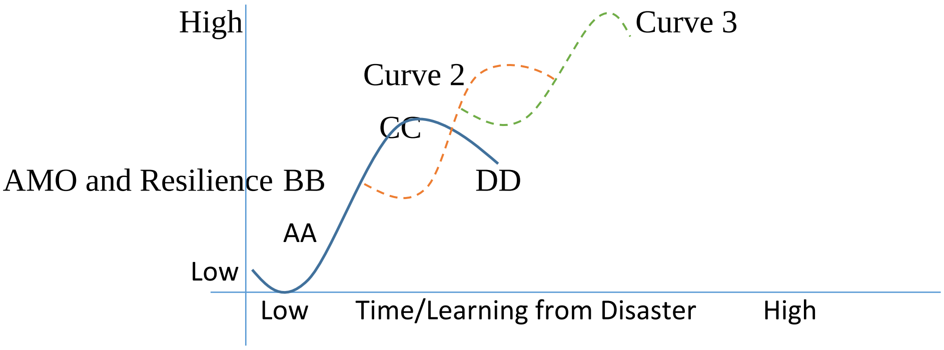

Figure 1: Continuous learning for AMO resilience in PBOs - Adapted from Handy (1994).

5. CONCLUSION

Learning from disasters or failures has in certain cases led to changes in regulations and practices, in turn leading to improved disaster mitigation and management practices. For this very reason, the negative perception of project failure should be reframed. Approaches to learning from failure should therefore be absorbed into organisational practice so that knowledge resulting from prior lessons can be applied to aid organisational resilience in future disasters. For better results it is also recommended that technical (development and application of 'industry 4.0') and social systems should be given equal attention.

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RAPID URBANISATION: EXPLORING THE ROLE OF THE BUILT ENVIRONMENT IN ENHANCING URBAN MENTAL HEALTH

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Background: The rate of the urbanisation of most countries of the world today has been unprecedented much more than it was prior to the 21st century. Studies statistically demonstrate that more than 50% of the world’s population are already residing in the cities, and by projection it will increase further to more than 60% by 2050. This is phenomenal and poses substantial challenge to the urban built environment especially regarding the mental health of the people. This is because studies shows that the built environment has both direct and indirect negative effects on mental health. It is equally revealed that the mental health of the psychiatric patients is linked mostly to the built environment designs and other related factors associated with it.

Purpose and Originality: This study adopted a literature-based research methodology to explore the impacts of the built environment on the mental health of urban residents.

Methodology: In a bid to understand the various argument in the literature on this subject area, over 30 literature were reviewed and critically analysed.

Findings: The result shows that the built environment can affect mental health negatively if it lacks such components as public open spaces for socialization, walkable spaces for physical exercises and green spaces. It also shows that the provision of these facilities and many others can help to facilitate the mental health well-being of the people.

Research Implications: In order to provide a built environment that is capable of enhancing the mental health well being of the urban residents, the building professionals need to revisit their plans, strategies and building skills. Importantly, these skills can be acquired through professional education in the built environment. Thus, necessitating the inclusion of higher and professional educational system in the building and construction industries.

Keywords: built environment, mental health, urbanisation, urban expansion, and urban population growth.

1. INTRODUCTION

There has been a phenomenal rate of urbanisation in most countries of the world today, a situation that made Gaston and Evans (2010)to conclude that rapid urbanisation has significantly eroded the countryside. For instance, in 1950,only 30% of the world's population resided in the urban centres, it rose to 54% in 2014, with about 60% projec1ted to live in cities by 2030, and 66% by 2050 (United Nations, 2014, 2015, 2016; World Bank, 2014). This massive increment in the urban population of most countries of the world mounts significant challenges to the urban built environment professionals especially in the area of creating an environment that can enhance the mental health of the people. In recent years, there has been an increasing interest on the influence of the built environment on health(Moore et al., 2018). The central argument being that the environment around us affects our mental health and well-being(Halpern, 2014). Jones and Yates (2013) asserts that built environment can have direct and indirect impact on the mental health of people. This according to them is because the environment has to do with housing, neighbourhood conditions and transport routes which shape the social, economic and environmental conditions capable of determining people's sound mental health. With this, Jones and Yates (2013) argue that what increases the health benefits of people is the ability of the building professionals to ensure that people live in a well-designed, adequately resourced and well-connected neighbourhood. This is mostly because the design of a house, the length of a street or the form of a development can affect mental health (Halpern, 2014).

With this, the importance of built environment in enhancing the mental health and life of the people cannot be over-emphasized especially so because human beings spends greater part of their lives indoors. Evans (2003) however, decries that notwithstanding the fact that human beings spend more than 90% of their lives indoors, there is still little known about the issues around built environment and health. As a result of this ,Moore et al., (2018) recommend the need to explore the influence of the built environment on mental health and well-being of adults and older adults. Thus, it becomes critically important to understand the impact of built environment on the mental health of the urban residents through considerable literature review. Accordingly, this literature-based study seeks to explore the impact of the built environment on mental health with the aim of identifying how the built environment affects mental health negatively as well as how it can be used to reduce the mental health challenges of the urban residents. This leads to two questions that this study seeks to address. Firstly, how does the built environment affect mental health, and in what ways can the built environment be used to enhance the mental health of the people?

The study is divided into some sections, the next section will centre on the methodology used in the paper, followed by a brief explanation of the term urbanisation. Afterwards, a section on the built environment in relation to mental health will follow. The next section after this will be an exploration of how the built environment affect the mental health of the people in cities. The discussion of the measures that the built environment professionals can take to ensure the enhancement of the sound mental health of the people. Then a conclusion will be drawn.

2. METHODOLOGY

This study is a literature review based research which critically explores and synthesize various literature on the built environment and its impact on the mental health of urban residents. It took more than two months to review considerable literature focusing on urbanisation, the built environment and mental health to find out some of the leading arguments on the subject area. To achieve this, a comprehensive review of articles and papers using my university's summons, google scholars, online thesis, the Business Source Premier (EBSCO), Emerald Management e-Journals, and Science Direct (Elsevier) electronic databases were carried out. Over 30 different articles from these sources were read, and their arguments for and against were noted and synthesized to be able to take a constructive stand and give out opinion on the trending arguments. However, some of the articles that do not necessarily relate directly to the central focus of the study and some that were over 10 years of publications were disregarded in the process, and the rest reviewed in this study.

3. THE CONCEPT OF URBANISATION

Satterthwaite (2007) defines urbanization as an increase in the proportion of the population of a country living in urban settlements. Crankshaw & Borel-Saladin (2018), added that urbanisation can only occur when the rate of urban population growth exceeds either the rate of national population growth or the rate of rural population growth. Importantly, urbanisation is associated with such terms as urban population growth and urban expansion (Bloch, Fox, Monroy, &Ojo, 2015; Fox, 2012). While urban population growth is defined as the absolute increase in the size of a country’s urban population, urban expansion is the spatial or physical expansion of the urban built up areas (Bloch et al., 2015; Crankshaw&Borel-Saladin, 2018; Shifa&Borel-Saladin, 2018). It is important to state that urban population growth most likely results in the expansion of the urban built areas and it is the expansion of these built up areas/environment that constitutes numerous health issues especially the mental health challenge which is the central focus of this study. Therefore, urbanisation can be seen in this study as the increase in a country’s urban population which results in the expansion of the built up areas. Now, how can we make sense of the connection between the urban built environment and mental health?

4. BUILT ENVIRONMENT AND MENTAL HEALTH

According to Amaratunga and Haigh (2011), the built environment has to do with the fields of architecture, landscape, surveying, building science, building engineering, construction. To Anderson (2018), the built environment are structures and facilities that are built in urban and suburban areas such as roads, utility systems, schools, subdivisions, housing, and some accompanying physical features. Writing on housing which is part of the built environment, Haigh et al. (2016) states that housing is an indispensable and multifaceted asset linked to livelihoods, health, education, security, and social and family stability. In fact, there is need to quickly note all the factors that Haigh et al. associates with housing because these are most of the role of housing as part of the built environment. While the rest of the concepts listed by Anderson is clear, what is not clear is what he means by the 'accompanying physical features'. Jones and Yates (2013), however, gave a straight to point definition of the built environment, stating that it is the physical structures engineered and designed by people which includes where they work, live, play and socialise. With this, Jones & Yates has provided us with some aspect of the built environment such as the living, working, playing and socialising aspects.

With this, it can be said that the built environment is a multi-faceted concept. No wonder, Bartuska (2007) states that the built environment is extensive; it is everywhere and it provides the context for all human endeavours. That the built environment provides the context for all human endeavours is worth underlining here, because this may mean that any environment that do not provide the context for all human endeavours can be frustrating and needs reconstruction to be able to meet that need. Importantly, Bartuska (2007), lists four important factors regarding the built environment that firstly, built environment is humanly created, arranged and maintained for human purposes. Secondly, the essence of its creation is to serve human needs, wants, and values. Thirdly, it is meant for the comfort and well-being of man and to help protect them from the overall environment. Fourthly, each and all of the individual elements of the built environment contribute either positively or negatively to the overall quality of environments. From what Bartuska listed, it can be summarised that the built environment is created by man both to serve and save him from negative environmental issues. This is why (Lee Bosher et al., 2016) sees it as life's infrastructure which protects and enhances our ethical and societal needs as well as reflects who we are while contributing to our vulnerabilities.

A closer look at the last line of Lee Bosher et at., will reveal that although the built environment has the capacity to protect humanity and reduce the risk posed by environmental hazards (Amaratunga, Haigh, Malalgoda, &Keraminiyage, 2017), it can victimize the people who are both its creators and users (Lamprecht, 2016). This has reveals that the built environment can have negative impact as well as positive impacts in the lives and health of the people who are eventually the creators and users. Malalgoda et al., (2013) and Amaratunga et al., (2017) respectively agree that the built environment plays a vital role in serving human endeavours and as such each of its components need to be in good shape and not destroyed in any way. This is where the quality of a built environment comes in handy, because the components of a poor quality built environment can be a disaster waiting to happen. This is because the quality of the built environment hugely determines its functions and effects on human lives and mental health because it is the décor of their everyday lives (Bergman, 2018).

Concerning mental health, the 2010 Global Burden of Disease study, estimated that a substantial proportion of the world’s disease burden came from mental, neurological and substance use (Whiteford, Ferrari, Degenhardt, Feigin, &Vos, 2015). Also, in 2010, it was statistically demonstrated that the mental disorders accounted for 56.7% out of 258 million global disability-adjusted life years(Whiteford et al., 2015). A more recent research conducted by Guthrie et al. (2018) shows that in England, over 6 million working-age population have mental health condition at a given time. Thus, making mental health and well-being an important public health issues (Moore et al., 2018).The World Health Organization (WHO) (2004, p.10) as quoted in (Guthrie et al., 2018), defined mental health as a condition where individuals comprehends their abilities and are able to cope with the normal stresses of life, work productively and able to make sound contributions to their communities. This is a clear definition of what sound mental health is all about, on the contrary, mental health challenges can be recorded when individuals cannot do all of these by themselves.

While (Guthrie et al., 2018) state that the causes of poor mental health challenges are multifarious and complex to fully understand, some scholars have shown above that the built environment is among the major triggering factors of mental health challenges. This is why it is important to further mobilize research geared towards investigating the factors that contributes to the mental health challenges of people in the context of the built environment. Remarkably, Moore et al. (2018)asserts that some of the upcoming studies should highlight the associations between the built environment, mental health and the well-being of people. This is crucial because it is one of the potential determinants of health in the cities (Melis et al., 2015).

