



LEEDS BECKETT UNIVERSITY  
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# INTERNATIONAL SUSTAINABLE ECOLOGICAL ENGINEERING DESIGN FOR SOCIETY (SEEDS)

CONFERENCE 2019

**CONFERENCE PROCEEDINGS**



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# **SEEDS Conference 2019**

**Sustainable Ecological Engineering Design for Society**

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## **CONFERENCE THEME: Growing Sustainability – Natural Capital and Society in the Built Environment**

The built environment has a greater impact on natural resources and produces more waste than any other industry. That in mind, beyond the green rhetoric research is being applied on the ground to address the balance between the built and natural environment. The International SEEDS Conference aims to bring together experts from around the world, focusing on the changes that are taking place and the benefits or consequences that are being predicted and measured regarding the built environment's impacts. As well as addressing technical issues, measuring energy efficiency and modelling energy performance, emphasis is placed on the health and well-being of the users of spaces occupied and enclosed. Understanding how buildings and spaces are designed and nurtured to obtain the optimal outcome is the focus of discussion and debate. This holistic approach draws together the research themes of energy, building performance and physics while placing health, well-being and ecology at the heart of the conference.

Sustainable building practices are rooted in the need for reliable information on the long-term performance and, more specifically, the expected service-life of building materials, components and assemblies. This need is ever more evident given the anticipated effects of climate change on the built environment and the many governmental initiatives world-wide focused on ensuring that structures are not only resilient but also can maintain their resilience over the long-term.

Through research and proven practice, the aim of the SEEDS conference is to foster ideas on how to reduce negative impacts on the environment while providing for the health and well-being of society. The professions and fields of research required to ensure buildings meet user demands and provide healthy enclosures are many and diverse. The SEEDS conference addresses the interdependence of people, the built and natural environments, and recognises the interdisciplinary and international themes necessary to assemble the knowledge required for positive change.

four main conference themes:

- 1 **Sustainable Place Making** (Social dimensions and natural capital considerations)
- 2 **Sustainable Behaviours** (Human and machine – smart buildings, smart cities)
- 3 **Sustainability Education**
- 4 **Sustainable Production** (Factories of the Future – building design for industry/business/agriculture)

Through research and proven practice, the aim of the SEEDS conference is to foster ideas on how to reduce negative impacts on the environment while providing for the health and wellbeing of the society. The professions and fields of research required to ensure buildings meet user demands and provide healthy enclosures are many and diverse. The SEEDS conference addresses the interdependence of people, the built and natural environments, and recognises the interdisciplinary and international themes required to assemble the knowledge required for positive and much needed change.

## Conference Sub Themes

Protecting nature and the natural environment	Planning and sculpturing positive change
Building and environment design	Reducing consumption and waste
Energy efficient modelling, simulation and BIM	Sustainability, ethics and responsibility
Integrating urban and natural environment	Behaviour change
Building performance, analysis and evaluation	Community building and master planning
Thermal comfort, air quality and overheating	Health benefits of alternative and natural materials
Green spaces, enclosures and buildings	Urban heat island and mitigation
Green technologies and IT	Building resilience
Renewable energy	Sustainable cities
Energy flexibility	Zero energy and energy plus buildings
Energy behaviour and lifestyle	Local producers and urban environments, edible
Dampness, water damage and flooding	Trees and green city landscape
Building surveys, thermography, building pathology	Edible urban landscape
Biodiversity	Education & Training
Water and air quality	Biomimicry and Biophilic Design

## Preface

Sustainability and the associated issues are expected to be considered at a very integrative and holistic way in addressing the three key pillars of sustainable development, namely the environment, technology and the associated economics, while taking into consideration the macro and micro contexts. The tenets of sustainability science are widely being incorporated as a tool for attaining sustainable development by nations and are becoming the core philosophy of national and multinational developmental agendas, especially since the inception of the UN-SDGs, for nations to integrate developmental policies with environmental, economic and social ethos. This event provides a platform to discuss the recognized and important problems affecting the sustainable built environment. Specialized practitioners and researchers have the opportunity to share their research and views on a range of topics related to Sustainability, Engineering, Ecology and Design for Society. Interested policy makers, researchers, practitioners and educators whose interest lies in the subjects of sustainability, design, engineering, energy and education will be more effective if they integrate their efforts in order to share and influence governments, the greater society at large and academic institutions in these topical areas. This conference provides the opportunity for researchers and practitioners to share emerging research, best practices, develop and promote a network of experts who are passionate about a sustainable future.

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# Obstacles of sustainable construction project management in South Africa construction industry

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**Keywords:** Construction industry, Sustainable construction, sustainable construction project management, Mpumalanga Province.

## ABSTRACT

*Green building is mostly adopted by the private sector or the private property development companies who are enjoying the benefits of it. Hence the study will explore the obstacles impeding the implementation of sustainable project management in the public sector in South Africa. Structured questionnaires were distributed to different construction companies and construction professionals involved in the public projects. From 80 questionnaires distributed, 65 were brought back and they were all valid and usable. Findings from the survey results obtained from the chosen respondents revealed that there is resistance to change from conventional to green practices by organization employees, Lack of awareness of green building methods and technologies, absence of dependable exact cost data/information, limited government involvement, the complexity of codes and regulations on green building and sustainable construction, high cost of green building material and also attracts a higher risk of delays in construction. From the findings the government of South Africa needs to play a huge role implementing sustainable construction project management in public buildings, which will benefit the government, and the end users and reducing the nation's carbon emission emanating from construction sector.*

## 1. INTRODUCTION

The construction industry is an engine for economic growth of any country, hence investment in infrastructure would promote the smooth flow of goods and services (Mashwama et al., 2016). Construction industry plays a huge role in influencing the competitive advantage of enterprise within the economy and it also attract foreign investors to invest in it (Forbes & Ahmed, 2011). It is the responsibility of the government and construction stakeholders to ensure that the construction industry keeps improving to keep up with new ways of building, and be able to adapt to new methods, systems and strategies of construction industry (Forbes & Ahmed, 2011 & Kubba, 2010). In addition, green building is increasingly being acknowledged in the construction property sector market as a response to the growing demand for environmentally friendly buildings (Chang, 2011). However, there are various barriers to sustainable building; mostly relating to poor government involvement and pioneering it, green building standards are

perceived difficult to be understood and people's perceptions about green building being expensive (Marco & James, 2016). According to, Hakkiem & Belloni (2011), the barriers of sustainable construction in developing countries are, lack of motivation, lack of economic incentives and weak legislation enforcement. Sustainable construction is a green building model applied throughout the design, construction and maintenance period or life cycle of the building, while protecting the environment (Claasen, 2017 & Griskevicius et al., 2010). Sustainable construction is using sustainable construction principles/ practices from inception to completion of a construction project while lessens the negative effect on the environment (GBCSA, 2017 & Ropper & Bead, 2006). Most greenhouse emission of about 41% come from buildings structures (Ampofo-Anti et al., 2015 & Claasen, 2017).

## **2. SUSTAINABLE CONSTRUCTION PROJECT MANAGEMENT**

### **2.1 Ecology and environmental friendliness**

Conservation of natural environment is one of the major drivers of sustainable project management (Claassen, 2017 & Chevallier, 2015). Moreover, South Africa has an obligation to reduce its carbon emission by putting in place environmental sustainability strategies and start practicing them (Windapo 2014). The growth of sustainable project management is directly related to the advance of environmental consciousness (Sanchez, 2015 & Tharp & Silvius, 2013). Moreover, if environmental consciousness gains motivation, sustainable project management simultaneously experiences huge growth and development (Robichaud et al, 2011 & Chevallier, 2015). It is rather a tedious task to protect the natural environment, however, various endeavors have explored constructive outcomes of the reception of green thinking in building design and construction (Hoffman & Henn, 2008).

### **2.2 Reduced operational cost of buildings**

The main economic benefit associated with green buildings is reduced operation cost (Gowri, 2004). Green buildings are designed and built in a manner at which there is minimal usage of electricity to power them and there is minimal usage of water, as green buildings have built-in water recycling mechanisms (Kubba, 2010). Sustainable project management is motivated by financial gain through the need to diminish the cost of building activities or operational costs after construction to yield higher returns from the investments (Windapo, 2014). Giving rise to the concept of lifestyle costing which is concerned with improving an incentive for money in the possession of corporeal properties by considering the overall cost factors identifying with the property amid its operational lifecycle (Woodward, 1997). Moreover, energy and water proficient buildings have possessed the capacity to lessen their running cost expenses notably, with utility being reduced by fifty percent than that of conventional buildings (Forbes & Ahmed, 2011).

### **2.3 Social responsibility and status**

Stakeholders are required to fulfil commercial social responsibility; hence people are driven to sustainable project management for status and noticeable conservation (Tharp & Silvius, 2013). Furthermore, status expands the desire for green buildings, and thus an increased demand for sustainable project management, regardless of the fact that going green is perceived to be expensive than the conventional way of doing things (Silvius & Schipper, 2012). Moreover, quickly rising media consideration, straightforwardness and responsibility on ecological care and conservation have framed a social trend to significantly amplify green construction (Lu, Y. et al, 2013 & Zhang et al., 2011). Green building is becoming more of a fashionable trend and therefore inducing the growth of sustainable project management (Mazmanian & Kraft, 1999).

## **3. HINDRANCES TO SUSTAINABLE PROJECT MANAGEMENT**

### **3.1 Green buildings are expensive**

The main barrier restricting the growth and development of green building is the perception that green building is expensive (Zhang et al., 2011). The green building councils worldwide have shown that although green buildings are initially expensive to construct, the economic benefits in the long-term are impeccable (GBCSA, 2017). The expenditures related to the construction of green buildings is regularly no more prominent than the expenditures of constructing a conventional building and the investment can be often acknowledged in the cost of energy and electrification and water over the long-term (Forbes & Ahmed, 2011 and Lambeck & Eschemuller, 2009). Furthermore, sustainable project management has the capability of bringing down construction costs as well as the amplified risk of delays in construction (Sanchez, 2015).

### **3.2 Lack of expertise or experience**

Green building projects differ from traditional construction projects as they require the utilization of special materials and building practices to accomplish sustainability (Lu et al., 2013). The concept of green building is accepted by a few South African construction companies, due to the lack of awareness, skill and expertise of sustainable project management (Ampofo-Anti et al., 2015). Additionally, a green project design procedure is intended to be a multiple effort from a numerous stakeholder to achieve all-inclusive outline arrangements that boost building performance as well as yield a profitable investment (Forbes & Ahmed, 2010:284). Sustainable project management incorporates an extensive variety of experts to build up a mutual vision of the project, with the goal that the broad green building regulation can be consolidated in the design from the very beginning (Sanchez, 2015 and Marco & James, 2016).

### **3.3 The complexity of green building rating systems**

Architects, Engineers, Project managers and construction labourers are confronted with a test to cater for the demand of new facilities, which should limit the negative effect on the natural environment (Alsand, 2015). The building should yield economic gain on investments and giving ecological advantages to the investor (Kubba, 2010). The green rating systems have been set up to decrease and encourage the construction of sustainable building which are friendly to the environment (Gowri, 2004 & GBCSA, 2017). The reason behind the commissioning of green

building rating systems is to educate the design teams and the construction team of what is broadly acknowledged in terms of green buildings, as well as the objectives that are proposed to be achieved (GBCSA, 2017).