Drawing from the above discussions, it is important to produce a working definition for both the built environment and mental health in this study. The built environment in this study can be defined as a securely constructed quality environment and life's infrastructure where people live, work, school, play, socialise with such components as places for physical activities which enhances social cohesion, social relations and networking, also green spaces and others which reduces stress, depressions as well as heightens the mental health of the occupants. Mental health in the context of this study can be defined as a state of the mind which makes a man fully capable of making a rational decision, taking charge of himself as well as contributes soundly and positively to the affairs of his/her live, families and communities.

Indeed, the above working definitions points the link between the built environment and the mental health of the people, thus, providing a comprehensive roadmap to answering the research questions posed. The next sections will centre on answering the research questions respectively.

5. HOW DOES THE BUILT ENVIRONMENT AFFECT MENTAL HEALTH

There are many ways in which the built environment can hamper the mental soundness of the people, engendering mental challenges and these can be discussed under some headings below:

THE QUALITY OF THE BUILT ENVIRONMENT

Galea et al. (2005), in their research conducted with about 1355 respondent shows that the people that resides in neighbourhoods characterised by a poor quality built environment are associated with greater individual likelihood of past six month and lifetime depression. This simply shows that there is increased level of lifetime depression for people living in poor and poorer built environments than people living in built environments that are characterised by better features. Ochodo, Ndetei, Moturi, and Otieno (2014), explained that a built environment is made up of both external and internal surroundings; that while the former deals with the external surroundings of the built environment, the latter has to do with the man-made components of the inside locations of the dwelling units. The internal and external built environment may or may not be of high quality. It can be argued that what constitutes a high quality and good environment is not necessarily its cost or its location, it can be said to be the quality of its internal and external components as well as the surroundings. Ochodo et al. (2014) draw a model showing what a poor quality built environment means. According to them, a built environment that has poor state of the roofs, insecure doors and windows, narrow access pathways, lack of street lights, inadequate garbage disposal, crowded housing, lack of green spaces and shopping facilities is a poor quality built environment. That this kind of environment can lead to psychological stress which in turns leads to mental disorders.

The inference from this is that the quality of the built environment or housing can lead to psychological stress - leads to depression which is one of the major pointers to getting mental disorders. Then what is depression? Widdowson (2011) defined depression as a disorder that affects both the brain, body, cognition behaviour, the immune system and peripheral nervous system not just a form of extreme sadness. That it is not just a passing sad mood, rather a disorder that is capable of interfering with ordinary functioning in work, school, or relationships. With these detailed explanations, one can easily conclude that it is only a thin line that separates depression from mental health. However, both can be a consequent of psychological distress and as such the building professionals need to create an environment that will not trigger these issues.

PLACE ATTACHEMENT

According to Sullivan and Chang (2011), the built environment can promote health especially when there is place attachment – place attachment refers to the psychological and social connections people have with their homes, the settings in which they grew up, and certain other places. From this singular statement, Sullivan and Chang (2011), has raised the importance of place attachment in built environment, stating that its availability enhances mental health and its absence can result to increased mental health challenges. This means a built environment should be created in such a way that it will enhance place attachment.

PUBLIC/WALKABLE SPACES

Lack of spaces for physical exercises like walking, running, jogging and cycling in the built environment can affect people’s mental health negatively.Renalds, Smith, Hale, and health (2010), reviewed about 23 articles on built environment and health, and show that neighbourhoods with more walkable areas are linked with increased physical activity, increased social capital, lower overweight, lower reports of depression, and decreased report of alcohol abuse. Villanueva et al. (2013) note that most studies on built environment and health have investigated the outcomes of physical activity like walking, cycling and other recreational physical activities on health, and found out that there is a strong relationship between the built environment, physical activities and health. Also, Lamprecht (2016) in their study notes that there are negative health consequences resulting from the lack of walking. This makes it very necessary for a built environment to have public spaces that can facilitate walking, cycling and other physical activities which is capable of reducing stress and depression, major pointers to mental health challenges in urban areas. According to House of Commons ODPM (2003), public space is a network of well maintained, people friendly and safe spaces that inspire people to walk, get to know their neighbours and respect their surroundings, spaces that everyone uses. This means that any built environment with little or no public spaces literally get people locked up in their own little homes without the opportunity to go out and meet with friends and neighbours. A situation that can increase boredom, stress, depression and consequently lead to mental health challenges. On this basis, it can be argued that increased physical activity, social capital, and the reduced rate of overweight and depression does good to the mental health of the people, while the reverse is the case where there is no environment for physical activities.

URBAN GREEN SPACES

According to Ward Thompson & Silveirinha de Oliveira (2016), urban green spaces may include places with natural surfaces/settings and urban greenery like street trees, blue space representing water elements ranging from ponds to coastal zones. They further states that green spaces include public parks; private gardens, woodlands, children’s play areas, riverside footpaths and beaches. Further to this, the Urban Atlas code 14100 explained that green spaces has to do with public green areas such as gardens, zoos, parks, and suburban natural areas and forests, or green areas bordered by urban areas that are used for recreational purposes(see European Union, 2011 as quoted in Ward Thompson & Silveirinha de Oliveira, 2016). Some of these elucidated factors vividly explains what urban green spaces are. However, it is difficult to agree that urban green spaces includes blue spaces representing water elements and beaches as listed by the former scholars, as such we adopt the latter definition. This is because as the name implies, urban green spaces has to do with those greenery areas in the urban centres including fields where children and adults have fun, some open spaces decorated with greenery for relaxation and comfort, gardens, woodlands, natural green environment where people can go and take fresh, natural and unpolluted air etc.

In a study carried out by Ward Thompson & Silveirinha de Oliveira (2016),they clearly states that urban green spaces improves mental health, reduces cardiovascular morbidity and mortality and produces other health benefits. They further explained that these health benefits are made possible through the mechanism of improved rate of physical activity, reduced exposure to air pollutants, psychological relaxation that alleviates stress, reduced noise and excess heat. Moore et al., (2018) state that the unavailability of green spaces in any built environment increases mental health disorders in older adults (see also Wu et al., 2015). These are very clear indication that the built environment with green spaces can significantly enhance the mental health of the people through the mechanism stated above, much more than an environment with little or no green spaces.

INSUFFICIENT ACCOMODATION

Insufficient accommodation in urban areas results to numerous problems which include housing/residential noise, overcrowding which in itself leads to lack of proper ventilation, increased risk of suffocation, and the transfer of sicknesses. Unfortunately, these complicates the already increased psychological distress in cities. Writing on psychological distress, (Evans, 2003), states that although housing/residential overcrowding and loud external noise sources from places like the airports raises psychological distress, they do not produce serious mental illness. However, in a more recent study by (Sullivan & Chang, 2011), they clearly state that the built environment can hinder sound mental health if it is crowded, noisy, and made up of dangerous places that increases stress, anxiety, depression, and violent behaviour. With this line of argument, one can state that whatever factors that causes psychological distress such as the designs of the built environment, overcrowding, noise, stress and violent behaviour resulting from mostly insufficient accommodation/overcrowding are capable of causing mental health challenges.

The above has shown us that the availability of certain factors as well as the lack of some other factors in the built environment can either improve the mental health of the people or result toits challenges. Having known these factors, what can be done now? The section below will summarise the ways in which the building professionals can use the built environment to enhance the mental health of the people in urban areas.

ENHANCING MENTAL HEALTH USING THE BUILT ENVIORNMENT

Regarding the issues of the quality of built environment, it is important to note that the building professionals should revisit the quality of the built environment in urban areas because it is associated with the quality of the life of the people (Bergman, 2018) & (Fleming, Goodenough, Low, Chenoweth, and Brodaty (2016). The building professionals need to be more careful and strict with their planning and designs so as to avoid creating an environment that is hazardous to human life(Amaratunga, Haigh, Malalgoda, &Keraminiyage, 2017), such that can turn the residents into victims(Lamprecht, 2016).In the creation of a built environment, the professionals can add some measures of aesthetic touch to enhance its quality because some scholars have proven that neighbourhood aesthetic quality is positively associated with higher mental well-being (Bond et al., 2012; Moore et al., 2018).

Another point to note is the creation of a built environment that can enhance place attachment by creating a safe environment, a necessary factor in facilitating the mental health of the people. Safety is one of the key factor in any built environment that can facilitate place attachment, a factor that when abandoned will amount to overwhelming stress and depression such that negatively affect the mental health of people massively. According to (Dempsey, 2008), safety is a fundamental requirement for social cohesion for people to feel safe in their living surroundings.

Further to this is the creation of urban public open spaces for increased physical activities in the built environment. As found out by (Villanueva et al., 2013), there are evidence that suggests that adults living in more walkable neighbourhoods with mixed land use and connected street networks have higher levels of overall physical activity and a lower body mass index (BMI) than those in less walkable neighbourhoods. It is suggested that places that encourage physical activity can both prevent and treat depression (Sullivan & Chang, 2011). To achieve this, the building professionals should design an urban built environment that has open spaces for increased physical activities in that way people will engage themselves in physical exercises that will improve their health on the whole and mental health in particular.

Cathy Baldwin and King (2017), also shows how important it is for the built environment to be constructed with open space or active ground floors that encourages social life and activities. This is what they describes as an environment for social cohesion, such that enables the residents to seek social connections outside their homes. Sullivan and Chang (2011) affirms that in the built environment, some places draw people together and thus support the development of social ties and enhance the development of social capital. Thus, such concepts as social ties, social capital and social cohesion has emerged in this study and needs to be explained albeit, briefly. Social capital explains the benefits that people can amass when interacting and working together in social networks (Cathy Baldwin & King, 2017), while social ties results from socialising in the neighbourhood, networks and interactions with friends and communities (Forrest & Kearns, 2001). Social cohesion describes the extent to which people from the same community or society get along, trust each other, and live peacefully together with or without social, ethnic and other demographic differences(Cathy Baldwin & King, 2017).

Another important factor to note by the building professionals and urban planners is the need to incorporate green spaces in urban built environment. According to (Sullivan & Chang, 2011) green settings have the capacity to alleviate mental fatigue and help restore a person’s capacity to pay attention. Ward Thompson & Silveirinha de Oliveira (2016) extensively researched the importance of urban green spaces in enhancing the mental health of people and found out that urban green spaces which includes places with ‘natural surfaces with specific types of urban greenery can enhance the mental health of the people. The details of how these can happen is fully documented (please see Moore et al., 2018; Stathi et al., 2012; Ward Thompson & Silveirinha de Oliveira, 2016). This entails that the built environmental professionals should devise ways of creating an environment with greenery spaces for the enhancement of the mental health of the people.

The above has clearly demonstrated the factors that need to be present in a built environment to enable it enhance the sound mental health of people. The next section is the conclusion.

6. CONCLUSION

One of the important factor raised in this study is that the world has reached its urban age as greater number of its population now lives in the cities. It was also stated that this rapid rate of urbanisation mounts significant pressures on the built environment especially in the area of enhancing mental health. This study explores the impact of built environment on the mental health of the urban residents and to find out the various ways in which the built environment contributes to mental health issues and the ways it can help to enhance the sound mental health of the people. The study which is based on literature review show that there is significant rate of mental health cases around the world today some of which are exacerbated by the kind and nature of the built environment that people inhabits. It is evident from the review that there can be poor quality built environment and good quality built environment, while the former increases mental health challenges, the latter reduces the mental health challenges. The study shows that the absence of open spaces, green spaces, walkable spaces, well-articulated building designs among others leads to an increased rate of mental health challenges. The study also reveals that a built environment that has public open spaces, walkable spaces, green spaces, limited rate of residential crowding, limited noise and safe can facilitate place attachment, social ties, social networks and social cohesion, such factors that promotes sound mental health of the people.