### **3.4 Resistance to change**

The crucial component in sustainability is change in the form of transformation towards additional sustainable practises (Silvius & Schipper, 2012). Furthermore, the progress required for sustainability, will thus be the implied arrangement of qualities that experts possess and that impact or directs conduct. Moreover, Hoffman & Henn (2008) contend that ecological advancement and green thinking in the built and engineering industry will keep on stalling if the substantial societal and mental boundaries that endure are not confronted.

Claassen (2017) state that the development of green building is not hampered by an absence of advancements and assessment strategies, yet rather is liable to different authoritative and procedural challenges caused by the reception of new techniques or technologies. Resistance towards new advances is due to the fact that they require process changes that include unforeseen dangers and expenses (Claassen 2017). The GBCSA (2018) reiterates by saying that sustainable headship requires one to take courage as it requires doing thing in a non-conventional manner. Furthermore, requires altering the way of thinking through ambition and bravery to eradicate set limitations.

## **4. RESEARCH METHODOLOGY**

### **4.1 Research Area, approach and design**

The research study was based in the Mpumalanga Province where new commercial property development projects are emerging. The commercial property sector plays a fundamental role in the economic development of the province. This sector comprises of both the public and private sector. The public sector performs an administrative, financier and guiding role in the commercial property market and the private sector becomes the primary implementing agent. For the purpose of the study we focused on the public sector who employs contractors and professionals from private sector to undertake the construction of primary and supporting structure. Quantitative approach method was adopted to investigate the hindrance of sustainable project management in the construction industry of South Africa. 80 Questionnaires were distributed and 65 were brought back which were all valid and usable. A well-structured questionnaire was distributed to different professional companies in Mpumalanga Province, such as civil engineers, project managers, directors, quantity surveyors, construction managers. The questionnaires were sent via e-mails, some were delivered to the known construction firms by the researcher. The secondary study was conducted from reliable scholarly sources such as articles, journals, books, publications, websites and site experience on the field.

### **4.2 Statistical package for the social science (SPSS)**

The quantitative data collected was analysed with Statistical Package for the Social Science (SPSS) a computer programme which is used for analysing data concerned with social

phenomena. The software was used to generate various statistical, including descriptive statistic, which provides a basic summary of all variables in the data (SPSS, 2004). The benefits of using SPSS is that it allows for scoring and analysing quantitative data at speed and it can also be used to perform multivariate analysis. SPSS also helps to present the data in a logical format (SPSS, 2004) thereby reducing time spent on calculating scores. However, accuracy in results is highly dependent on inputs, hence the need to accurately capture data from the questionnaire.

### 4.3 Computation of the mean item score (MIS)

5-point Likert scale was adopted for the study which gave a wider range of possible scores and increase statistical analyses that are available to the researcher. The 5-point scales were transformed to mean item score abbreviated as (MIS). The computation of MIS was calculated from the total of all weighted responses and then relating it to the total responses on a particular aspect. The MIS was adopted to rank the factors from highest to lowest and expressed and calculated for each item as follows:

$$\text{MIS} = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{\sum N}$$

Where:

n1 = number of respondents for strongly disagree

n2 = number of respondents for disagree

n3 = number of respondents for neutral

n4 = number of respondents for agree

n5 = number of respondents for strongly agree

N = Total number of respondents

## 5. FINDINGS

### 5.1 Promoters of sustainable project management

Respondent were asked based on their experience as to which factor promotes the use of sustainable project management in construction projects. Public and market demand for green buildings was ranked first with (MIS=4.56 & STD=0.985); Educating and training of stakeholders and clients on the future benefits of green buildings was ranked second with (MIS=4.45 & STD=1.148); Heavier taxes and penalties on unsustainable construction practices was ranked third with (MIS=4.33 & STD=0.823); Project team to create a culture for the adoption of green building practices was ranked fourth with (MIS=4.31 & STD=0.972); Interest free lending schemes provided by government to overcome financial barriers was ranked fifth with (MIS=4.29 & STD=1.117); Upgrading courses to supplement knowledge regarding sustainable construction was Ranked sixth with (MIS=4.20 & STD=0.991); Bonuses for staff in obtaining green mark award for their building with (MIS=4.01;STD=0.878); Global warming scare was ranked eighth with (MIS=3.98; STD=0.962); Subsidy or incentives from government for green building projects was ranked nine with (MIS=3.88 & STD=1.147); Green buildings help increase health of occupants was ranked ten with (MIS=3.75 & STD=1.020); and Simple green building practices for the transition from conventional to green practices was ranked eleven with (MIS=3.65; STD=1.138).



Table 1, Promoters of Sustainable Project Management

<b>Promoters of Sustainable project management</b>	Mean	STD	R
Public and market demand for green buildings	4.56	0.985	1
Educating and training stakeholders, clients on the future benefits	4.45	1.148	2
Heavier taxes and penalties on unsustainable construction practices	4.33	0.823	3
Project team to create a culture for the adoption of green building practices	4.31	0.972	4
Interest free lending schemes provided by government to overcome financial barriers	4.29	1.117	5
Upgrading courses to supplement knowledge regarding sustainable construction	4.20	0.991	6
Bonuses for staff for obtaining green mark award for their building	4.01	0.878	7
The global warming scare	3.98	0.962	8
Subsidy or incentives from government for green building projects	3.88	1.147	9
Green building help increase health of occupants	3.75	1.020	10
Simple green building practices framework to adopt in the transition from conventional to green practices	3.65	1.138	11

## 5.2 Obstacles of sustainable project management

Respondent were asked based on their experience as to which factor is an obstacle of sustainable project management in construction projects. Resistance to change from conventional to green practices by organization employees and Lack of awareness of green building methods and technologies were ranked first with (MIS=3.99; STD=1.089 & 1.123 respectively); Absence of dependable exact cost data/information was ranked second with (MIS=3.88; STD=0.981); Limited government involvement and The complexity of codes and regulations on green building and sustainable construction were ranked third with (MIS=3.75; STD=0.876&1.058 respectively); High costs of green building materials was ranked fourth with (MIS=3.68; STD=1.189); Attract a higher risk of delays in construction was ranked fifth with (MIS=3.61; STD=0.889); Lack of experience and Perception that green buildings are expensive was ranked sixth with (MIS=3.59; STD=0.875 & 0.989 respectively); Lack of expertise or training and Lack of governmental support were ranked seventh with (MIS=3.47; STD= 1.189& 0.986 respectively); Lack of interest from clients was ranked eighth with (MIS=3.33; STD= 0.857); Lack of knowledge regarding green building principles and Limited access to green building material supplier were ranked ninth with (MIS=3.05;STD=0.978& 0.969); Limited financial incentives was ranked tenth with (MIS=2.92 & STD=1.109); Lack of communication and interest among project team members and Absence of general familiarity with the benefits of green building was ranked eleventh (MIS=2.87 & STD= 1.160 & 1.111); and Lack of management and time to implement green construction practices was ranked twelfth with (MIS=2.65; STD=0.907).

Table 2, Obstacles hindering SPM

<b>Obstacles hindering the adoption of sustainable project management.</b>	Mean	STD	R
Resistance to change from conventional to green practices by organization employees	3.99	1.089	1
Lack of awareness of green building methods and technologies	3.99	1.123	1
Absence of dependable exact cost data/information	3.88	0.981	2

Limited government involvement	3.75	0.876	3
The complexity of codes and regulations on green building and sustainable construction	3.75	1.058	3
High costs of green building materials	3.68	1.189	4
Attract a higher risk of delays in construction	3.61	0.889	5
Lack of experience	3.59	0.875	6
Perception that green buildings are expensive	3.59	0.989	6
Lack of expertise or training	3.47	1.189	7
Lack of governmental support	3.47	0.986	7
Lack of interest from clients	3.33	0.857	8
Lack of knowledge regarding green building principles	3.05	0.978	9
Limited access to green building material supplier	3.05	0.969	9
Limited financial incentives	2.92	1.109	10
Lack of communication and interest among project team members	2.87	1.160	11
Absence of general familiarity with the benefits of green building	2.87	1.111	11
Lack of management and time to implement green construction practices	2.65	0.907	12

## 6. CONCLUSION

Resistance to change from conventional to green practices by organization employees; Lack of awareness of green building methods and technologies; Absence of dependable exact cost data/information; Limited government involvement; The complexity of codes and regulations on green building and sustainable construction; High costs of green building materials were the obstacles of sustainable construction project management. Public and market demand for green buildings; Educating and training stakeholders, clients on the future benefits; Heavier taxes and penalties on unsustainable construction practices; Project team to create a culture for the adoption of green building practices were the promoters or influencers of sustainable project management. From the findings the government of South Africa needs to play a huge role implementing sustainable construction project management in public buildings, which will benefit the government, and the end users and reducing the nation's carbon emission emanating from construction sector. Sustainable buildings are initially expensive to construct, the economic benefits in the long-term are impeccable. To effectively ignite rapid growth of sustainable project management, the government ought to finance development costs associated with the construction of green buildings.

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# The study of implementing ecosystem services in an urban environment

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**Keywords:** Ecosystem Services, Urban Environment.

## ABSTRACT

*Urban Environments are constantly finding ways to improve and benefit the people living in them today. Progressive changes in Urban Environments mean spaces are having to adapt. Generally, this adaptation has been produced by intense global environmental changes which are swamped by the local environment, (Grimm, et al., 2008) and influenced by demographic imbalance. Over time a collection of populated areas will encounter a crisis in the changes of these environments, fabricating new economic development and master planning. Thus, affecting the surrounding natural environments and ecosystems. Ecosystems are important in the natural and Urban Environment with many being prone to change by developmental needs of the human race. It is increasingly crucial to sustain and retrieve ecosystems to improve the overall balance of nature and urbanism. Ecosystem services construct the genesis to support ecosystems and provide a catalyst to evolve Urban Environments. This study will explore the effectiveness of including specific services in the Urban Environment. A summary of the future behaviour of urbanisation will be summarised. Four types of Ecosystem Services; Supporting Services, Provisional Services, Socio-Cultural Services and Regulating Services will also be discussed. (Millennium Ecosystem Assessment, 2005) This will provide an analysis of their constructive abilities and the impact they offer on a working and functional Urban Environment. Two international cities which currently implement the use of services will be highlighted as case studies and used as a template for contemporary data of Ecosystem Services, allowing analysis on the types of services used. Using primary research methods, a survey will be used to collate data on the views and opinions of professionals towards Ecosystem Services. This will contribute to the methodology of this paper to produce an integral model for an ideal urban space. Using Leeds South Bank as the study area, the research on this paper and the results of the survey will construct an ideal design in South Bank for the use of specific Ecosystem Services. Overall, with the outcome of a more sustainable, functional environment to the community.*

## INTRODUCTION

‘Urbanisation is the increase in the proportion of people living in towns and cities (Geography, 2018). As these spaces continue to advance, it has seen more people migrate to these areas each year. Since the Industrial Revolution, there has become a mass demand for labour workers in urban areas which have seen the urban population increase dramatically. This has produced an enhancement in economic development and infrastructure, which has formidably shown the progression of urbanisation over time. Global patterns have now seen 50% of the world population live in cities and this is expected to rise 66% by 2050 (Atkinson, 2016). Therefore, humanity is now seen to be living in an urbanised world. City life is expanding and expected to

develop continuously as a result of population surge. This is projected to add 2.5 billion people to the world's urban population by 2050 (Department of Economic and Social Affairs, 2014). This effect on Urban Environments can potentially lead to the negligence of nature, with factors including climate change and extensive energy consumption to occur. Thus, revealing damages to our environment and resulting in cities having to take drastic changes to adapt in sustainability. 'As major cities reach their boundary limits, urban administrative sprawl will no longer provide an effective solution. Instead, demographic and lifestyle changes will serve as major catalysts in the shift toward increasing sustainability. This shaping the vision of the built environment' (ARUP, 2014).