Therefore, in order to address the increased mental health issues in urban centres in the context of the built environment, the building professionals need to revisit their urban plans, patterns and designs, as well as get the necessary trainings and professional qualifications that will enable them to create a built environment that is not only peaceful but also generates place attachment, increased social ties, relations, cohesion and enhances mental health. This is in line with the argument of (Villanueva et al., 2013)which summarises that public open spaces, green space, perceived safety, the accessibility, aesthetics and quality of destinations can be of immense help to promote good mental health of people.

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DEVELOPING A FRAMEWORK FOR IDENTIFYING THE RESILIENCE OF NATURE-BASED SOLUTIONS (NBS) AGAINST SHALLOW LANDSLIDES, EROSION, AND FLOODING

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ABSTRACT

Background: Human encroachment on the coasts is extensive and expected to increase over the coming decades globally. Due to the close proximity to the sea, human settlements are threatened by strong cyclones, precipitation events, and sea level rise which lead to erosion, flooding, and landslides. These natural hazards are major problems of the modern era that affect human life and property, and are expected to exacerbate in the coming years.

Purpose and Originality: As an alternative to the traditional engineering solutions, nature-based solutions (NBS) can be a viable solution to maintain the resilience of coastal zones, although their benefits have not been clearly demonstrated. Green infrastructure (GI) concept is identical to NBS, and it refers to the man-made infrastructure within natural spaces that can improve ecology and be resilient while bring economic, environmental and social benefits to the communities.

Methodology: Based on a systematic critical literature review of NBS, a generic, multidisciplinary framework was developed to identify the resilience indicator sets of NBS against shallow landslides, erosion, and flooding.

Findings: In this paper, three resilience indicator sets were identified which are critical for protection of coastal communities against natural hazards. These indicator sets were linked with Industry 4.0 concepts to enhance the sustainable applicability of the framework.

Research Implications: The proposed framework stages can be used to establish functional coordination among different stakeholders e.g. engineer, asset owner, land manager, eco-engineers and community. This would also provide a systematic mechanism to assess the effects of natural hazards, propose solutions, and implement strategies for NBS to mitigate the effects of climate risks. Additionally, to achieve long-term resilience, multidisciplinary knowledge of the risks and processes occurring at different stages of framework is necessary. To achieve this, in future, key performance indicators will be developed within each resilience indicator set in context of natural hazards.

Keywords: green infrastructure, industry 4.0, nature-based solutions, natural hazards, resilience indicators.

1. INTRODUCTION

The world is largely affected by climate change, misuse of resources (land and water) and unsustainable planning, leading towards landslides, flooding and coastal erosion. Temperature increase, changing weather patterns and carbon emissions coupled with rising sea levels and coastal erosion are the most devastating events that endanger human life, property and infrastructure (Keesstra et al. 2018). In spite of these, there is increment in the coastal communities' population; in 2017 about 40% of the world's population lived near coasts for their livelihoods (fishing) and economic benefits (tourism, cultural services, shipping). As population density and economic activity in the coastal areas increases due to lack of awareness and risk perception, pressures on coastal ecosystems increase (United Nations 2017). For example, in China, there is an increase of 13.9% per year coastal population as compared to 3.9% in the western regions. Similarly, in USA, coastal people contributed more than 6.6 trillion dollars to gross domestic product in 2011. This situation highlights the economic, environmental and social vulnerability of coastal communities to hydro-metrological hazards due to unsustainable coastal development and management as well as depletion of ecosystem services (Spalding et al. 2014).

The hydro-meteorological hazards are usually attributed to atmospheric weather patterns caused by factors related to temperature, precipitation, wind speed, humidity and they may accelerate natural hazards such as landslides, flooding and coastal erosion. Similarly, human actions (carbon emissions and climate change) can exacerbate the impacts of hydro-meteorological hazards (Parida et al. 2015).

To combat natural hazards sustainably, novel approaches are required based on regional demand. The nature based solutions (NBS) are aimed at conservation, restoration or construction of ecosystems that have the natural ability to protect coastal communities against erosion, flooding, and landslides. Green Infrastructure (GI) is identical to NBS, and refers to the natural spaces in an area that improve ecological conditions and bring social, economic, and environmental benefits to communities. Indeed, these concepts has gained significant reputation as a way to address challenges in coastal zones. In this paper, NBS and GI are considered synonymous due to the role of vegetation within them which can be considered as an important ecosystem service which, in turn, increases the resilience of the coast. Although NBS/GI is an effective approach, more evidence is required to strengthen the case for its application (Keesstra et al. 2018).

Resilience in an NBS system would relate to the persistence of natural systems in the face of changes in ecosystem services due to natural or anthropogenic causes. Resilience and NBS have a positive relationship with each other and both can bring economic, social and environmental welfare to coastal zones in the form of coastal protection. Resilience is an important driver of NBS success; however, there is a lack of indicators that would identify NBS effectiveness (Dong et al. 2017). Coastal communities would need complete understanding of changes in land due to natural hazards to build resilience which, in turn, is not easy to measure. Resilience indicator sets can be a viable solution to understand and combat natural hazards, as they can be analysed and measured, as well as provide a platform to assess the needs of vulnerable communities, analyse the problem and design solutions (Bergamini et al. 2014); however, measurements only depend on the local experience, perception and observations of the local communities.

Risk perception refers to a person or community's interpretation of the hazard and its risks. Risk perception gives an overview of hazard or risk, through which stakeholders assess the potential impacts and consequences of a hazard and choose appropriate responses (Birkholz et al. 2014). In this paper risk perception will be used to achieve long-term resilience, multidisciplinary knowledge of the risks and processes occurring at different stages of framework. To achieve this, in future, key performance indicators (KPIs) will be developed within each resilience indicator set in context of natural hazards. Whereas, KPIs is the measure of a process that is critical to the success of a project or framework and a set of KPIs within resilience indicator set would allow to identify resilience potential of NBS (Mickovski and Thomson 2017).

The Industry 4.0 concepts are increasingly used for demonstrating sustainability of construction projects. Industry 4.0 can play a major part in building resilience against natural hazards. For example, the introduction of information and communication technology (ICT), including the big data, has been modifying new spheres for many fields particularly for construction and environment (Ullah 2019). ICT systems are a convenient means to provide wireless sensor networking, mobile phone applications, etc., to environment management projects. In the Industry 4.0 age, manufacturing systems are capable of monitoring physical processes, create a cyber-twin of the physical world, and make intelligent decisions. Similarly, different kinds of sensors, (e.g., position, speed, force, torque, acoustic emission, surface roughness, temperature, and thermal deformation sensors) are being used recently in environment related projects (Ullah 2019). ICT and sensors, both technologies allow direct communication with engineering systems, thus, allowing environmental and construction challenges to be solved and adaptive decisions to be made in due course (Zhong et al. 2017). As these concepts have not been considered in NBS context in the past, and the success and effectiveness of NBS can be demonstrated using them, ICT and sensors will be in the focus of this paper as they can play part to build resilience against natural hazards in the age of Industry 4.0.

The aim of this study is to develop a generic framework for identification of the resilience of NBS as innovative solutions to cope with natural hazards in coastal zones in the age of Industry 4.0.

2. METHODOLOGY

In this paper, a generic multidisciplinary framework is developed based on systematic critical literature review to identify the resilience potential of NBS against natural hazards within the context of Industry 4.0. This approach is justified because systematic literature review aims to address the problems by identifying, critically evaluating and integrating the findings of all relevant quality studies by addressing one or more research questions (Siddaway 2014). The framework has been developed through critical analysis of recent publications and technical reports related to NBS. Different publications search engines such as Science Direct and Google Scholar were used to explore NBS. Hence, the systematic review provided the basis to identify three resilience indicator sets (economic, environmental, and social), which are critical for protecting coastal communities against natural hazards.

3. FINDINGS

The critical systematic review revealed that methods of monitoring resilience are not clearly mentioned in previous studies and a new framework based on resilience indicator sets, perhaps within the context of Industry 4.0, is required. The resilience indicator sets could be linked with Industry 4.0 concepts to enhance the sustainable applicability of the framework.

Development of resilience indicator sets for NBS: In this paper three resilience indicator sets are developed from systematic critical literature review of previous research such as the indicators identified to monitor the progress of implementation of the Strategic Plan for Biodiversity 2011-2020, the Aichi Biodiversity Targets and a toolkit for the indicators of resilience in socio-ecological context (Bergamini et al. 2014). From the critical review of previous research, it was revealed that three identified resilience indicator sets are vital to build resilience against natural hazards, however, a connection of three resilience indicator sets and industry 4.0 is missing in literature. Hence, three identified resilience indicator sets (economic, environmental and social) for natural hazards will be incorporated within industry 4.0. As a result of industry 4.0 at different stages of the framework, this would facilitate selection of suitable NBS, problem identification, stakeholders risk perception, design and implementation of NBS for building resilience against natural hazards.

The economic resilience indicator set will be used to assess the financial costs of NBS, but also property value change, livelihoods creation, and economic stability of the coastal communities. To cover the social aspects of the NBS such as community engagement, communication between relevant stakeholders, local people involvement and social profits (recreation, coastal protection, aesthetics), a social indicator set would be deployed in the framework. The environmental resilience indicator set would cover the environmental (geology, land use, water, ecology) aspects of NBS such as problem identification, selection of suitable NBS, design and implementation of NBS (Stokes et al. 2014).

The identified resilience indicators (financial, livelihoods creation, social profits, coastal protection, geology, land use, water, ecology) within each indicator set will be used to develop KPIs to test and verify the framework. However, the development of KPIs within a given trial area has a range of potential success and limiting factors. This range depends on the specific characteristics of the NBS and its way of interacting with the socio-ecological systems, including the potential for trade-offs in benefits and costs within every given challenge (Narayan et al. 2017). Lessons and knowledge generated by these activities can then be used to connect local visions and strategies to build resilience against natural hazards.

Resilience framework for NBS: NBS has gained central position in managing societal challenges through novel approaches, stimulated by nature (European Commission 2015). The NBS frameworks reported in the literature, namely, Reguero et al. (2014) applied the Economics of Climate Adaptation framework in the US Gulf Coast to quantify the cost of NBS (oyster reef and marsh vegetation) under different climate scenarios and recommended it as a cost effective solution (it not only protected the coast, but also provided additional benefits in the form of ecosystem services). Similarly, Narayan et al. (2017) tested the resilience of NBS (wetland) to reduce property damage during natural hazard (flooding) and found that loss is minimized up to 1%. However, these two research studies do not necessarily contextualize the resilience indicator sets within Industry 4.0 for NBS.

The proposed framework (Fig 1) consists of five different stages, while resilience exists as a common theme and incorporates Industry 4.0 at different stages of the framework. The future steps show that the framework would be used in future to develop KPIs and manage stakeholders risk perception at all the stages of framework.

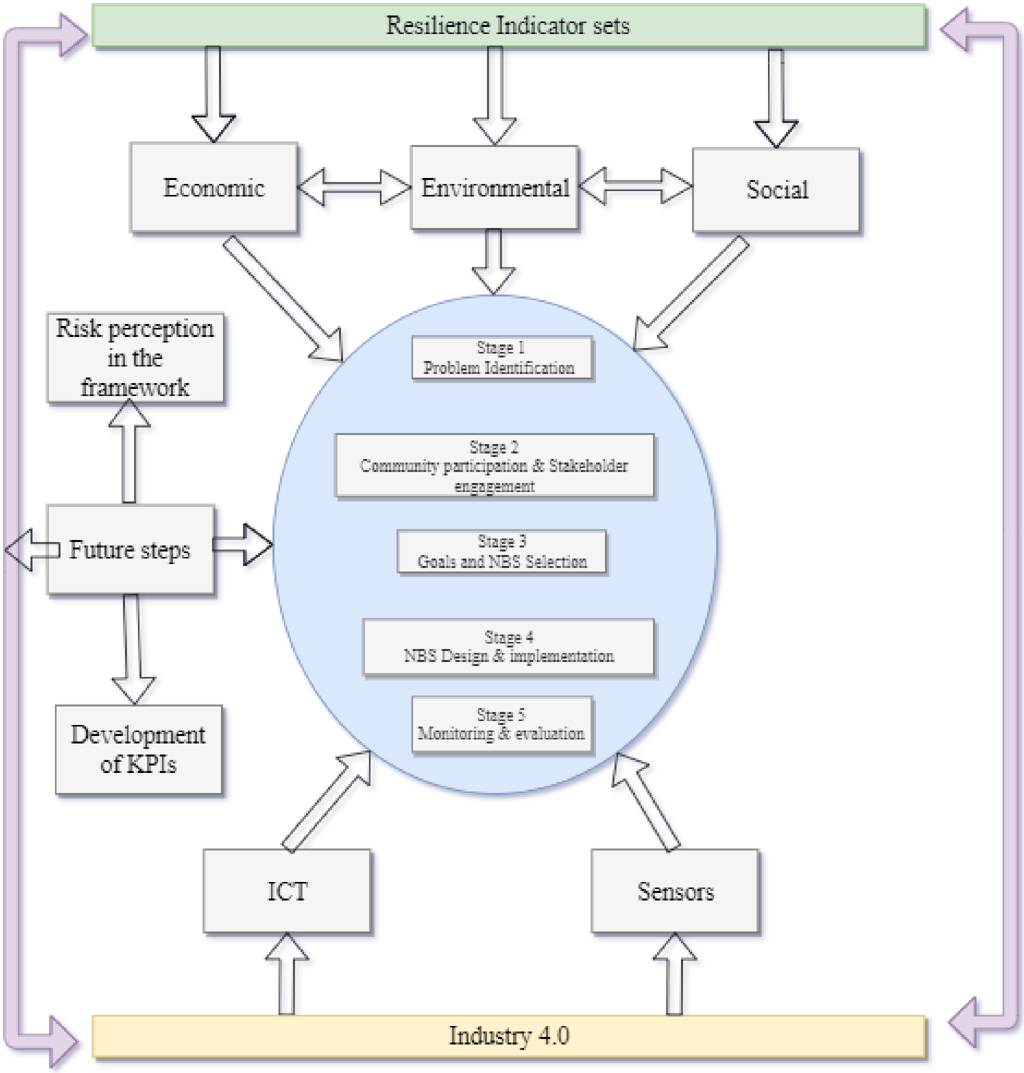

Fig 1: Resilience framework for NBS

In **Stage 1** the problem will be defined (erosion, landslide, flooding, etc., Enserink et al. 2010) and established through visual observation, field or laboratory testing. The limitations and objectives of NBS will also be set then, by describing the scenario in its economic, environmental and social dimensions. Hence, resilience indicator sets are significant to recognise the problem in context of damage to resilience (e.g. social, economic and environment). Similarly, risk perception will identify the hazard and choose right course of actions with consultation of stakeholders. In context of industry 4.0, sensors will be used to collect natural hazard data in order to establish the extent of problem. In this case, sensors can be used to plan ahead for hazard management. In **Stage 2**, multifunctional and multi sectoral stakeholder involvement will be expected to understand the need of vulnerable people and risk management (Eckersley 2006) on the background of a critical review of any previous disaster management practices. This step is effective to adopt sustainable solution, ensure transparency and legitimacy of knowledge according to local demands. Community participation is an important factor in co-designing of NBS, as it creates sense of ownership and self-governance of green areas in local people. In addition, NBS have shown positive effect on the behaviour of people when they are actively participating and managing green places (Frantzeskaki et al. 2018). Moreover, risk perception, local knowledge and collective actions of community play important part in adapting to natural hazards. The major stakeholders expected at this stage are planners, engineer, asset owner, land manager, eco-engineer, scientist and community. Stakeholders would engage across all the stages of framework to discuss progress of NBS. Different means of collaboration, such as private-public partnerships, social innovation, or, dialogue platforms for stakeholders can be used as methods to facilitate the communication process. From industry 4.0, ICT could benefit NBS by providing a platform for collaboration between researchers and stakeholders to plan NBS in context of resilience indicator sets. For example, in Taiwan, ICT was used to categorize the proposed site into different environmental risk zone based on the available data. This approach helped different stakeholders in planning and decision-making process (Lin et al. 2017). **In stage 3** the selection and assessment of proposed NBS will take place. For instance, for the negative effects of natural hazards identified in coastal areas, the ultimate goal will be to minimize hazard by adopting suitable hazard preventive measures. However, a suitable solution should be taken into account, which includes resilience indicator sets to maximize the chances of resilience. For this purpose, it is necessary to develop guidelines and procedures to select the most appropriate NBS to implement restoration methods in the vulnerable area, based on the ecosystem present situation and size of the region (Lange et al. 2018). The proposed solution could have positive or negative impacts in the region; therefore, there should be sub-objectives to combat the situation. For instance, to minimize the effects of natural hazards is main objective, sub-objective can be coastal protection by using viable NBS such as willow saplings or vegetated concrete blocks in the identified area. Sensors can play their part to obtain (e.g. soil, climate data), can be used to plan and design NBS. For example, the signals collected from the respective sensors in the field are used to understand the underlying phenomena (why is it happening), predict (what will happen), and, thus, decide the right course of action. In addition, when the resilience of NBS is studied (on the basis of obtained data) in laboratory settings, the signals collected from various sensors are used to explain the underlying aspects (Zhong et al. 2017). In **Stage 4** stakeholders should clearly define their spectrum of green solutions and how they will be installed in the light of regional demands. Moreover, the proposed solution should be assessed on the basis of resilience indicator sets, whether the approach will be economically, socially and environmentally acceptable. Different stakeholders such as designers, managers etc. can play significant role to adopt socially acceptable strategy. The implementation processes need to support openness, transparency in governance processes and acceptability of knowledge from community, practitioners and policy stakeholders. They also need to create different institutional spaces for cross-sectoral negotiations amongst different stakeholders for fostering adaptive co-management and knowledge sharing about NBS and enhance cross-sectoral partnerships. Hence, advanced knowledge and research are fundamentals of NBS, to design, manage, implement and optimize the performance of NBS, and concepts from Industry 4.0 can help (e.g. readily available physical scale models to solve technical issues or predict natural hazards and remediation (Stokes et al. 2014). **Stage 5** is critical to analyse the resilience (economic, environmental and social) and develop KPIs of NBS, because long-term evaluation is necessary to tackle any failure and to promote active learning to improve future of NBS (Frantzeskaki et al. 2018).

In the next steps, risk assessment and development of KPIs would be carried out to ensure resilience within all the stages of framework. For example, the NBS elements will have to be risk assessed for each framework stage. Stakeholders' perception and understanding of natural disasters is socially constructed. Therefore, in the stage 1 and

2, stakeholder’s differences in risk perception could lead to conflicting situations impeding the effectiveness of NBS. Hence, risk perception may amplify social, environmental and economic impact of disasters well beyond their direct consequences. Likewise, the major risks during stages 3 and 4 would be, awareness of the potential of NBS to perform resilience function, assignment of resilience function or mix of functions (planting/seeding, and protection risks) to NBS and the drivers for inclusion of NBS in the design and implementation. During the stage 5, the risks associated with NBS may include characterization and sampling frequency of NBS as well as the multidisciplinary approach towards the monitoring and evaluation (Mickovski, 2018).

4. DISCUSSION AND CONCLUSION

The resilience framework (Fig 1) is unique in its nature as it gives different stages for NBS, includes three interconnected resilience indicator sets within industry 4.0 context. It provides an emphasis to include community and stakeholders to address exact problems and then review, design, implement and evaluate NBS to address them in solution-oriented teams (cross-sectoral connections; European Commission 2015) on the background of Industry 4.0 concepts.

Industry 4.0 seems to be effective to build resilience against natural hazards. However, there are certain challenges for implementation for industry 4.0. It is an underexplored, new field in terms of academia and industry. Therefore, it is difficult to predict long-term effectiveness of this technique. In case of this paper, multiple stakeholders are unaware about the industry 4.0, and need proper technical training for sensors and ICT. It would be vital to learn novel techniques of industry 4.0 for due course management. However, it would require extra time, space and financial resources to educate the relevant stakeholders. Moreover, due to little technical knowledge of stakeholders, it can be difficult for them to adopt and implement new technology in limited period of time (Bartodziej 2017). Yet, it can hinder the progress of NBS due to time and financial constraints. Therefore, advanced research and knowledge is required to develop a connection between NBS and Industry 4.0. Stakeholder and community engagement is important for all the stages of framework, however, different challenges can be foreseen. It is considered that the multi stakeholder engagement can slow down NBS development due to diverse backgrounds of stakeholders. In addition, it is not easy to satisfy all the stakeholders on common theme, as it is a complex and hectic process (Kaczorowska et al. 2016).

Acknowledging the very high level this framework has been developed at the moment, we plan to develop a comprehensive set of KPIs within each indicator set to enable the measurement of actions, demonstrate transparency to stakeholders and build a knowledge base for the stakeholders involved. The application of such a framework and the associated KPIs will then be tested and verified with a case study. For example, a sustainability assessment method based on key performance indicators (KPI) relevant to eco-engineering (Mickovski and Thomson 2017) can be used as planning tool in order to predict and mitigate the NBS-associated risks in all the stages of framework. In future, KPIs will be developed based on three resilience indicator sets, through community participation and stakeholder engagement. Hence, the framework will seek to capture quantifiable measures as well as the more subjective dimensions of resilience in sustainable manner. The advantage of using this approach is that it can be applied to all stages of framework and monitor the overall performance of framework based on resilience as a driver while accounting for the risks within resilience indicator sets (Mickovski, 2018). For long term resilience of NBS, proper management should be ensured from beginning till end (Rey et al. 2019) and Industry 4.0 concepts such as big data management or building information modelling (BIM) may provide useful tools.

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POTENTIAL OF EXPLOITING CONSTRUCTION 4.0 ASSOCIATED INNOVATIONS AND TECHNOLOGIES IN IMPROVING DISASTER RESILIENCE IN THE VIETNAMESE BUILT ENVIRONMENT

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ABSTRACT

Background: For decades, Vietnam has been known as a country significantly vulnerable to climate change and its associated phenomenon including disasters. Following detrimental impacts caused by manifold disaster events throughout years, disaster resilience has become increasingly vital in the development of the Vietnamese built environment.

Purpose and Originality: Improving disaster resilience of the Vietnamese built environment has faced many challenges in various aspects. This paper presents the technical challenges for achieving a resilient built environment in Vietnam, followed by the potentials that Construction 4.0 technologies can offer to overcome those challenges.

Methodology: The findings are based on a comprehensive review of literature and an exploratory questionnaire survey which was conducted in purpose of establishing a framework to integrate disaster risk reduction more effectively into the Vietnamese built environment.

Findings: The key technical challenges identified are associated with tools and platforms for assessing DRR integration, risk assessment, existing vulnerable buildings, disaster mapping, building codes and accessibility of disaster data. Through Construction 4.0 technologies, such barriers can be tackled by facilitating the project stakeholders' involvement more effectively in the process, enabling simulations on structural performance and resilience of the construction, improving assessment of design options, minimizing unlawful activities, etc.

Research Implications: In the face of focus being placed solely on Vietnam, the framework is applicable to other countries that possess similar cultural and social characteristics, economic situations and geographical features with an endeavour to achieve a more resilient built environment.

Keywords: Disaster, Built Environment, Construction 4.0, Resilience, Vietnam.