Driving educational focus on the use of Ecosystem Services, it can improve lifestyle and economic changes to the urban community. The overall principals of these services are to provide ecological design as a planning and design strategy for cities (Cook, 2016). These principles suggest for a more ecological reshape of our cities design which considers a community of biodiversity in an urbanised world, enhancing a more productive and greener environment. Now, with half of the population living in an urban area, it makes them the main consumers of Ecosystem Services. Ecosystem services are split into four categories constructed by the Millennial Ecosystem Assessment. These are, Supporting, Provisional, Socio-Cultural and Regulating services. All these services play a role in the significant net gains of economic development and human well-being (Environment & Ecology, 2018).

### **Supporting Services - Nutrient Cycle**

Nutrient cycling describes the movement within and between the various biotic or abiotic entities in which nutrients occur in the environment. This is influenced by the diversity of organisms which rely on elements to exist. These include oxygen, hydrogen, carbon, phosphorus and nitrogen and are known to be within biogeochemical cycles. The majority of these elements are carried through water, soil and the overall atmosphere and produce the ecology of global nature (Bailey, 2018).

The Nutrient cycle initially had its first break in cities and was influenced by food production as it began to routinely travel with farm products to supply cities. This has caused the cycle of nutrients to be inefficient as it has become a rarity for nutrients to return to the origin of the soil. This has been caused by industrial style farming which has seen nutrients accumulate in urban sewage causing an increase in pollution in worldwide waterways (Sustainable Agriculture Research & Education, 2012). This has shown to be inefficient in urban ecosystems due to the course of environmental effects in waterways.

### **Supporting Services - Soil formation**

This is a solidifying factor towards the build-up of land and the groundwork of all ecosystems. It supports provisional services and is a supplement to many functions, providing settlement towards food and biomass production. This is seen in agricultural lands where soil ensures storage, filtration and transformation of nutrients, substances and water. It also provides provisions in habitats, biodiversity as well as the physical environments of human infrastructure (FINVERS, 2008). One element which can affect the conditions of soil is by degradation. This is caused by physical factors such as wind and chemicals in the depletion of nutrients, thus

affecting soil organic matter and organic carbon content, loss of biodiversity and loss of water retention capacity. All these influence the destruction of ecosystems (FINVERS, 2008).

The effects of soil can impact the Urban Environment as it is the foundation for urban settlement and provides a range of Ecosystem Services including water management, transportation, and green infrastructure. However, soil can be largely affected by increasing capacity of urban infrastructure. As a result of this, access roads, parking spaces and pavements create a drastic decrease in water retention capacity which results in flooding of houses during heavy rainfall (European Commission, 2014). Soil is also an important influence within green spaces and biodiversity within cities. In many ways, this can be a benefit to 'help regulate air quality and climate...reducing energy consumption by countering the warming effects of paved surfaces' (Project Evergreen, 2018).

### **Supporting Services - Primary Production**

In ecology, Productivity is the increase in the amount of new living material produced in an ecosystem, usually in the formation of Biomass. Depending on the ecosystem, primary production can vary from 'solar energy input, temperature and moisture levels, carbon dioxide levels, nutrient availability, and community interactions' (Khan Academy, 2018). Depending on these factors it can affect the performance in the role of producing energy. This production supports the population of animals and the activity of decomposer organisms which are sustained by trophic webs that recycle the nutrients required to support primary production. The role that primary production can take place in an Urban Environment is within areas where vegetation can grow and benefit from its environmental habitat. This can range from green spaces such as parks, rivers flowing through cities or the inclusion of greenhouses in residential settlements where this is maximised (Khan Academy, 2018).

### **Provisional Services - Food**

The provisions of food production are notably found in rural agricultural areas where space is maximised. This image normally conjures harvesting crops to farming to optimize the supply of food. With 71% of the UK land being used for farming, (Department For Environment Food & Rural Affairs, 2016) it is not seen to be an issue to feed today's human race. Yet, whilst developing infrastructure continues to deplete rural grounds and the urban population overtakes the rural population, 'urban agriculture is soon gaining relevance all over the world'. (Orsini, 2014) 'Urban agriculture can be defined shortly as the growing of plants and the raising of animals within and around cities' (Ruaf Foundation, 2018). This is seen in local dwellings for the consumption of the people producing them. The positives of this can help lower urban poverty and improve food security within the community. Another benefit is 'Urban agriculture uses city water and recycles organic discards' (Orsini, et al., 2015). Therefore, this is seen as a sustainable approach to manage this resource.

With limited space in cities, it is increasingly necessary to devise strategies towards the implementation of agriculture. A study presented by in Bologna (Orsini, 2014) presents the potential opportunity of rooftops to be used as gardens to produce food and essential greenspace. Green links can be produced between each rooftop garden to maximize the production of food. These rooftop gardens also 'reduce the expense of heating and cooling and



at the same time improve urban air quality...and can contribute to biodiversity in the urban environment'. This strategy resulted in the increase of fauna and the annual production of 12,495 vegetables per year, 77 % of the urban vegetable requirement (Orsini, 2014). Whilst urban agriculture is beneficial towards biodiversity and food production in cities, it is not seen as the best sustainable solution for intensified consumption. Thus, it is down to urban sprawl creating a consistent need for mass production. In other ways, food production can be improved by soil management, improved pastures and avoiding the shift in agricultural land which can lead to 'millions of hectares of deforestation' (World Resources Institute, 2014).

### **Provisional Services - Energy**

There have been environmental concerns in the development of energy supplies leading to the discussion of potential changes. Therefore, this has led to 'renewed interest in the investigation of energy demand behaviour and associated environmental emissions' (Anderson, et al., 1996). Cities are using 86% of fossil fuel as its energy consumption (OECD, 2008). This is a major concern towards climate change and therefore the production of a sustainable energy source is crucial for the developing urbanised world. The key to this would be to take advantage of the renewable energy provided to us by the environment. A study constructed by (Serra, 2010) examined that ways to achieve this reduction would be by the implementation of photovoltaic technology. By strategically including solar-powered systems positioned on buildings, it will help to maximise the energy provided by the sun and help cut the production of Co2 emissions. The advantages of using solar powered energy are the annual electricity production would minimise CO2 emissions and reduce by 26.1% if only solar power was used (Serra, 2010). This strategy can also be used for wind turbines depending on their location and the quality of air movement in the environment. A disadvantage of this use would be the aesthetic figure, especially in an Urban Environment where residential and commercial areas would be affected. This is why renewable energy such as wind turbines is the most beneficial in open rural spaces.

### **Provisional Services - Water**

Being critical to the function of environments with 71% of the earth's surface covered by water (USGS, 2016). Water supplies ecosystems with life and function to all beings. These ecosystems can range from lakes, rivers, coastal water, seas and groundwater, and are crucial for the delivery of fish production, water provisioning and recreation (Grizzetti, et al., 2015). Water is also the provision to all other Ecosystem Services being critical in the formation and development of ecosystems. This affects provisional, regulation and cultural services and in recreational terms, it also supplies a purification process.

With a diverse range of uses water supplies, it is important to consider the challenges water brings within an urban settlement. This is due to 'the lack of access to safe water and sanitation and increasing water-related disasters such as floods and droughts' (UNDESA, 2014). To control water within cities, procedures must take place to ensure the circulation of water is sustainable. This is adopted by water pollution control and effective drainage and harvesting standards. Within buildings, it is also fundamental to include health and plumbing codes as well as the harvesting of rainwater in public properties (Environment Agency, 2010). Conservation is

important for the reuse and recycling of water. This can be improved by wastewater treatment plants.

### **Provisional Services - Wood & Fibre (Raw Materials)**

The awareness of Wood and Fibre stems from the community of forestry's and woodland. Forestry's are a significant influence on the world, and this is due to the services provided by trees. Being an important source in building material the impact trees can have on their surrounding environment is easily overlooked. They are the provisions of habitat, photosynthesis and water retention, and most importantly provides the regulation of air. In an urban context, trees have an outstanding influence on cities. 'They can store carbon, help improve air quality, support natural flood management, create habitat for wildlife, provide spaces for recreation and inspiration, and create new business opportunities' (Greater London Authority, 2018). All of these factors contribute to the sustainability of an ecological Urban Environment and conclude to provide a diverse range of services.

Trees in Urban Environments range also influence cultural and regulating services. Aesthetically, they can provide beauty and inspiration in the vision of parks and walkways. They also enhance health and recreation, raising awareness of productivity and wellbeing. In regulation terms, trees can reduce noise pollution, air circulation and prevent the formation of heat islands. Areas covered by trees have the lowest average temperatures and also reduce the temperature in the surrounding city (Kronenberg, 2012).

### **Socio-Cultural Services - Leisure & Recreational**

It is important communities consider opportunities to be more involved and active in their environment, contributing to good health in a positive environment. These benefits usually include selected infrastructures such as gyms, sports fields and green spaces in local parks, which can maximise an active lifestyle by encouraging exercise. This is important as in America 'green space has been linked to reduced levels of obesity in children and young people' (The Kings Fund, 2018). Stress reduction is also another element these services provide, 89% of Americans report they experience high levels of stress (Town of Manchester, Connecticut, 2018). Therefore, with consistent use of recreational experiences, it can help decrease stress.

Progressive development in other multiple recreational services ensures rejuvenation to the local community and their demands. Early attempts at leisure and cultural regeneration were dominated by mass and popular culture, consisting of pubs, clubs, and multi-leisure venues (Bromley, 2006). These products display selected services that are more favourable for human satisfaction and the economy. This can be vital to the overall satisfaction of the city and provide a catalyst for stronger improvements in human well-being.

### **Socio-Cultural Services - Education & Health**

With a resilient population, Education and Health are becoming more central to the importance of a sustainable community. Health is a fluctuating crisis in cities with city health dwellers finding it difficult to develop effective interventions, with increased concerns regarding the future of urban sprawl, urban violence, transport concerns and influences on the environment. They are all becoming contributing factors to the disruption of wellbeing (Glouberman, et al., 2006). One

factor which needs to be considered is how planning produces a role in the healthcare industry. To address this 'urban planners and policymakers currently, tend to focus on healthcare in cities rather than health' (Myerson, 2016). This normally involves the delivering of healthcare services in hospitals and the environment instead of actual health. Many features are considered to provide a healthy city including improving housing quality and the inclusion of 'public health priorities such as cutting smoking, alcohol and drug use rather than looking at wider determinants associated with the built environment' (Myerson, 2016).