1. INTRODUCTION

Vietnam is prone to a wide range of natural hazards and has been identified as a hotspot of primary future climate impacts and vulnerabilities in Asia. The most prevalent types of disaster in Vietnam are storms and floods, which account for 49% and 37% of all events respectively (Thao 2014). The impacts of disasters upon different sectors of the economy are so detrimental that the annual loss is recorded as 1-1.5% of GDP (Give2Asia 2015). Thus, disaster resilience has become the priority issue for Vietnam. The construction industry and the built environment is one that is directly exposed and most susceptible to natural hazards. During the period 2005-2015, there were a total of 649 events battering the country that resulted in 469,256 destroyed and 174,653 damaged houses on the annual average (Tri Thuc Tre 2015). The last two months of year 2016 alone had witnessed 317,000 residential properties collapsing as a consequence of five devastating flood incidents, making the total loss in 2016 reach US$ 1.7 billion (Pham 2016). Besides, the Vietnamese transport system incurred a loss as much as US$ 100 million per annum due to floods and landslides (Ky 2016).

Over the last ten years, Vietnam has recognised the importance of resilient built environment and has correspondingly achieved a noticeable progress in integrating disaster risk reduction (DRR) into national and provincial socio-economic development planning framework. However, the Vietnamese built environment's achievements have remained limited due to many different challenges, which can be categorised into physical, social, cultural, political, economic, and technical strata. This study paper presents the technical challenges for achieving a resilient built environment in Vietnam, followed by the potentials that Construction 4.0 technologies can offer to overcome those challenges.

2. METHODOLOGY

The core of this paper was derived from findings of an exploratory questionnaire survey whose one of the primary objectives was to identify the most prevalent and critical challenges for integrating DRR into the Vietnamese built environment. The survey participants consisted of planners, architects, project managers, engineers and surveyors. The data set was built upon a total of 161valid responses.

The survey's findings on technical challenges revealed potential areas for the application of Construction 4.0 technologies. A comprehensive review of literature was then carried out to identify which technologies are currently associated with the concept of Construction 4.0, and in which aspects they can help to cope with the identified challenges. The literature comprises of academic databases, professional reports, and conference proceedings using keywords such as: industry 4.0, construction 4.0, ICT, built environment, construction industry, disaster, resilience, disaster risk management, and disaster risk reduction.

3. TECHNICAL CHALLENGES FOR ATTAINING RESILIENT BUILT ENVIRONMENT IN VIETNAM

The Government of Vietnam sees attaining resilient built environment through DRR as a crucial integral element of the national socio-economic development. Nonetheless, the progress of integrating DRR has remained limited due to various challenges. The exploratory questionnaire survey has revealed a number of prevalent challenges, some of the most significant are concerned with environmental degradation, proximity of urban population to coastal and floodplains, insufficient funding, poor disaster risk management planning, and lack of training and education. Noticeably, there parallelly uncovers six technical challenges that are considered critical to require attention. These technical challenges are presented in the Table 1. The prevalence level of each challenge is determined by the cumulative number of responses that indicated 'Agree' and 'Strongly agree', while the criticality level is constituted by the frequency of that factor being chosen as one of the most five critical challenges.

Table 1: Technical challenges for attaining resilient built environment in Vietnam

Technical Challenges	Prevalence		Criticality	
	Frequency	p-values*	Frequency	p-values*
Challenge 1: Existence of vulnerable old building stock and at-risk infrastructure	110	0.042	51	0.032
Challenge 2: Lack of tools and platforms to assist in assessing DRR integration	97	0.048	28	0.044
Challenge 3: Lack of proper disaster risk assessment in construction	110	0.039	34	0.044
Challenge 4: Inadequate disaster mapping	62	0.040	15	0.035
Challenge 5: Scatter of data on vulnerabilities and risks to disasters	84	0.045	12	0.039
Challenge 6: Incompatibility of building codes and lack of enforcement	73	0.049	13	0.038

*: p-values from Chi-square tests conducted to determine whether there is a relationship between prevalence frequency and built environment discipline and between criticality frequency and built environment discipline.

According to the Table 1, the data set is statistically significant with all the p-values are less than 5%. The use of low-quality building materials and unfavourable building typologies and designs for natural hazards and extreme events is explicitly the greatest technical barrier for attaining resilient built environment in Vietnam. In this respect, the challenge is much associated particularly with the housing sector. From the working experiences of the researcher, there are two common underlying driving forces that makes the sector uncapable to overcome this challenge. The first driver is the economic difficulty of vulnerable low-income households where financial shortages hinder their endeavour to build safer shelter, and the other is limited capability of builders and construction workers in building disaster-resilient houses.

The challenge that draws the second most attention is lack of assessment tools pertaining to the process of integrating DRR. Currently there exists no legitimate assessment framework with inclusion of indicators to evaluate precisely the implementation of DRR in design, construction, operation and maintenance practices. Besides, it was widely agreed by the respondents that disaster risk assessment in Vietnam has been conducted in an inadequate manner. In support to this particular finding, the other part of data set also shows that in construction projects in Vietnam the criteria required for the analysis major hazards remains superficial; and that the analysis of main causes of vulnerability remains shallow and does not follow scientific process. Last but not least, the three challenges which are concerned with building codes, disaster mapping and data fragmentation are interconnected. The current building codes of Vietnam are designed with little consideration given to flood-resilient construction meanwhile enforcing building regulations pertaining to flood resilience require very detailed authorised risk maps and scenarios which are unavailable in Vietnam at present.

4. CONSTRUCTION 4.0 INNOVATIONS AND TECHNOLOGIES

Construction 4.0 was derived from Industry 4.0 concept, which describes the trend for the swelling use of information and automation technologies in manufacturing sector (Kagermann 2013). This section presents an insight into the Industry 4.0 concept in the context of the construction industry; and the set of innovations and technologies it can offer to enhance the performance of the sector.

4.1 The concept of Industry 4.0 in the construction industry

The term 'Industry 4.0' was originally developed by the German Federal Government in the purpose of promoting their high-tech strategy in the field of manufacturing. It has conventionally been used as an alternative way to express the planned 4th Industrial Revolution by emphasizing its massive technological potential. This is considered to be comparable to technical innovations which constituted the previous revolutions: (1) the field of mechanism, (2) the use of electricity, and (3) the beginning of digitalisation (Lasi 2014).

The significance of Industry 4.0 in manufacturing towards improving the performance of the sector has been widely recognised. In contrast, the construction industry has ben unable to adequately secure the benefits of Industry 4.0 and compete with the manufacturing sector (BDC 2016). Oesterreich and Teuteberg (2016) suggested that the lack of investment in research and development is responsible to such low progress in applying new technologies in the construction sector. In fact, inherent characteristics of the construction industry make it more challenging to apply new technologies (Shrestha 1995). These include complexity of construction projects, unpredictable environment, high fragmentation in the supply chain, temporary nature of construction projects, and strong resistance to changes. Yet, in similar to the industrial revolutions, the construction industry has evolved through various phases which sees Construction 4.0 as the rise of innovations and technologies.

4.2 Construction 4.0 innovations and technologies

Oesterreich and Teuteberg (2016) established a wide range of interdisciplinary technologies and concepts which enables the digitalisation, automation and integration of construction process at different stages. These are grouped into three main clusters: smart factory, simulation and modelling, and digitalisation and virtualisation (Figure 1).

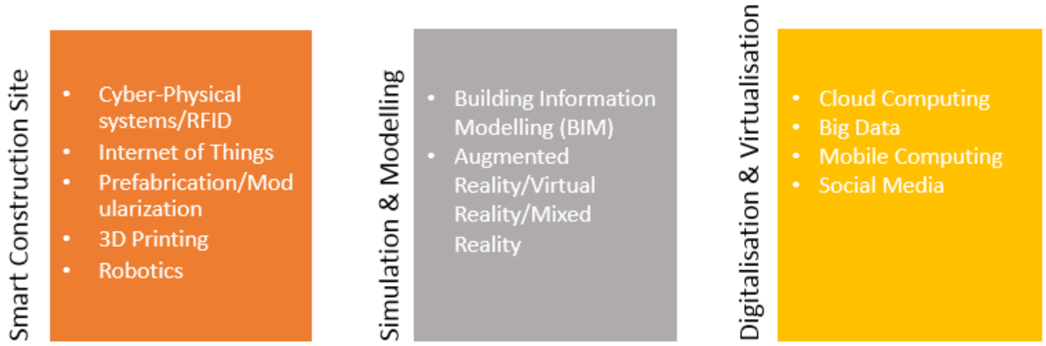

Figure 1: Key Construction 4.0 technologies (Oesterreich and Teuteberg 2016)

5. ENHANCING DISASTER RESILIENCE OF THE BUILT ENVIRONMENT THROUGH CONSTRUCTION 4.0

5.1 Smart Construction Site

The first cluster in Figure 1 comprises a variety of technologies and concepts to automate the construction process and to establish a smart factory for the construction environment. In general, there are a few noticeable approaches to create a smart construction site in respect to enhancing disaster resilience.

The first approach deals with the integration of Cyber-Physical Systems (CPS), which can be utilized to facilitate bi-directional coordination between virtual models and physical construction (Akanmu and Anumba 2015). In terms of disaster risk management, the application of CPS can substantially support construction project stakeholders in analysing disaster preparedness issues, identify critical assets, assess vulnerabilities and potential threats, and also identify risk levels with inclusion of proper controls to mitigate disaster risks (Jain 2017).

Sensor technology is an essential part of smart construction site, and Radio-Frequency Identification (RFID) together with Internet of Things therefore offers various solutions for the automation of the construction process. In the context of disasters, it enables site personnel to effectively track and manage construction tools, equipment, materials as well as prefabricated building components for the purpose of reducing potential damages caused by, for examples, flood and storms, and hence optimising project schedule and project cost. Besides functions that served the disaster preparedness (Sardroud 2012), RFID has also proved its importance in rescue operations in the aftermath of disasters. In the context of Vietnam, since replacing old and vulnerable building stocks and at-risk infrastructure entails substantial funds, which implicates a lengthy process, RFID is perhaps the most viable solution for the time being.

In line with an endeavour to construct a resilient built environment, Modularisation or Prefabrication has demonstrated to offer significant benefits for disaster-prone areas, especially coastal and floodplains in the context of Vietnam for instance. These include faster replacement of damaged buildings, environmental friendliness and affordability (Fenner 2017). Moreover, prefabricated construction carries specific building codes and requirements for high-risk areas. Materials used for modular buildings are not different from conventional way of construction, but the method of assembly of elements in fabrication can improve the resistance of the building in its entirety.

While Prefabrication has been broadly adopted in construction companies, Additive Manufacturing or 3D printing, which in the future perspective enables the automate manufacturing of the most complex architectural components at no extra cost, is currently under high level of aggressive research. 3D printing can be adopted to build a multi-purpose disaster prevention and relief material distribution centre in the disaster-prone community (Saunders 2018). It is considered as a more environmental-friendly mean to manufacture structures, and the materials used also possess higher level of both design flexibility and structural strength. In the other words, 3D printing in combination with Prefabrication allows efficient and safe construction in a relatively short period of time with reasonable cost control. All of these features make 3D printing an ideal solution for post-disaster reconstruction.

The final approach is Robotics, which has drawn a great deal of interest in its application to manage disaster risks. In Japan, robots have been used to collect data on historical disasters and accordingly establish plans for mitigation of disaster events. In the United States, robotic systems have also been actively researched in terms of the development of rescue robots, human-robot interfaces, communication aids, filed evaluations and infrastructure improvements (Stormont 2009).