As residential areas become more dependent, schools' infrastructure is becoming increasingly common and so 'education for sustainable development is therefore necessary for the context of efficient urban governance' (United Nations, 2014). Considering this it is also important to consider the environment of the school, which can improve student wellbeing and academic interaction. This could be a contributing factor to the way we design school in towns and cities. Implementing hospitals and schools will not necessarily produce the overall frameworks of education and health services. However, it is the understanding and education of these services that could produce the biggest influence on the Urban Environment.

### **Socio-Cultural Services - Spiritual & Belonging**

Features provided by this service include places of worship to spaces of interaction, in essence for the growth of religious experiences. Churches and mosque provide social cohesion and togetherness in making communities more interactive with each other and god. 'The conservation value of sacred sites is recognized because sacred forests, groves and sites typically harbour higher species richness, biodiversity and biomass than the surrounding land uses' (De Lacy & Shackleton, 2017). Much of this infrastructure is considered aesthetically pleasing and sacred providing a diverse function to the community. It is fundamental for the inclusion of spiritual services in an Urban Environment due to the diverse demographics of cities. Sacred sites are numerous and can be found scattered throughout most urban settings. It is clear places of worship need to be sustained in populated areas, as they are deemed sacred (De Lacy & Shackleton, 2017). To conclude, it would be more efficient to reshape and value places of worship rather than implementing new infrastructure.

### **Socio-Cultural Services - Aesthetics**

Providing relations with their natural and built environment, Aesthetics have been seen to rectify infrastructure in relation to the history and art of a community, with the considerations of their overall form and function (Blanc, 2013). The frameworks towards Aesthetics are mass and space, proportion, symmetry, balance, contrast, pattern, decoration, massing, Unity and rhythm (Vinchu, et al., 2017). These factors are shown to improve the wellbeing in the formation of unique buildings with the appreciation of nature. The elements which indicate this is taking into consideration the natural world without human intervention (Wagner & Alfaro, 2015). Also, frameworks between extreme mobility and immobility provide a contemporary analysis of aesthetic engagement to desire physical safety in urban spaces, bringing into play a learning experience, narratives, visions, landscapes, and panoramas (Blanc, 2013). Within an Urban Environment, it is important that 'to consider a city aesthetically is to not only judge its buildings and architecture, but also to include historical and social elements as part of its total sensory

package' (Kaminska, 2007). This displays the importance of architecture in the built environment.

### **Regulating Services - Climate Regulation**

On a European scale, climate regulation is one of the most important services. In relation to greenhouse gases and atmospheric conditions. Climate regulation is the strategy in reducing these factors, this by 'recognizing the different responsibilities of economically developed and less economically developed countries' (Bulkeley, 2013). Increased urbanisation and population growth have seen Alarming changes in this regulation, since 1990, global emissions of greenhouse gases have increased by 45%, and by 30% since 2000 (JRC European Commission, 2011). Over time cities have been seen a site for climate vulnerability and so it is important to consider the design of the Urban Environment to control the effect of the climate. Due to excessive energy use in the populated area such as transport and industry, it is becoming common that cities are central in producing emissions.

A constructive method to control climate regulation in Urban Environments is by design and improved renewable energy. 'The design of cities creates unique microclimates that affect variables including temperature and wind' (Carter, et al., 2015). This example is shown via heat maps due to the complex environment of mass infrastructure. This can be eradicated by including heating and cooling systems to reduce energy consumption and implementing sustainable rooftops where biodiversity life can interact with the urban community. Other elements also include improved public transport systems, reducing vehicle emissions and expanding green spaces where wellbeing can be enhanced.

### **Regulating Services - Flood regulation**

In urban sites the potential of flooding is possible and due to the unpredictable measures of climate change, flooding can have a significant influence on areas located along 'rivers and coasts, which increases the exposure of people and assets to flooding' (UFCOP, 2017). These areas of settlement would usually lie on floodplains. Another influence of flooding can be affected by inadequate infrastructure, and mainly affects 'the urban poor, especially those living in slums in flood-prone locations without access to resources that could mitigate flood impacts' (UFCOP, 2017). To control flooding in an Urban Environment, resources must take place in improving infrastructures such as flood defences and improved drainage capacity. It is also important to consider 'the importance of land use planning and policy to address underlying disaster risk drivers, which include unplanned and rapid urbanisation' (UFCOP, 2017).

One method that can help regulate flooding is providing a solution through flood risk assessment. This is initial guidance to help reduce the risk and protect all elements of the urbanised world. These include multiple infrastructures such as housing and cultural heritage. An example of regulating flooding is the Leeds flood alleviation scheme. 'This approach will adopt a combination of Natural Flood Management and engineered measures to help slow the flow and catch water further up the catchment so that flood peaks are reduced further downstream' (Leeds City Council, 2018). Although this measure is deemed economically resourceful it is an effective solution in the long term.

## **Regulating Services - Disease Regulation**

Regulation of disease is important as dense environments can be prone to Infectious diseases. 'They are a product of the pathogen, vector, host, and environment' (Patz & Confalonieri, 2005). These are commonly found in areas with stretched resources and commonly occur through environmental contamination and biodiversity change. Although diseases are typically common in rural areas it is important to factor control regulations in dense urban areas. While disease control can't be eradicated, the spread can be minimised by improved control and environmental conditions. This can be regulated with clean airspace, improved water systems and clean food production. Another element is the investigation of forthcoming diseases and supply services such as quality health care. This can be influenced by public health laws. These help to control diseases by improving the accessibility of resources. This includes contraceptives and vaccinations, all to minimise disease exposure (Gostin, et al., 2017). To conclude and control diseases. It will be essential to have a communication strategy in place that is open about the crisis and takes citizen's concerns into account, to build the trust of the population.

## **Regulating Services - Water & Air Purification**

The implications of Water Purification are essential to an improved environment and factor the benefits of health, recreation and the economy. This is impacted on water services provided by the environment. It essentially uses the 'purification process by providing clean drinking water and water suitable for industrial uses, recreation, and wildlife habitat' (ESA, 2018). All these factors provide the safety net to clean and sustainable water for humanity and its surrounding environment and this is supported by the implementation of water treatment plants with filtration. These services can provide the Urban Environment will efficient clean water sources for the demands of the population and their usage. Maintaining a clean biological environment in rivers adjacent in cities will also help reduce pollution.

The common responsibility of air purification is to filter pollutants depending on the type of ecosystem. This varies from 'region, topography, season/climate, ecosystem type, ecosystem fragmentation or connectivity, and the species composition of that system' (EPA, 2016). Essentially clean air is another common factor that should be recognised in Urban Environments, 'Air pollution created by human activities, such as certain land management practices, crop fertilization, and vehicular and industrial emissions, are also drivers of change in regards to air quality' (EPA, 2016). And so, it is important to consider the quality of air for human wellbeing. One way this can be considered in Urban Environments is by improving green spaces and infrastructure by the product of natural resources. Trees and wetlands help filter pollutants from our air, and so this presents that trees and vegetation in urban parks and soil management can help to sustain the surroundings of the environment and provide clean air. Another example this can be managed is by implementing engineering qualities to the surroundings. Xian in China has constructed an air filtration tower in its cities which have managed to produce more than 10 million cubic metres (353 million cubic feet) of clean air since its launch in 2017 (South China Morning Post, 2018).

## **LITERATURE REVIEW**

### **Singapore**

An influential city in south-east Asia. Singapore has vastly denoted itself as a global hub in trade, tourism, finance and technology. With an increasing reputation, 'Singapore has established a series of long-term goals and 10-year plans to reconcile rapid economic development and environmental sustainability' (King, 2014). These long-term goals include ambitious targets for 'energy efficiency; water consumption; local air quality; use of public transportation; green and blue spaces, including park space and water catchment areas; and green buildings' (King, 2014). All these elements are produced by the significant inclusion of specific Ecosystem Services to make the city a more sustainable product. Although these are long-term goals for the city, 'Singapore has in the past years placed great emphasis on environmentally friendly urban development, which is reflected in several governmental policies' (Sieber, et al., 2015). This is in the approach to maintain environmental sustainability.

Since 1965 Singapore has educated the importance of a clean environment, and so produced a vision in creating a 'Garden City'. The concept of this was a tree-planting initiative to help the improvement of air quality (Newman, 2014). The ideology behind the garden city then progressed to Singapore to produce frameworks in green urban development. This included building green neighbourhoods, upgrading to green flats and forming green communities (Newman, 2014). One way this is applied in Singapore is by including vertical greenery on facades and green rooftops, influencing factor towards Cultural Services. This adaptation allows increased pollination and habitats, rainwater retention and cooling of buildings in which sustains a prime example for the complementary of Ecosystem Services. This 'has produced Singapore to be one of the greenest cities in the world with 47% of its land value being occupied with green space' (Gan, 2015). Overall Singapore has been foreseen as a city in a garden and respectively that name has been given due to infrastructure interlinked with biodiversity and the number of green spaces implemented into the city. This all to not just improve the built environment but also the daily lives of Singaporeans. The use of Ecosystem Services has been used throughout the expansion of Singapore and sets a prime example of how cities can be designed to compensate the use of these services, providing the increase in ecology within urbanisation and create a built environment focusing on social and economic values of the public.

### **Copenhagen**

Leading in sustainable development, policies and future technologies have impacted Copenhagen to becoming an advanced model in mitigation for humans. With the infrastructure in place to integrate energy efficient buildings, future climate development and green transport, Copenhagen's goal is to become carbon neutral and assimilate climate into its energy supply (Samuals & Karasapan, 2014). These new policies have seen goals to reduce Co2 reduction by 10% and will be sustained through new renovation projects to produce energy efficient buildings. One was this is implemented is pumping cold seawater into homes to produce a cooling effect, minimising costs of electricity by 15%. This illustrates the impact selective energy systems can have on homes using recycled water as its main function to improve energy costs. Whilst water has a significant impact on buildings, measures have also been put in place by

Copenhagen to improve the use of water. This is by the modernization of wastewater treatment plants and sewage systems which have impacted the surrounding Urban Environment to improve flooding and reintroduce biodiversity. Sewage systems have also had a significant impact on treatment plants fuelling 77% of its energy consumption. This is produced by the conservation process of excess sludge produced in sewage (Samuals & Karasapan, 2014). This process has also helped to produce energy to nearby homes and has seen the function of Ecosystem Services to be more than efficient and diverse in infrastructure.

Many cities in the world are influenced by the heat island effect and so Copenhagen has produced a plan to overcome and minimize this effect. Like Singapore, Copenhagen has included a strategy to improve green spaces to influence artificial cooling. This infrastructure has been shown by multiple pocket parks and green roofs on buildings surrounding the city. 14 pockets have been established throughout the city providing an alternative for greener transport in cycle routes and accessibility of the city with 90% of Copenhagen's living approximate 15 minutes away from each park (Samuals & Karasapan, 2014). This infrastructure is projected to increase greener commuting and adaptive urban planning whilst using recreation services as a driving factor towards the development of the cities' infrastructure. Copenhagen is a prime example of how cities can reach sustainable accreditation, and this is shown by the Ecosystem Services included within selective master planning for the city. It has taken into consideration the use of greenspaces, efficient energy projects and its adaptation towards climate change for the benefits of its urbanised world.

## **RESEARCH METHOD AND METHODOLOGY**

To advance this Study, The Leeds South Bank Area will be used as an integral model for the implementation of specific Ecosystem Services in an Urban Environment. Leeds South Bank is currently one of Europe's biggest regeneration schemes (Invest In Leeds City Region, 2018) and has the utmost potential to benefit from Ecosystem Services to produce a functional environment and a more sustainable city for the future.

Qualitative research methods in a participation survey where used to review the views and opinions of Ecosystem Services. 26 participants were asked to select each Ecosystem Service they believed are most important in an Urban Environment as well as any infrastructure that could help South Bank and Leeds to help its regeneration flourish. Professionals from the Leeds City Council working in the urban planning and built environment were selected as primary subjects followed by students and senior professionals all working in similar backgrounds in the Leeds area. Participants from Leeds City Council were specifically selected due to their developed understanding on the Leeds Urban Environment as well as having significant power to adopt South Bank. Prior to the survey, each participant was asked to sign and complete an ethics and consent form. This was constructed so participants could understand the type of research that was in place, the risks and benefits of participating and the overall outcome of the research.

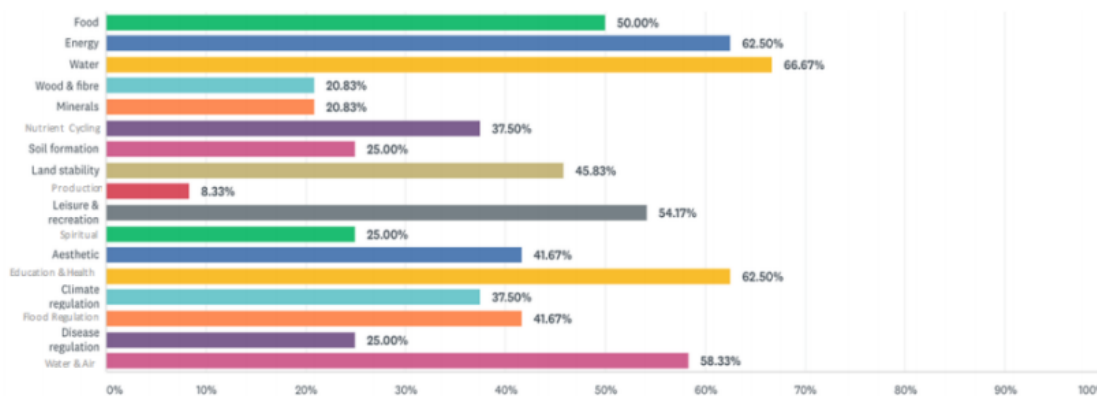
The range of questions in this survey included, the understanding of an urban ecosystem, urban Ecosystem Services in an Urban Environment, essential products in a sustainable environment,



changes that could develop in the future for cities, considering urban design and three factors of redevelopment that could be included in the Leeds South Bank Area. These questions are all important in the construction and understanding of an urban ecological design.

## RESEARCH RESULTS

Below shows a graph of the selected Ecosystem Services that were chosen by a range of professionals from Leeds City Council that believed were most important in an Urban Environment. These responses came from a diverse range of specific professions. This included Architects, Architectural Technologists, Urban Designers, A Nature Conservation Officer, An Urban Forester, A Landscape Architect, A BIM Coordinator, A Public Health Worker and Sustainability Professionals. Students that are involved in built environment studies also influenced these results.



It was concluded that Water was the most favourable service at 66.67%, followed by Energy and Education & Health at 62.5%. Other services in Water & Air purification, Food and Leisure & Recreational also achieved a 50% plus rating, deeming them also important services. Services that were not as favourable were Primary Production, Wood & Fibre and Mineral all achieving under 21%. This resulted in Provisional services to be the most influential. Additional results from the survey concluded that Reduce, reuse and recycling was the most essential approach in the sustainability of the Urban Environment followed by the reduction of Co2 emissions. Population increase was also denoted as the main change in the near future for Urban Environments whilst environmental degradation was the least influential. Participants also agreed that Biodiversity and greenspace should be mainly considered in urban design, whilst built infrastructure in residential and commercial property was less considered. The outcome results of three improved factors to benefit Leeds South Bank concluded that green infrastructure should mainly be considered. This featured improved green buildings, connections between parks and walkways, and open spaces. Secondly, improved transport infrastructure was considered in improved access, pedestrian routes, and more public transport maximising links in and out of the city. Thirdly clean air and reduction of waste should be considered. Other factors from the survey included Safety, Education facilities, improved community and public realm and the conservation of historical buildings.

## Model

Following the collection of data from each survey, the analysis of each Ecosystem Service and the contemporary data from the literature review. An ideal model in South Bank Leeds has been created to maximise the approving Ecosystem Services from the results of the governing professionals in the Leeds city council. The outcome of this model is to provide South Bank with an ideal masterplan which is sustainable and suitable for the change in urbanisation in Leeds. This would be used as a suitable analysis of implementing specific ecosystem services in an Urban Environment.



The overall data produced from the model indicates that a diverse range of services is included to construct the overall environment. In order to maximise these services, South Bank has been transitioned from an existing industrial area to a hub of opportunities where green spaces have been maximised, transport routes improved, and renewable energy has been considered.

## DISCUSSION

Analysis of each Ecosystem Services suggests that each one can have a crucial role in an Urban Environment, with many occupying each other to produce functionality of the working urban world. From the analysis of the surveys, services in which have considerably influenced the model's design are Supporting and Socio-cultural Services. These factors can significantly transform and cement the future settlement for South Bank. The survey responses from Leeds City Council also produced vital data on the important factors that could improve the redevelopment schemes of Leeds. Professionals and students made it clear that green space was the ideal solution to help regeneration along with improved accessibility options. Greenspaces are proven to have a significant impact on the overall surroundings of the environment. Implementing this into South Bank will reduce the heat island effect, improved air quality and produce public access routes into the city and around South Bank. This has resembled both case studies in which have included green infrastructure in their built environment, expressively improving wellbeing and biodiversity. The model implies green roof and walls, public areas of leisure and pathway trees are proposed. Following on from Orsini Case study on rooftop gardens, (Orsini, 2014) these have been implemented to the surrounding roofs to maximise food

cycle and improve air quality. Solar Panels have also been implementing following from Serra's case study (Serra, 2010). These were all deemed important within the survey's data.

The most important ecosystem which was chosen by professional concluded to be Water and so implementing this into South Bank was achieved through the river Aire, an additional man-made lake has been included into the centre of the south bank. This will help produce food and fauna into the area. Another element of including water into this design was to improve flood regulation. Although Leeds has already put the infrastructure in place. This design can act as an overflow to regulate the surrounding area. This is also facilitated by the number of trees within the area improving water retention. Water was then shown to be an important influence on food, water, aesthetic and flood regulation services.

Improved major transport was difficult to implement due to a specific road system in place and so road infrastructure is limited. To redeem this, accessibility options within improved public pathways and cycling paths can produce direct connections to and from the city. This infrastructure can be beneficial to new surrounding residential areas in south bank. Residential areas have been put in place due to the potential population increase of the city. Public and cycling pathways can also maximise walking and minimise emissions from commuting in cars. This improving the public realm and the surrounding environment. It will also improve human wellbeing and influence recreational activities. The factors included in the South Bank design can provide an effect on these activities. Potential options for future transport infrastructure could include a tram system from South Bank to the city centre which can help cut down the use of private vehicles and maintain the existing road system. Leeds already has proposals in place to improved transport by HS2 station. This can also contribute to the regeneration of South Bank.

These services discussed can conclude the most influential services within the Urban Environment. It can act as a template on how to reshape the future cities to meet the demands of the human race and the sustainability of the future environment. Provisional policies should be put in place to maximise the awareness of these services in urban design and master planning in which can construct a method to future designs of vastly developing cities.

## **CONCLUSION**

The aim of this research was to study each Ecosystem Service with the outcome of creating the ideal urban environment. More specifically using the Leeds South Bank area as the ideal urban space to implement these services. The analysis from each Ecosystem Services which was integrated within the design and the data from surveys provided by individuals in the Leeds City Council generated enough data to produce a contemporary plan for a proposed urban space. The data also creates an insight into the type of Ecosystem Services that will benefit South Bank the most. Key findings within this paper shown each Ecosystem Service can have an ideal role to play on a functional Urban Environment. More so the value services provided by greenspaces, the importance of renewable energy, strategies to reduce climate change, the significance of water and the substantial impact of cultural services are all deemed priority in the future of a sustainable urban world. Finalising on maximising these services the most appropriate design solution would be to interact the Leeds South Bank Area with the enhancement of biodiversity,

improving life to all. And could be advantageous, by implying the future of urbanisation to consider approaches of a more biophilic design.

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# Improving the Effectiveness of Building Automation by adaption to the Users Context

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**Keywords:** Home Automation, User Context, Effectiveness Improvement, Sustainable Development

## ABSTRACT

*The operations of either residential housing or commercial buildings are energy intensive, estimated to occupy around 40% of all energy consumed worldwide by the year 2030 (by GeSI - SMARTer2030). ICT-enabled smart home or building solutions are thus expected to contribute to sustainability gain in term of improving energy and resource efficiency. These technologies not only enable buildings to be automated and centrally controlled but also help to provide a healthier and more comfortable living or working environment. While studies in smart home system show good results in reducing the energy consumption of a building by automating tasks to tear down unused appliances, most of the applications are limitedly implemented based on fixed schedule reassembling user behaviour or routines, which is one of the main obstacles for home automation systems (HAS) to be widely acquired. As a solution for this matter, this study aims at exploring actual contexts of the user for HAS to adapt in real time in a more meaningful way so that not only the goal of reduced energy consumption is improved, but the user comfort is also taken care of in the best way. Using available studies on the expected reaction in HAS (in this paper we focus on German use case), a rule-based dictionary will be defined as a set of meaningful adaptations which can later be implemented in a home automation system. Then, the study will discuss possible ways to assess this model based on heuristic evaluation in comparison with available studies to prove an improvement in terms of energy efficiency.*

## INTRODUCTION

It is a matter of the fact that modern buildings contribute a significant amount of energy consumption comparing to other sectors. Reports show a high percentage of CO<sub>2</sub> emission, in terms of energy consumption, from Home/Building sector. Building/Home Automation thus becomes a well evolving field of research and applications, where the energy consumption of buildings can be monitored and reduced by installing smart automation systems. Several different technologies are available to achieve these tasks, but an overall integrated solution is still missing.

Existing work in Home Automation System (HAS) gives already good results in reducing energy consumption, but it remains a static solution that does not react on the unusual behaviour of users. User habit in a home or building environment affect the energy critically, and it is common sense that human actions in utilizing facilities at home or office buildings can make a huge difference. Therefore, the actual context of users should be taken into account to adapt the building automation system in real time in meaningful ways, so that the goal of reduced energy

consumption is improved and at the same time, the user comfort can be taken care of in the best way.

The paper is organized as follows. Within this Introduction, we discuss problem definition driving this study, investigate related work in the field using a systematic literature review method and summarize into two areas: Home Automation System (HAS) and User Context. The section entitled Research Methodology describes the scientific methodology this study has followed. Overall integration architecture and the features of heuristic evaluation are presented as Research Results. Summary of research findings and future work are discussed, and finally, a conclusion is drawn in the last section.