5.2 Simulation and Modelling

The second cluster is concerned with simulation and modelling. In this central part of Construction 4.0, Building Information Modelling (BIM), which is the most emerging and well-known technology, helps to virtually design and manage construction projects by simulating model of a building. BIM can be beneficial for the disaster resilience of the construction industry and built environment (Oesterreich and Teuteberg 2016). According to Sertyesilisik (2017), the primary benefits BIM can offer in the pre-disaster phase include:

- Enabling of assessment of design options to reduce waste;
- Facilitating involvement of design team far sooner in the process to eliminate environmentally inefficient items;
- Activating deconstruction ability analysis;
- Accommodating simulations on structural performance and resilience of construction;
- Improving occupational health and safety performance; and
- Ensuring smooth and effective work-flow and lean performance.

In respect to the post-disaster evacuation and reconstruction, BIM can assist in:

- Enabling rapid and effective evacuation;
- Improving fire safety management;
- Enhancing quality management and adaption of the construction process to change orders; and
- Enhancing supply chain's resilience.

Another remarkable approach of this cluster is the use of drones in combination with virtual reality technology. Areas that are prone to disasters, such as flooding in Vietnam for example, will benefit significantly from visual imaging and 3D mapping. The utilisation of drones provides great advantages in terms of cost, response time and importantly ability for identifying and assessing infrastructure that is critically damaged. In the event of disaster, drones can be useful to support infrastructure, deliver supplies and establish communication (EKU 2017).

5.2 Digitalisation and Virtualisation

The final cluster includes articles relating to digitalisation and virtualisation, such as Cloud Computing and Big Data. These innovations are of special importance to provide a platform to ensure effective application and operation of technologies in the other two clusters. In construction environment, Cloud Computing deals with provision of integrated services with the opportunity to be accessed via the internet for collaboration between different parties in project (Oesterreich and Teuteberg 2016). The adoption of cloud-based solutions allows all project stakeholders to retrieve information from any communication device with internet access. Meanwhile, the implementation of Big Data can help to collect correct data generated by manifold agents such as BIM models and the likes of embedded sensors, machine, computers or people (McMalcolm 2015). In the context of disasters in Vietnam, for instance, the analysis of weather data makes it possible to identify patterns and probabilities of disaster risks in order to obtain enhanced decision making or performance improvements in future construction projects, especially those located in coastal and floodplains.

The Figure 2 summarises the potential contribution of each cluster of Construction 4.0 technologies to tackling with the identified technical challenges in attaining resilient built environment through DRR in Vietnam.

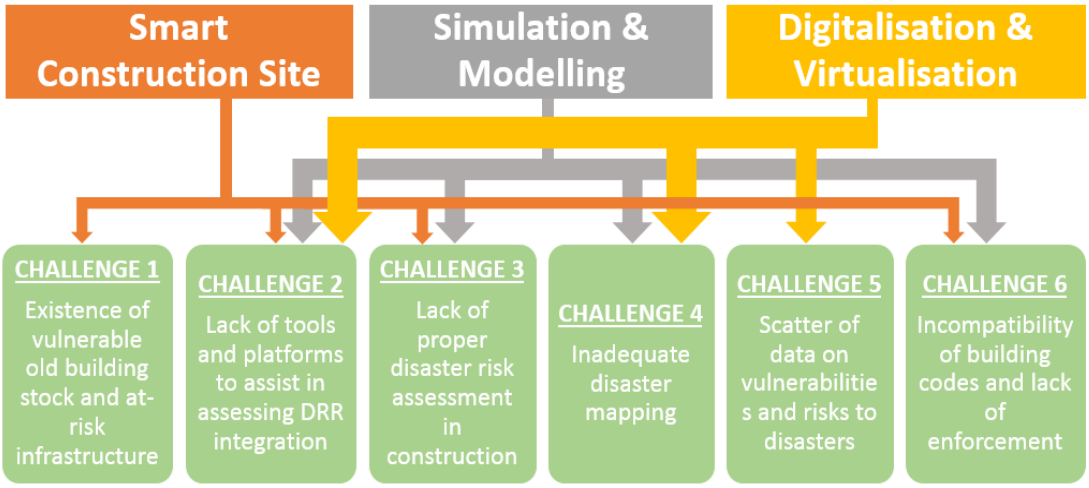

Figure 2: Contribution of construction 4.0 to overcoming technical challenges of DRR

6. CONCLUSIONS

Despite attaining resilient built environment having been recognised over a decade, the implementation of DRR in Vietnam has been facing a number of technical challenges, which mainly deal with tools and platforms for assessing DRR integration, disaster risk assessment, existing vulnerable building stock, disaster mapping, building codes and accessibility of disaster data. These barriers, together with the increasing recognition of the 4th Industrial Revolution, has prompted the needs to utilizing innovative technologies to improve the performance of disaster risk management in construction environment. It is demonstrated that Construction 4.0 innovations and technologies can be of much helpfulness to tackling with the identified challenges in various ways. Their potentials are explicit, however, ensuring the application of these concepts and technologies in an effective and prevalent manner is not a simple task. Future research with focus on the practical implementation is highly recommended to make a scenario, where disaster resilience in the Vietnamese built environment is substantially improved through Construction 4.0, become more viable.

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THE APPLICATION OF THE FLOOD RESILIENCE CIRCLE TO THE CITY OF BIRMINGHAM

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ABSTRACT

Background: Like many cities, Birmingham is exposed to a range of different flood risks from a variety of sources and has experienced a number of significant flooding events in the past two decades. The impacts of these flood events include physical damage to critical infrastructure, buildings and homes; commercial, industrial and residential contents; as well as significant losses caused by business interruption and general disruption to communities. Human losses are also experienced in the form of psychological harm, distress and, in extreme cases, fatalities. There is a growing concern that the current redevelopment and regeneration taking place in the city, coupled with more extreme weather events, will exacerbate these events in the future.

Purpose and Originality: In recognising that flooding cannot be prevented and in line with government policy towards 'living with water', the concept of resilience has become vital for city planners and decision makers to adopt a more managed approach to flood risk. This study aims at identifying the current challenges and opportunities of managing flood risk in the city of Birmingham, drawing on a desk based account of current flood risk management (FRM) practice and diagnostic evidence.

Methodology: This interrogation adopts the use of a 'flood resilience circle model' to help inform the process and consider and address the challenges in a methodological manner aligned to an integrated approach to flood risk management.

Findings: Elements that make up the key FRM stages of prevention, preparation, response and recovery are described. The findings will be of interest to policy makers and decision makers on how to address current weaknesses in FRM practices towards the prospect of a sustainable approach that improves the resilience of the city and delivers multiple benefits.

Keywords: flood hazard, flood resilience, flood risk, flood risk management

1. INTRODUCTION

Major cities around the world have suffered substantial losses caused by flooding, recent ones include Prague (2002), Bern and several other cities (2005), New Orleans (2005), Hull (2007), Queensland (2010), South-western England (2013–2014), the French Riviera (2015) and Texas (2017). The impacts of these flood events include physical damage to critical infrastructure, buildings and homes; commercial, industrial and residential contents; as well as significant losses caused by business interruption and general disruption to communities (Jha, et al., 2012). Human losses are also experienced in the form of psychological harm, distress and, in extreme cases, fatalities (McNulty & Rennick, 2015). These damages caused by floods continue to increase (Jha, et al., 2012). Over the past three decades more than 100 million people have been affected by floods annually with more than 2.8 billion people affected since 1990 across the globe (Guha-Sapir, et al., 2017). However, data from the EM-DAT source show that flood events are becoming more frequent due to the significant increase in the number of reported flood events. Furthermore, forecasts show that these events will increase in both frequency and severity (Allan, 2011; Min et al., 2011). For example, it has been projected that UK flooding may escalate by up to 30 times over the next 75 years, with huge financial implications (Evans, et al., 2008).

The past two decades have seen a number of flooding events affecting the city of Birmingham, UK from sources including watercourses, surface water, sewers and groundwater (Birmingham City Council, 2017a). Flooding continues to constitute a major nuisance to key features of the city, with a growing concern that a combination of rapid urban expansion and extreme weather events will significantly exacerbate these problems (Miller & Hutchins, 2017). However, for many years, the standard response to mitigate against flooding has been by the use of flood defence systems. In the case of Birmingham, flood defence walls, storage tanks, balancing ponds, land drainage and highway drainage are some of the structural measures that have been put in place to reduce the likelihood of flooding and its impacts (Birmingham City Council, 2012).

Due to the interplay of extreme floods, population growth and rapid urbanization, flooding has increased such that these conventional flood risk management (FRM) measures of concrete structures and other defences have now become inadequate and unsustainable across various communities (Duy, et al., 2018). However, thinking has changed from the single concept of outright resistance of inundation towards the establishment of a softer and more sustainable measures of dealing with flood risk through the concept of resilience (DEFRA, 2005). While the concept of resilience is an emergent approach to help cities deal with natural hazards including flooding (Duy, et al., 2018), yet, it has enjoyed prominence in both academic research and policy. However, Hammond et al. (2015) believe that for a city to be resilient to flooding, innovative and adaptable strategies are needed to manage flood risk. According to Liao (2012), these strategies must ensure that the city possesses the capacity to endure flooding and regroup itself in order to minimize potential impact while socio-economic identity is maintained. It is acknowledged that no strategy can totally eradicate the impact of flooding, but based on Liao’s definition of a resilient city, the adopted FRM strategy must possess three key properties which are essential when it comes to preserving individual safety and urban identity. These properties are: (i) localized flood-response capacity, (ii) timely adjustments after every flood, and (iii) back-ups components in the subsystem, i.e. standby resources that can be activated during or after flood event. One of these properties is evident in the UK flood management system (the localised flood-response), where the local authorities have lead responsibility for managing local flood risk which places the Birmingham City Council in the position to manage flood risk within the city. However, if the city is going to be resilient to flooding, the authority in charge must adopt innovative and adaptive FRM strategies which will possess the other properties identified in Liao's definition.

The aim of this study is to identify the current challenges and opportunities of managing flood risk in the city of Birmingham, drawing on a desk based account of current flood risk management (FRM) practice and diagnostic evidence. The investigation adopts a critical lens to the current flood risk strategy and approaches towards identifying opportunities for improvement at the city, community and property level. The study is structured as follows. Section 2 provides information on the current management of flood risk in Birmingham while section 3 presents the flood resilience circle model which is adopted to address the challenges in the FRM strategy.

2. THE FLOOD RISK MANAGEMENT SYSTEM IN BIRMINGHAM

2.1 Study Area

Birmingham is a major city in England, the largest city of the West Midlands conurbation and one of England's vital industrial and business regions. The city provides for a managerial, recreational, and social focus. In 2016, the estimated population of the city was over 1 million and covers a land area of about 270 sq. km (Office for National Statistics, 2017). It is the largest local authority in both the United Kingdom and Europe (Birmingham City Council, 2017b). The Area is served by the Environment Agency West Midlands Area and Severn Trent Water.

2.2 The FRM nature of Birmingham City

As defined by Schanze (2006), flood risk management is the continuous and holistic societal analysis, assessment and mitigation of flood risk. Flood risk management in a narrow sense embodies the practice of managing an existing flood risk situation while, in a broader sense, it encompasses the planning of a system with the sole aim of reducing the flood risk (Plate, 2002). Birmingham City Council has a responsibility under the Flood and Water Management Act 2010 to develop a strategy for managing flood risk and also holds the duty of maintaining the strategy. The city council, however, has an emerging Local Flood Risk Management Strategy (LFRMS) developed with the principal aim of ensuring that flood risk within the region is clearly understood and aptly managed. The role is one of coordinating flood risk management, rather than managing it. Therefore, the strategy intends to inform the public about all the stakeholders involved in managing risk, improve their understanding of the level of flood risk and acquaint them with the measures that can be taken to manage the risk. The LFRMS sets out to achieve its aim through seven objectives which are: defining stakeholders' role; developing a clear understanding of the type and level of flood risk; identifying who manages flood defences; describing how flood events are managed and investigated; outlining how flood risk schemes are prioritised; reducing the impact of development; and considering the environment.