### **Research goals**

The current research aims to investigate in which way the effectiveness of home automation installations can be improved by tracking or sensing and interpreting the actual user context, given available sensors within the automation system as well as incorporating sensors from smart devices. Therefore, the study will cover three issues: § To investigate the impact of actual user context on smart home systems taken into account different dimensions of user context. § To abstract a sound way to integrate user context into HAS. § To observe the efficiency improvement of HAS in term of energy usage by semantically reacting to high-level contextual data in a specific use case.

## **LITERATURE REVIEW**

To learn the background work that has been done in the field is essential for good quality findings. The authors follow a systematic literature review methodology to search, analyze and review papers and journals to form an overall view on related matters. (Klimova, 2018) has presented a well-organized literature review which enhances searching quality by focusing on content and relations between topics of interest. The two well-evolved fields of research: home automation and user context are of primary benefits. This study tries to form strong understand in the impact of user context or user behaviour in the context of home automation and how beneficial extracted knowledge could be utilized in the quest to improve HAS efficiency, thus, contributing to the advancement in Home Automation (HA) social adaption.

The process of data selection includes a periodic search for articles. We used the following terms as searched keywords: User Context, Home/House Automation, Smart Home, Context-aware in the renowned scientific databases: ScienceDirect, Scopus, and Springer. A large number of results returned indicate the popularity in the fields and also implied that the keywords we used might be too broadly linked. To this end, compositions have been applied to connect keywords (e.g., AND) as a mean to filter related results as well as to point the search focus to relations between keywords. Other journal databases: ACM Digital Library, IEEE Xplore, Taylor & Francis Online, and Cambridge Core were also used to fulfil the necessary materials for reviewing

Table 1 describes the details of the literature review process. This includes the following information: task description, an objective of each task and specific activities to achieve these



objectives. The outcome of this process is a list of what we believe to be relevant and can be leveraged to build a foundation for our research.

**Table 1. Details of the literature review method**

Task	Objective	Activities
<b>Keywords search</b>	To find all relevant articles	<ul style="list-style-type: none"> <li>▪ Extracted keywords relevant to research goals: <i>user context</i> in <i>home automation</i> system.</li> <li>▪ Searched in different databases and skimmed through returned results.</li> </ul>
<b>Combine keywords</b>	To filter closely related and useful articles in the context of this research	<ul style="list-style-type: none"> <li>▪ Leveraged advanced search features in scientific databases: conditions on keywords, compositions.</li> </ul>
<b>Inclusion and exclusion criteria</b>	To define the scope to later select articles as we are interested in more recent findings	<ul style="list-style-type: none"> <li>▪ Selected language of results: English.</li> <li>▪ Selected articles from 2010.</li> <li>▪ Selected articles with high impact factor and published in top conferences.</li> </ul>
<b>Sources selection and analyze</b>	To select most relevant and available articles for deeper analysis.	<ul style="list-style-type: none"> <li>▪ Scanned article's content, including abstract, keywords and marked good items for analysis. This task is done with the help of Mendeley tool.</li> <li>▪ Looked for full-text documents to support further reading.</li> </ul>
<b>Quality assessment</b>	To select relevant articles capable of addressing the research questions	<ul style="list-style-type: none"> <li>▪ To eliminate duplicate and irrelevant studies.</li> <li>▪ Looked into the content of articles and cross-referenced to detect additional relevant papers (or keywords).</li> <li>▪ Enriched the literature collections for any new relevant keywords found and discussed to finalize results for next step.</li> </ul>

Searching for keyword Home Automation alone returned more than 20,000 results (ScienceDirect) and same result applied to keyword User Context. This incident is not surprising, although both research fields are not new, the attention has never dropped, especially in studies towards conserving energy and consciousness in consuming energy, which are covered in the theme of sustainable development. Due to the nature of this study, we only look into the intersection where user context meets home automation that can enhance the efficiency of HAS.

### **Home Automation System (HAS)**

Smart Home/Building have been studied and developed over the last three decades. To define what is smart buildings, several studies have been conducted to provide an adequate view. (Toschi et al., 2017) conducted a survey to summarize the current state of the art of the smart home automation and has pointed out several different definitions.

- “One which provides a productive and cost-effective environment through optimization of its four basic elements including structures, systems, services and management” (Wigginton, 2014).
- “A smart home is a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants” (Chan et al., 2009).
- (Buckman et al., 2014) defines Smart Buildings as buildings which “integrate and account for intelligence, enterprise, control, and materials and construction as an entire building

system, with adaptability, not reactivity, at the core, in order to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction”.

In summary, Smart Home or Building concept refers to all buildings in general, commercial or industrial buildings, apartment buildings, and private houses. Although the terms Smart Buildings and Smart Home are used interchangeably from time to time, the two concepts are slightly different. Smart Buildings refer to significant economic buildings (e.g., office buildings, shopping mall) with shared facilities, HVAC systems, and multiple users. On the other hand, Smart Home may, in principle, indicate private housing or any form of residence, for example, standalone house or an apartment, where fewer users are interacting with the system in a personalized environment. Thus, a smart home is designed to be adaptive and user-centered. Within this study, to simplify the concept, we account for Smart Home or Home Automation System (HAS) in the scenario of a single user. Smart homes are residential units substantially integrated with a communicating network of sensors and actuators centrally connected and monitored by intelligent systems. Initially, HAS monitors the energy consumption of home appliances and automating the process of switching on/off devices to maximize energy usage efficiency. Recent years, emerging new technologies and artificial intelligence have matured to the point where systems are becoming more intelligent, and objects can even communicate to human. Backboned by smart systems, HAS embraced significant potentials towards achieving comfort, security, independent lifestyle, enhanced quality of life while taking into account environmental impact. Smart home energy efficiency services assist homeowners in reducing energy demand, whether directly (through automated energy-saving mechanisms, such as lowering the heating on hot sunny days) or indirectly (e.g., by providing the user with centralized access to data about their real-time energy usage and energy bill).

According to (Balta-Ozkan et al., 2013), main components forming a smart home architecture are: communication network infrastructure, intelligent control and management, a sensor network around the house, and automation services. Smart home services are the benefits that the smart home provides to the user, for example, the ability to manage demand, the mean to remotely control the house and connected devices or automated actions that will be executed based on, mostly, fixed predefined schedule. A connected network of technological components facilitates smart services.

Figure 1 shows the CASCA architecture – a project conducted by Washington State University. The CASAS architecture (Cook et al., 2013) facilitates the development and implementation of future smart home technologies by offering an easy-to-install lightweight design that provides smart home capabilities out of the box with no customization or training. Sensors implanted around the home read data on the surrounding environment and transfer to a central controller. Data from sensors is the input of intelligent-based systems (e.g., activity recognition, activity discovery, positioning service). Any reaction to the HAS or information will be transferred back to the user through this network, controlled by the central manager.

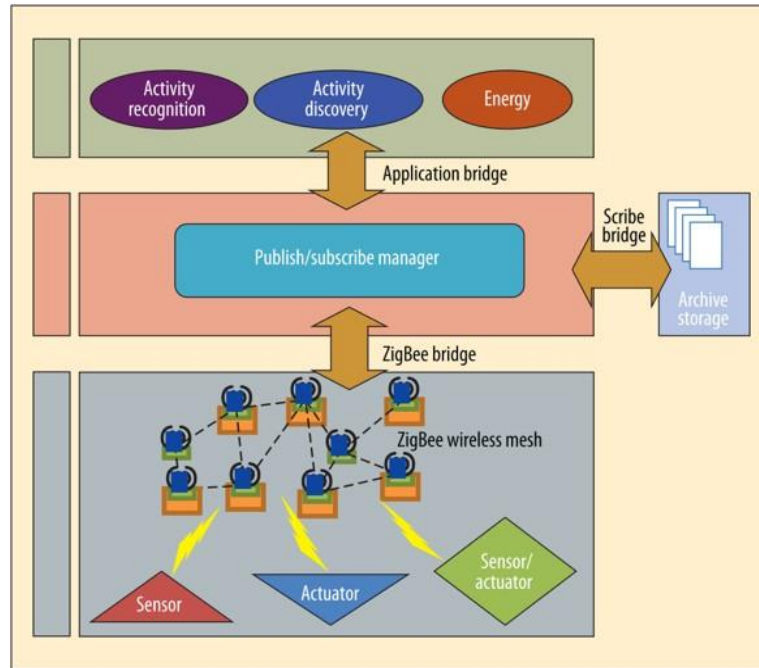


Figure 1. CASAS smart home architecture overview

Source: CASAS: A Smart Home in a Box. Computer (Long Beach, Calif). 46, 62–69.

### User Context in HAS

According to (Yang, 1AD), the user context is any relevant information that can be used to characterize the situation of a user. There are three critical aspects of user context: where the user is, whom the user is with, and what resources are nearby. Typically, user context consists of the user's location, profile, people nearby, the current social situation, and environmental status. User context particularly has a significant impact on the effectiveness of a HAS.

Lifestyle and habits of users have a direct effect on the energy performance of dwellings and facilities. Hence, in the built environment, the user plays an essential and centric role, advanced control strategies must adapt to user behaviors trying to keep a commitment between energy consumption and comfort requirements (Vázquez et al., 2011). User Context Detection thus is well evolving as a renowned research topic and used in many different applications. It is well known how to use sensors to get parameters from the users' environment. This source of data embraces huge potentials in coherence with machine learning on detection purposes, for example, to recognize user activity using machine learning methods, or to detect abnormal behavior by profiling owner. Having access to this user context data, smart home security services might be able to offer the ability, using sensors, to monitor movement in the home and identify potential intruders, to be alerted about open doors and windows, or to program random room lighting patterns to deter thieves from a temporarily unoccupied property (Balta-Ozkan et al., 2013).

Regardless of the sustainable aim to reduce energy usage in a smart home, user comfort cannot be neglected. The user has been, and should always be, the central of HAS system design. Most common component in the house controlled by HAS is the HVAC system. An example of a feature

in context-aware HAS system is adjusting the heating system or controlling temperature in the house. (Vázquez et al., 2011) pointed out that the smart system tries to establish comfort conditions by adjusting the setpoint temperature according to user comfort temperatures, occupying status, and occupancy predictions. This study also listed common context-aware control strategies for energy efficient HAS.

- On/Off controller – switching on devices when people arrive home and switching them off when they leave the dwelling;
- Scheduled controller – establishing comfort settings during the expected or normal building usage schedule;
- Combined controller – setting comfort level based on schedule but adjustable with user context;
- Fuzzy controller – predicting the future occupancy based on external knowledge or machine learning algorithms.

### User Context and HAS Integration Enablers

HAS platform provides the development environment and essential means to build the bridge between user context and HAS. We aim to extract abstraction or high-level information from raw sensor data with technical support tools. Table 2 presents comparisons between most well-known platforms for HAS based on the following features: support for user context extension, supported protocols, and ease of use in terms of connections and configurations.

Table 2. Compare context integration feature of HAS platforms

HAS Platforms	Context-aware supported features	Protocols	Ease of use
Home Assistant	<ul style="list-style-type: none"> <li>▪ <b>CalDav</b>: connect to WebDav calendar and generate binary sensors.</li> <li>▪ Google Calendar Event: connect to Google Calendars and generate binary sensors.</li> <li>▪ Fitbit sensor: to expose data from <a href="#">Fitbit</a> to Home Assistant.</li> <li>▪ Google Maps: to detect presence using the unofficial API of <a href="#">Google Maps Location Sharing</a>.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Google APIs</li> <li>▪ Yaml<sup>1</sup> format configuration</li> <li>▪ HomeMatic</li> <li>▪ ZigBee</li> <li>▪ Most common smart devices and services: Alexa, TV, lightbulbs, etc.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Support almost all common protocols to connect devices.</li> <li>▪ Easy to connect with Google Calendars.</li> <li>▪ Modular components simplify the connection.</li> <li>▪ Programming language: Python</li> </ul>
FHEM	<ul style="list-style-type: none"> <li>▪ Online calendars connection supported.</li> <li>▪ Need to define and configure external services explicitly.</li> </ul>	<ul style="list-style-type: none"> <li>▪ eQ3 specific: HomeMatic, FS20, EM1000, etc.</li> <li>▪ Most common devices: LG, Philips TV; Alexa, etc.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Support for a lot of protocols used in house automation, audio/video devices, weather services, online calendars and more.</li> <li>▪ Notify to external program, e.g. WhatsApp.</li> <li>▪ Modular architecture, easy to add special devices.</li> <li>▪ Programming language: Perl</li> </ul>
OpenHab	<ul style="list-style-type: none"> <li>▪ Google Calendar</li> </ul>	<ul style="list-style-type: none"> <li>▪ HomeMatic, Bluetooth</li> <li>▪ Wire, z-wave, wifi</li> <li>▪ Common devices: LG, Philips, etc.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Ability to integrate a multitude of other devices and systems.</li> <li>▪ Has its own set of concepts, rules and scripts.</li> <li>▪ Programming language: Java</li> </ul>

<sup>1</sup> <https://yaml.org/>

# RESEARCH METHODOLOGY

## Introduction

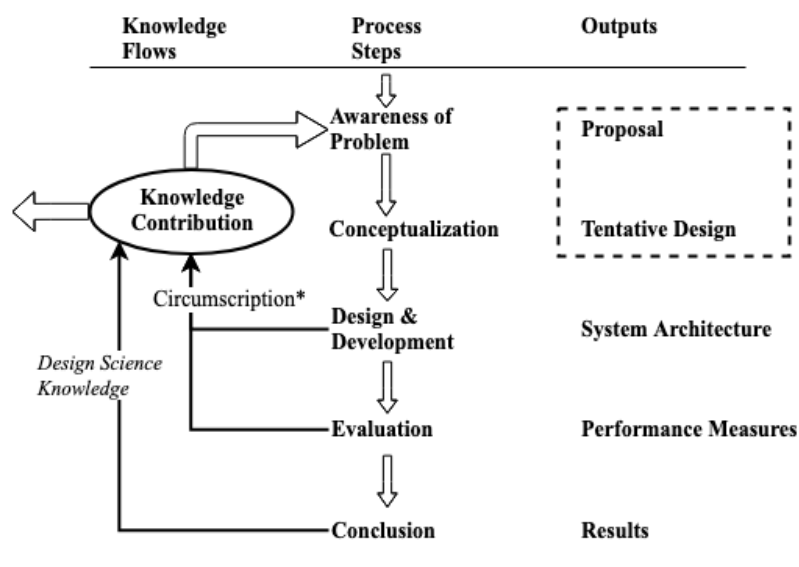
Williams and Babbie (2006), identified research approach as: “systematic and orderly approach taken towards the collection and analysis of data so that information can be obtained from those data.” It is, to the authors, critical to understanding the aims of research clearly to determine and choose the appropriate technique to achieve research's objectives (Wright and Losekoot, 2012). In the quest of finding a possible solution for our topic of interest, the authors find Design Science Research methodology best reflect our nature of research; thus, we follow this approach to conduct our study.

- Research design aims to give a clear picture of the structure of the research and the used methods such as data collection, research questions, and sources of data. Research design enables the researcher to outline all needed method and tools for the research like selecting theory of project and research methodology (Kilani et al., 2016)
- Design Science Research is research that creates this type of missing knowledge using design, analysis, reflection, and abstraction (Vaishnavi et al., n.d.).

In Figure 2, we present an overview of the whole research strategy, divided into five phases: scoping or problem identification, theoretical research, conceptualization, system development, and evaluation. This methodology is adaptive from the original design (Vaishnavi et al., n.d.)

## Awareness of Problem

During this phase, we investigate the state-of-the-art along with existing issues in the field. Our research approach starts with defining and understanding what problems we are trying to solve, thus, looking for a suitable solution. From these learning, we identify our research scoping (e.g., define the context where the research focus on) and move to the next step of the analysis process. The output of this phase is a clearly defined research context – a proposal, which will then be used as the input for the next step.



\* Circumscription is discovery of constraint knowledge about theories gained through detection and analysis of contradictions when things do not work according to theory (McCarthy, 1980)

Figure 2. Design Science Research Methodology

### **Conceptualization**

The Conceptualization phase immediately follows the proposal and is intimately connected with the proposal developed based on the Awareness of a Problem. A Tentative Design is a potential outcome of this phase. This phase is the early stage of a system design that we will then set up and implement.

### **Design and Development**

The Tentative Design is further developed and implemented in this phase. To make sure the proposed solution is technically possible in a specific use case, we explored different HAS platforms in term of context integration supported features. An abstract architecture to integrate user context into HAS is carefully designed. As part of this phase, we also develop an implementation applying the architecture within the German context.

### **Evaluation**

Once constructed, the architecture we proposed needs to be evaluated according to “criteria that are always implicit and frequently made explicit in the Proposal (Awareness of Problem phase)” (Vaishnavi et al., n.d.). To achieve our listed research goals, we decided there is no better way to evaluate an improvement by comparing with existing solutions. Due to the nature of HAS, the scenario (including user relevant attributes such as living condition and social standards) where a system has been installed affects its efficiency in multiple ways. As an outcome of this phase, we carried out a heuristic measurement in terms of energy efficiency and compared with measures of a typical German use case (Sarmiento et al., 2017)

### **Conclusion**

This phase is the finale of our research effort. We review the results deriving from the study and validate revised hypothetical predictions. By examining the work and verify if we have met all research goals, we discuss the contributions of this study, what has been left for further research and the quality of our solution in all terms.

### **User context integration architecture**

As mentioned above, although studies have shown possible solutions to build a HAS using different technologies, sensors, and smart devices, an overall integration with user-centric contextual data is still missing. In this section, we present an overall architecture to integrate the actual context of users into HAS in a sound way. This architecture is an extension of a typical design for implementing a HAS (Cook et al., 2013). Figure 3 shows an overview of this architecture. The infrastructure substantially consists of four main sections, which are: Physical Appliances, IOT Hub, Context Builder, and Reaction Dictionary.

A controller connects all physical devices installed in a HAS such as home appliances (e.g., heater, refrigerator, ventilation controller, air conditioner), smart lightbulbs, smart meters (e.g., thermostat) and sensors (e.g., motion detector) through various protocols. The connected devices and data from sensors are centrally managed and monitored by an IOT hub.

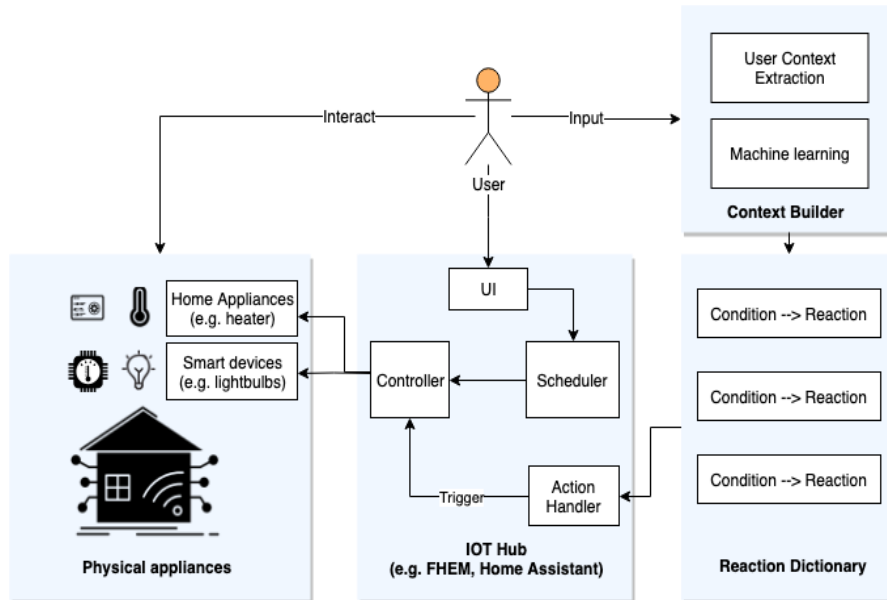


Figure 3. The overall integration architecture

There are quite many different platforms that enable these connections. Later in this study, we will discuss different platforms that have been studied and compared to identify their ability to handle user context from external sources. Each of the HAS platforms has its structure and protocol to manage connections to external devices and services. The most common method is through API and HTTP protocol. A typical structure of a HAS platform would support a user interface for the user to interact with the system, including monitoring and remote controlling devices. Apart from predefined UI provided from the platform, most HAS platforms support external application building through API. Another vital component within an IOT hub is the scheduler. The scheduler refers to user-defined events to switch on and off devices at a specific time daily, weekly, or monthly based on the similar living environment. For example, the scheduled controller establishes comfort temperatures (standard-based) during the expected home usage schedule. It is common in office buildings, or even in houses where inhabitants do not want to be bothered with or usually neglect the manual heating/cooling adjustment. According to (Vázquez et al., 2011), the energy performance is relatively ineffective, but comfort ratings are satisfactory provided that people are at home during the scheduled time.

**Context Builder** component is in charge of handling high-level data from accessible contextual user data (e.g., calendar events, health data, sports activities). The output of this module can be knowledge which the designer will use to decide corresponding reactions or adaptations. Besides predefined knowledge base (built upon surveys or specific use case of a particular country, region or neighborhood), machine learning algorithms such as classification, fuzzy prediction are fit in this module to provide more meaningful knowledge out of low-level sensor data.

**Reaction Dictionary** contains system actions corresponding to specific user context. In this design, the dictionary can be built independently, which brings the benefits of further extensions or capability to integrate into other systems. This knowledge structure is organized as a rule-base dictionary, in the form of  $A \Rightarrow B$ , where A is context-aware conditions and B is system reaction.

Conceptually speaking, Context Builder and Reaction Dictionary are separated due to different usage purpose. In some cases, we can present reaction dictionary as an output of the Context Builder for the reason that they are closely connected in terms of technical implementation.

## A GERMAN USE CASE IMPLEMENTATION

Figure 4 is the activity diagram of the automation on controlling heating or cooling system adapting to occurring events. In the following demonstrated scenario, an example is given on adapting HAS system to the extent of one context attribute - calendar event.