2.3 The Flood Type and Level of Flood Risk

Some of the key objectives of the LFRMS are to prevent the predominant types of flooding and develop a clearer understanding of the flood risk within the region. According to a report published by Birmingham City Council, the city has experienced a number of flood events in recent years with many of these arising from watercourses, surface water, sewers and groundwater (Birmingham City Council, 2017b). The vulnerability of the city is due to its location as well as topographical and geological characteristics (Birmingham City Council, 2017a). However, flash flood events have become the most commonly experienced as a result of the features of landscape and the urban nature of the city which aggravate the risk. Also, this type of flood often leaves people with little time to prepare or evacuate (Birmingham City Council, 2017a).

The next sub-sections describe the various flood types commonly experienced within the city, highlighting the stakeholders responsible for managing risk at each level.

2.3.1 River Flooding

Although Birmingham does not have large rivers that could result in the kind of flooding that draws national attention and intervention of the Environment Agency (Birmingham City Council, 2017a), it has 12 main rivers with several ordinary watercourses and reservoirs (see Figure 1). Most of these water-bodies possess natural floodplains which are areas intended for overbank flow or as buffers for the impacts of flooding. Nonetheless, parts of the rivers have been heavily modified in places by human activity – some parts of these rivers have been redirected and constricted which now flow within engineered walls (Birmingham City Council, 2017a).

The Environment Agency holds responsibility for the management of flood risk on Main Rivers while the flood risk management of other water bodies not specified as main rivers remains the responsibility of Birmingham City Council. However, in both cases, the riparian owner is responsible for the maintenance of the watercourse through their land.

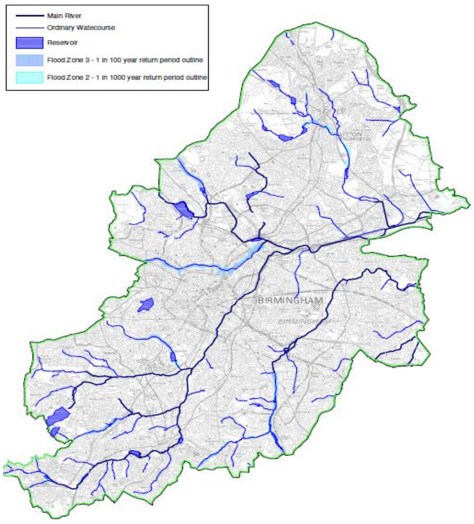

Figure 1: Flood map for ordinary water courses in Birmingham city
Source: (Birmingham City Council, 2011)

2.3.2 Surface Water Flooding

Surface water is rainwater which is on the surface of the ground and has not moved into a watercourse, drainage system or sewer. Surface water flooding occurs in the case of where high rainfall exceeds the drainage capacity in an area. The urban nature of Birmingham with significant impermeable areas across the city generates significant surface water runoff which places extreme pressure on the existing drainage systems (Whitehouse, et al., 2015). Birmingham has a history of surface water flooding, where heavy rainfall overwhelms drainage systems and watercourses (Whitehouse, et al., 2015). In 2009, it was estimated that 22,900 properties are at risk of surface water flooding in Birmingham, making the city highest ranked settlement of properties at risk from surface water flooding after London (Birmingham City Council, 2015). The easiest indication of this kind of flooding is the presence of surface water runoff on the highway. In the case of Birmingham City Council, maintenance of highway drainage is undertaken by Amey, the Council's Maintenance and Management Partner (Birmingham City Council, 2017a).

2.3.3 Groundwater Flooding

Groundwater flooding tends to occur after long periods of continuous rainfall. Continuous rainfall results in more water permeating into the ground and causing a rise in the water table above normal levels. For Birmingham, the presence of a geological fault that travels from the North east to south west, passing just to the south of the city centre (Birmingham City Council, 2017a) means that there is variation in groundwater depths across the city. Therefore, the flood risk presented by groundwater is concentrated in the area immediately surrounding major and minor watercourses (Whitehouse, et al., 2015). While there is localised areas of groundwater flood risk, there is predominantly low groundwater flood risk in the area to the north west of the fault, with wide variation from low to very high risk to the south east of the fault. Flooded basements are a primary indication of groundwater flooding. As the water level rises the water may emerge above ground level causing flooding of buildings and roads as well as infrastructure and services, such as underground trains and sewers. When water gets to the surface the damaging potential also rises. However, the City Council is the management authority responsible for managing the groundwater flood risk at local level according to the Flood and Water Management Act.

2.3.4 Sewer Flooding

Sewer flooding occurs when sewers are overwhelmed by heavy rainfall or when they become blocked. Individual property and land owners have responsibility for their own piped drainage infrastructure. Where piped drainage becomes part of the general shared infrastructure it is generally adopted as public and becomes the responsibility of Severn Trent Water.

3. THE FLOOD RESILIENCE CIRCLE

Figure 2 shows an approach referred to as the flood resilience circle developed by Royal Haskoning (Royal HaskoningDHV, 2018), which can be applied to help make cities more resilient to flooding. This approach considers a four-phase intervention to flood resilience comprising prevention, preparation, response and recovery phases. The model depicts a 3-step activity necessary to carry out each phase. The inner circle represents how cities are being affected by flooding and how they can move to being a resilient city. Cities are being exposed to the reality of changing climate whose damaging effects are already evident in every corner of the world (UNICEF Office of Research, 2014). While extreme weather events are a natural feature of the climate system (Steffen, et al., 2017), these events are becoming more frequent and more intense as a result of climate change (see figure 2).

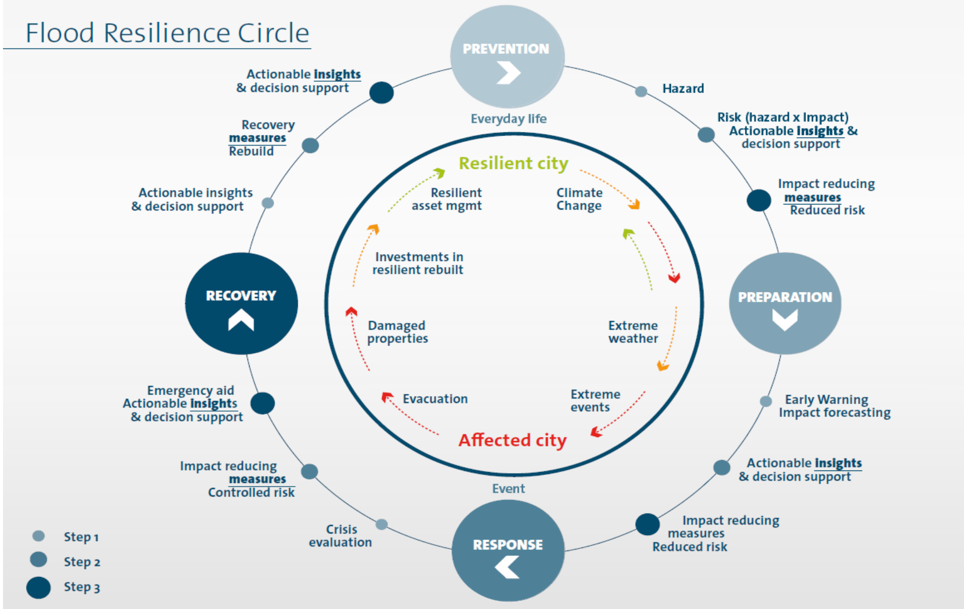

Figure 2: the Flood Resilience Circle
(Source: the Royal Haskoning DHV, 2018)

According to Steffen et al., (2017), this increase in frequency of occurrence is due to the fact that these events are now occurring in a more energetic climate system, in an atmosphere that is warmer and wetter than it was in the 1950s. In the UK, the occurrence of extreme weather events has increased in recent years, with four of the five wettest years on record for the UK occurring since the turn of the millennium (2000, 2002, 2008 and 2012) (Met Office, 2014).

These events expose weaknesses within the cities flood risk management approach and create opportunities for learning about building for the future to make cities more resilient. For any city with a risk of flooding there is always the choice of redesigning the city so that it is resilient to floods. As depicted in Figure 2 for the affected city to become resilient, it has to learn from these extreme events and invest in resilient rebuilding to help protect residents in an efficient and cost effective manner and also encourage business continuity. Planning for resilience makes investments in people, assets, and the value created in cities more secure.

Meanwhile, the outer circle indicates the four-phase approach to developing resilience within the city. This represents the FRM strategy required to adapt the key features of the city against flood impacts. These four stages are described.

1. Prevention: This is also referred to as flood avoidance and entails activities that are carried out prior to flood event. It involves identifying flood related hazards and having proper understanding of flood risk. Prevention measures focus on reducing the chances of flooding and the impacts of flooding, in case it floods, by trying to discourage development in flood prone areas thereby limiting flood risk exposure of both people and properties.
2. Preparation: This approach agrees with the fact that it is not possible to completely eradicate the risk of flooding and therefore it builds on developing preparedness to minimise the consequences of floods. With more effort put into preparation, the easier it will be for cities to cope with severe and unpredicted events and to help reduce shock. These measures include the development of flood warning and forecasting systems. The purpose of flood warning is to offer advice about future flooding so that people can act to minimize the impacts.
3. Response: Even with the application of non-structural flood mitigation measures such as the flood avoidance and preparation strategies, it is key to recognize that residual flood risk will remain. These plans are aimed at dealing with this residual flood risks and their aftermath. The response involves several activities which form the flood emergency plan. An appropriate and implementable emergency plan will facilitate emergency response through the efficient allocation of rescue resources and evacuation plan in order to minimise flood impact.
4. Recovery: This approach enables cities to bounce back, in good time and probably better than it used to be, after a flood event. Measures include reconstruction and rebuilding which may also provide opportunity for making the features of the city more resilient to similar events. In the process of recovery, two things are vital: first, is to ensure that the city gets back to its normal life even while reconstruction work is on-going; and second, is to reduce the reconstruction time as much as possible.

4. SIGNIFICANCE OF THE MODEL TO BIRMINGHAM FRM STRATEGY

Historically, the standard response to managing flood risk in the city has been through a reliance on engineered flood defences in the form of walls, storage tanks and drainage systems. However, current flood risk strategy in the UK has moved towards more sustainable approaches that adopt the concept of resilience and living with water, to build back better. This study sort to critically examine the current approaches of managing flood risk towards identifying opportunities for improving the resilience of the city. The flood resilience circle model was developed to provide a coherent basis for the systematic evaluation of the current approaches of the flood risk management. This approach followed the key stages of integrated flood risk management, and incorporated key contemporary features including Integrated Catchment Management and Strategic Governance.

5. CONCLUSIONS

Birmingham city has experienced several flooding in the past, particularly the surface water flooding. About 22900 properties currently exposed to this kind of flooding-Surface water flooding. Previous flood events have exposed weaknesses in the city’s current FRM approach, though the approach is still in its developmental stage but it creates opportunities for improvement as the strategy is being laid out. It is identified that the role of the city council who has the lead responsibility for developing the local FRM strategy is more of coordinating flood risk management, rather than managing it which is key issue with consequence as the overall role becomes operational, rather than strategic. Also, the current paper has identified the current nature of the Birmingham FRM and the analysis of the current state of the Birmingham FRM in line with the flood resilience circle model will help identify challenges and possible opportunities to develop an adaptive, strategic and sustainable FRM system. The application of the flood resilience circle model to the Birmingham city FRM practise is part of an ongoing study to identify the challenges and opportunities of making Birmingham a flood resilient city and further work will be done to investigate the Birmingham FRM practise in terms of the four approaches highlighted in the flood resilience circle. The next step in the research will be to apply flood resilience circle model to Birmingham city.

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BIG DATA ANALYTICS AND BIM SYSTEMS FOR DISASTER RESILIENT BUILT ENVIRONMENT

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ABSTRACT

Background: The built environment is increasingly advancing towards a resource efficient circular economy and is leading to more efficient and customisable manufacturing through Industry 4.0.

Purpose and Originality: Research on disaster management mostly focuses on the possibility of using particular types of data for natural disaster management. Although this topic has been intensively examined and analysed by several researchers from different fields of science such as: architecture, engineering, and construction (AEC), further investigation on the integration of big data analytics with BIM systems for disaster resilient built environment is lacking.

Methodology: This paper reviews the current literature on big data analytics with BIM systems to identify gaps in research and aims to examine the application of big data in disaster resilience and management.

Findings: BIM is a process for creating and managing information of construction projects across the project lifecycle. It offers building teams the opportunity to save time and money by reducing friction within a project. Furthermore, BIM models provide several important benefits for the facility management industry as: increased productivity, efficiency transformation, and improved liveable environment. Big data includes a mixture of structured, semi-structured and unstructured real time data originating from variety of sources. It has been used in different construction fields like: optimisation of energy consumption, management of construction waste prediction and minimisation, facilities management and operations, and building asset management. Big data is captured from sensors built into buildings, bridges and any other construction that enable monitoring each one at many levels of performance.

Research Implications: This paper analyses the importance of integrating big data analytics and BIM systems for disaster resilience by involving the advantages of BIM implementation that will emphasize the disaster management process.

Keywords: Big Data, Big Data Analytics, BIM, Disaster Resilience, Disaster Resilient Built Environment.

INTRODUCTION

Natural disasters such as: earthquakes, fires, flooding, tornado can happen everywhere and anytime. These can cause serious problems such as: human death, properties and infrastructure destruction, and equipment loss. For instance, in the Haiti earthquake that happened in 2010, around 1.5 million people have been directly affected and around 105,000 homes have been completely destroyed and more than 208,000 damaged (Haiti PDNA 2010). Moreover, the impacts of disaster events can disrupt the progress of nations, often pushing them many years back. When there is a disaster, every second counts. To avoid unnecessary human life loss, it is important to have a well-thought out emergency evacuation plan. The natural disaster impact assessment is important in helping people estimate replacement costs and performing cost-benefit analyses in allotting resources to prevent and mitigate the consequences of damage (Petrucci, 2012). Moreover, the increasing use of technology and emerging technological innovations such like: radio frequency identification, social media applications, and big data analytics can play a powerful role in helping all stakeholders during the disaster management cycle.

The built environment is significantly impacted by disasters. Due to important risks posed to society by the rising number of disasters, the importance of achieving a disaster resilient built environment has been widely recognised. It plays a crucial role in every city and need to be functional and operational in case of a disaster and aims to protect people and other facilities. Moreover, the process of making a disaster resilient built environment is a complicated one where many challenges are included (Malalgoda, Amaratunga and Haigh, 2014).

Big data are datasets that are too large for traditional data-processing systems and that therefore require new technologies for capture and analysis (Pritee C., Akshanda B., 2018). It is a mixture of structured, semi-structured and unstructured real time data originated from variety of sources such as: people, computers, machines, sensors, and any other data generating device or agent. Moreover, it is a process of inspecting, differentiating and transforming big data with the goal of identifying useful information, suggesting conclusion and helping to make accurate decisions. Many achievements in different disaster management phases that are associated with big data sources were performed. Big Data can help in both alleviating and recovering from the negative consequences of disasters (Papadopoulos et al., 2017). Emerging technological topics related to this new ecosystem of big data aim to monitor and detect natural hazards, mitigate their effects, assist in relief efforts, and contribute to the recovery and reconstruction processes (Yu, Yang and Li, 2018).

BIM is a process for creating and managing information on a construction project across all phases of a construction project: design, construction, operation, and maintenance. It is also a tool to visualize the whole constructed projects comprising cost and time (Pellinen, 2016). Moreover, BIM has various advantages and abilities to address the problems faced by the construction industry today such as: increased collaboration, reduced rework on site through better planning and design, improved efficiency, cost savings at both delivery and operational stages, improved customer satisfaction, reduced safety risk, and faster project delivery. BIM provides a platform for professionals to work in an integrated environment at any stage of the building delivery process. (Fadeyi, 2017). For instance, at the operation stage, BIM ensures the high standard of sustainability is maintained by making available all the data related to replacements, refurbishments and renewals.

This research question is: What is the role of integrating big data and BIM within disaster resilience and management? The aim of this paper is to investigate the integration of big data analytics with BIM systems for disaster resilient built environment. The following section will discuss the current literature on using BIM and big data for disaster resilience.

LITERATURE REVIEW

Big data and BIM for disaster resilience have been researched to show how built environment can be efficiently managed before, during and after natural disasters. This section will review the current literature on these researches.

Big data and disaster resilience

Research has demonstrated the efficiency of using big data for disaster resilience. Big data from sensor networks, social media, and from other sources are available and demonstrates its usefulness in disaster management already (Rahman, et al., 2017). During disasters, there is an increased communication since people try to contact family and friends in the disasters zone. In addition, huge data emerge and there are many ways to spread the information about these disasters by enabling citizens to share information and ask for help. In addition, research has identified several ways that people use to collect data in case of natural disasters such as: family communication, situation updates, and services access assistance, etc…

Nowadays, scientists are facing one of the biggest challenges of managing large volumes of data produced in case of disasters, so big data has a powerful role in all phases of disaster management. Based on big data, the emergency managers make risk assessment through critical infrastructure operating data or sensor data, and anticipate the impacted population through smartphone data or social media data (Yang, Su and Chen, 2017). Moreover, big data give real-time clues of on-site disaster information through data mining in all four phases of disaster management: prevention, preparedness, response, and recovery (Yang, Su and Chen, 2017). Traditional data storage and processing systems are facing challenges in achieving performance, scalability, and availability requirements of big data (Grolinger et al. 2013).

Currently, data storage systems are numerous and offer restricted scope for collaboration. Also, there are several examples of social media platforms being used by emergency response agencies. For instance, the US Centre for Disease Control and Prevention uses Twitter as a platform to communicate disease-related warnings to the public while the American Red Cross has a Tornado Application for smartphones (Android and iOS), which provides alerts about tornado related hazards and provides helpful information.

Big data analytics in disaster management provide solid insights to take real-time decisions (Akter et al. 2017). Big data analytics can have positive impacts in various scenarios such as: provide important information to those in a disaster area pre and post disaster and help in determining information about unclaimed properties. Moreover, the volume and speed in which data moves across social media applications is significant and helps to improve the authorities' situational awareness during such events. Thus, online social media can act positively and solve many problems during natural disasters.

Despite the popularity of big data, there is a lack of clarity in term of its understanding and applications in disaster resilience and management. For instance, studies have investigated how people use social media to respond to disasters and how relevant measures are taken to allow recovery, yet research need to be expanded and look into the analysis of unstructured data to explain disaster resilience for sustainability (Papadopoulos et al., 2017).

BIM and disaster resilience

Moreover, many researchers have argued that there is a strong relationship between BIM and disaster resilience by confirming the benefits realized through BIM implementation. Findings reveal BIM’s contribution to the disaster resilience in the pre-disaster and post-disaster phases particularly through impacting the performance of the supply chain, construction process, and rescue operations (Sertyesilisik, 2017). BIM is an efficient tool for enhancing disaster resilience and has several advantages such as: structural simulations, contribution to the occupational health and safety performance, reducing man-made hazards, facilitation in rapid evacuation.

BIM can be used for estimating the building damages in case of a disaster and assessing the damage cost and environmental impacts (Alirezaei et al. 2016). In the post-disaster phase, BIM can assist the recovery and reconstruction phases by improving resilience and allowing fast recovery of the community and reconstruction of the built environment. BIM can also support effective waste management participating in the recovery phase by allowing reduction in waste through deconstructability analysis (Sertyesilisik, 2017). Thus, BIM plays a powerful role for enhancing disaster resilience of the construction industry in the pre-disaster and post-disaster phases.

This paper analyses the efficiency of big data analytics for disaster resilience with integration of BIM systems. The first task is collecting the unstructured data that emerge from different sources in case of occurrence of a natural disaster. Second, big data analytics is performed carefully by identifying the missing data and making sure of the data validity and reliability. Based on this analysis, recommendations for building resilience solutions are generated for a critical examination of the following aspects: factors, issues and dependencies of the disaster, resilience factors and frameworks. Third, identifying the BIM implementation that will emphasize the disaster management process is an important task in this research.

BIM and emergency evacuation

Building emergency management concerns various major aspects, such as emergency preplanning, emergency psychological human behaviour, and timely information communication. BIM can play a significant role in the process of emergency evacuation due to its comprehensive and standardized data format and integrated process (Wang et al., 2014). In addition, BIM provides information that is much more valuable than the actual 3D interpretation of objects in the model. In BIM, the 3D view can be enhanced by the addition of an information folder that includes several details. For instance, in case of a fire, the 3D view can allow managers to know that there is an extinguisher in the building, however this 3D view can also be improved by adding an information folder that provides other details such as: the localization**,** price, type of dispenser, temperature range, and picture of the device as well (Stančík, Macháček and Horák, 2018). Therefore, BIM plays a powerful role in rapid and precise emergency management activities, such as real-time evacuation path guidance.

DISCUSSION

Research has shown the importance of using big data for disaster resilience and the efficiency of BIM for enhancing disaster resilience. There is a need for integrating big data analytics with BIM systems for disaster resilient built environment.

The use of BIM as the information system for disaster and emergency planning is a new concept and efficient. With the technological advancements, big data tools can process large amounts of disaster-related data to give insights into the rapidly-changing situation and help drive an effective disaster response (Qadir et al., 2016). Moreover, big data greatly help policy makers and first responders to come up with quick and concrete decision on the number of people impacted during natural disasters, type and nature of the damage and where to allocate the resource. One of the most useful advantages of BIM is the ability to share this data points easily, so it is a significant tool to use during disasters. Most of the information gathered in case of a disaster for BIM use is what emergency responders would like to see available in the future. Therefore, BIM can help in creating this collaborative environment, where all the disaster managers can sit together and exchange the available data between themselves and come up with suitable solutions.

The possibility of BIM-big data integration for disaster resilience enables disaster managers the efficiency of disaster and emergency response that requires good operations. Location technology has become so fine-tuned that the exact position of a disaster can easily be determined by emergency responders and BIM plays an important role in the post-disaster phase in this scenario. When the emergency responders have the exact data, BIM enables the team rapid evacuation, controlling the evacuation regulation compliance of BIM data, assessing evacuees’ behaviour in the evacuation phase, and enhancing safety management.

CONCLUSIONS

When disaster strikes, access to information is equally important as access to food and water. This relationship between information, disaster response and help becomes integral. Big data give real-time clues of on-site disaster information through data mining in all phases of disaster management. BIM plays a powerful role in fast and accurate emergency management activities. Moreover, the need for disaster resilient built environment and community is growing due to the increase in the frequency and magnitude of disasters. This paper reviewed how big data analytics can help disaster resilient built environment and accelerate disaster recovery, and examined the importance of using BIM in disaster resilience as well. In addition, it indicated the efficiency of integrating big data analytics with BIM systems for disaster resilient built environment. Thus, the BIM-big data integration for disaster resilience allows disaster managers to act timely, effectively and efficiently especially that managing disasters require instant and precise operations.

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