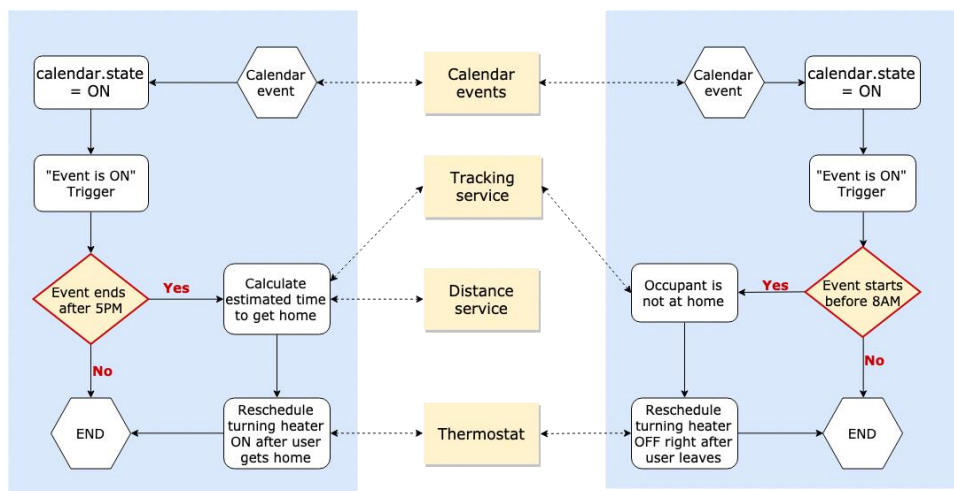


Figure 4. Activity diagram of the automation on thermostat based on calendar event

### Scenario: Reschedule turning heater/cooling system ON/OFF based on calendar event

Occupant's calendar is linked and updated at a defined frequency. The Home Assistant server creates an entity to store the nearest event as user context data - referred to as a sensor. The calendar entity is associated with a state object, which stores essential information of the event itself, e.g., start time, end time, location, and description. Whenever an ongoing event is detected, the calendar state object is toggled to ON, and the system understands that the user is possibly attending the event at a specific location. We extend the fixed schedule to adapt to this abnormal behaviour through a smart action plan in Home Assistant - called automation.

We focus on German use case referenced available studies to specify system requirements. Existing HAS systems allow users to configure these settings to their favours. Defining system requirements is essential to simulate a real use case and to be used as the comparable base for the adaptive model.



## **EVALUATION**

The ultimate goal of this study is to improve the efficiency of the smart home system in terms of energy usage by adapting to the user context. As stated, home automation strategies are usually being done based on a daily or weekly basis thanks to fixed schedule mechanism offered by most of the HA platforms. Adapt meaningfully to the different context of users can significantly improve the effectiveness of a system; however, in unusual conditions. This sort of behaviors is noted to be unpredictable and usually, do not follow a periodic basis. For this matter, we carry out experiments to evaluate the implemented model bearing this concern in mind in an ongoing study.

For HAS, the system effectiveness is reflected by the amount of energy that can be reduced with active smart strategies. The point of this phase is to verify the role of adapting to user context in improving system efficiency. Energy consumption in terms of power usage is primarily affected by the period devices are in use. By shutting down the appliances while not in use, the to-be-wasted energy is expected to be sufficiently saved. In this sense, increasing the time power-consumed devices in off or standby mode will reduce the energy usage at a certain amount. Experiments and observation need to be carried out within a specific use case, in consideration with transient power in the process.

## **DISCUSSION**

We have approached to solve the identified problems by exploring an overall user context integration architecture and developing a prototype to showcase the practical potential of this approach. The research is ongoing to strengthen the scope and evaluate the system efficiency more thoroughly in different aspects.

Another alternative solution could be approaching the user context from another angle. A manually collected reaction dictionary is a good starting point to develop such a system, while an auto-generated one with the aid of machine learning can grow the context sphere to produce widened and substantive knowledge. By focusing only on user context, the study can find more ways to gather and analyse user context data, one of that can be, applying machine learning on a more extensive data set. Useful information can be extracted from this way of problem approaching.

An interesting point worth mentioning here is to apply this model in a multi-user environment. From the start, we simplified the specification to direct our focus into a big picture or overall architecture. However, the multi-occupancy living environment is different than what we have as a starting point. With almost different characteristics, applying such model to multi-user environment could face new challenges: to accurately detect and distinguish user, to efficiently maintain user preference, to react meaningfully to various circumstances and users.

## **CONCLUSION**

The purpose of the study is to provide a sound way to leverage actual contextual user data to improve the effectiveness of the Home Automation System. Based on the scoping research, it is

evident that reacting more meaningful to real user context enhance the efficiency of a HAS system in case of unusual behaviours. There exist quite many works in responding to abnormal user behaviours within HAS. However, most of them are done based on positioning and user activity recognition inside the house. This work has shown that integrating user context into smart home system improve energy efficiency if the system adapts in a meaningful way.

One of the most significant contributions of this work is that we proposed an extended architecture, in which the existing structure of a HAS is reused. A high-level contextual data structure can be built by different means, including predefined rules, machine learning, or prediction model. By separating this data structure, it increases the possibility for an external system to share user context knowledge base; thus, enlarge application potential.

The architecture has been proven possible with a proof of concept. A robust prototype provides a showcase of how to implement such an integrated system in reality, which is very significant to the context of HAS. The study utilized modern technologies and open-source smart home platform to develop the prototype.

Although the results of our study are positive, its scope is confined within a single-user context, which somewhat restrains the use cases. Future research has plenty of space to extend from this ground. One possible direction is to extend such principles and model to a multi-user environment. This direction poses challenging in teaching the smart home to adapt to personalized context based on their preference, in another word, to distinguish each user and react to the different context of a different subject. Moreover, expanding the context builder module is also promising, where machine learning power can be applied to learn from user behaviour and develop an informative knowledge base to improve HAS energy efficiency.

## **ACKNOWLEDGEMENT**

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# Could retrospective implementation of BIM in high-rise social housing prevent another Grenfell Tower tragedy?

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**Keywords:** BIM, refurbishment, social housing, Grenfell Tower.

## ABSTRACT

*On 14<sup>th</sup> June 2017, Grenfell Tower, a high-rise social housing block in North London caught fire, resulting in 72 deaths, (BBC, 2018a). A year prior to the fire, the tower had undergone refurbishment work to address the building's sustainability performance and improve its appearance, (Booth et al., 2017). Changing or refurbishing a building can compromise the existing 'system' of how a building works; to ensure refurbishment does not impact on building safety, Building Regulations must be strictly followed. A year on from the tragedy, it is evident that relevant regulations and procedures were not adhered to during this process, (Waite et al., 2017).*

*An independent review of Grenfell commissioned by the Government suggested several recommendations, including making Building Information Modelling (BIM) a stronger factor to improve building safety on existing and new high-rise buildings, (Hackitt, 2018). Currently, there is currently little to no evidence of BIM being used in the social housing sector. BIM has demonstrated to be a cost and time saver on projects, (Malleon, 2018) so it seems surprising to not investigate a process that could aid the current housing stock, particularly when the government's Decent Homes Standard on existing social housing shows 525,000 council dwellings do not meet a fit living standard, (Kentish, 2018), many of which are classified as high-rise buildings.*

*Using Grenfell Tower as a case study, this paper aims to address the failures throughout the refurbishment works. It examines how implementing BIM retrospectively to Grenfell Tower could have ensured superior futureproofing and improved the overall safety of the building throughout its remaining lifespan.*

*The research paper has been compiled through a desktop study, and includes secondary research using news articles, textbooks and academic journals. From this research, the paper establishes whether implementing BIM to the case study could have prevented the tragedy from occurring. The discussion concludes that BIM poses a good opportunity to retrospectively implement BIM into high-rise social housing for safer and more efficient refurbishments.*

## 1. INTRODUCTION

BIM implementation in new construction projects is becoming the norm, with uptake in architectural and engineering (AEC) practices rising from 13% in 2011 to 74% by 2018, (Waterhouse et al., 2018). Gov.uk reported, implementing BIM into a project's framework can

reap savings of >20%. (2015, quoted in Malleson, 2018). However, using BIM retrospectively has not had so much usage, (Alwan, 2016) with a distinct lack of research on BIM applied to social housing projects, and even less so for the use of refurbishments. The aim of this paper is to assess if applying BIM retrospectively to Grenfell Tower would have been a useful tool for building safety.

This paper uses Grenfell Tower as a Case Study for its focus because there are many similar tower blocks in the UK under the social housing sector that the findings of this research can be applied to. This could conceivably result in major and important improvements in the safety of social housing throughout the country. Worryingly, there are still 410 tower blocks that have similar variables to Grenfell that could still be at risk, (Wilson, 2018). There has been an out-cry to raze these post-war towers to the ground, the London mayor, Sadiq Khan, publicly expressed the hope that “the worst mistakes of the 1960s and 1970s are systematically torn down” (2017). However, Architects for Social Housing (ASH) disagree with this stance, saying that it is a tactic to get rid of ‘sinking estates’, (ASH, 2017), and that refurbishment is a better result for efficiencies and the residents of the building, this idea is also backed up by Philips, (2018) who refers to Gaterell & McEvoy (2006) and Power (2008) who agree that refurbishment and retrofit is cleaner, safer and a more cost-effective method with less CO2 emissions produced than demolishing and rebuilding.

To focus the case study question, when discussing ‘social housing’, this research paper considers both council housing and housing association properties in England that are managed by registered providers or social landlords. This category of housing provides affordable living for people on low income and is usually run on a not-for-profit basis. (Shelter UK, n.d.) Local Authority are managed by the Department for Communities and Local Government (CLG) arm, (Steel, 2018).

## **2. LITERATURE REVIEW**

### **2.1 Overview of UK high-rise social housing stock**

In the years following World War II, an urgent need had arisen in rehousing people who had been displaced by the war, as well as a general need for new housing stock caused by the slum clearance initiative, encouraged by the Housing Act of 1930, (University of the West of England, 2008). High-rise buildings duly became a popular choice for social housing providers; they were considered a quick and cheap way to rebuild the country.

By the 1980s, many of these high-rise social housing towers had fallen into decay. The government addressed this problem by issuing refurbishments throughout the country. During this time, Thatcher’s government reduced the number of Building Regulations from over 300 to just 26. According to the BBC (2018b) documentary, ‘The Fires That Foretold Grenfell’, this was to, “cut the red tape”, and make it easier for construction/refurbishments to progress. Many of these tower refurbishments centred around making buildings more efficient and cheaper to run, using methods such as adding external cladding to improve thermal performance and update building appearance.

In the current climate, there is a high demand for the government to build new affordable social housing, (Economics Online, 2018). However, the existing stock is also a major problem; the government's Decent Homes Standard publication released in 2018 revealed that 525,000 homes do not meet the prescribed acceptable standard, a large proportion considered as dangerous, (CIH, 2018).

## **2.2 Failed Refurbishments**

Refurbishments have indeed been taking place in recent years but have not always been successful. The following summary highlights multiple examples of social high-rise towers that were subject to serious fires after refurbishment works were completed.

1991: Knowsley Heights (11 storeys) – Merseyside. This was the first tower block cladding fire in Britain. Renovations included a rainscreen cladding system added to improve the building's thermal performance and external appearance. A fire set deliberately by youths reached the walls of the tower and spread rapidly up through the newly installed insulation of the cladding system. (BBC, 2018b). Following the fire, an investigation by the Building Research Establishment (BRE) showed the cladding used was of 'limited-combustibility'. It was also found that firebreaks had not been installed between the cladding and the walls, which allowed the fire to spread considerably quicker (Thorp, 2017). Fortunately, lives were not lost from the incident.

1999: Garnock Court (14 storeys) – Scotland. This block of flats had colourful plastic cladding and new uPVC windows added during a refurbishment to improve the appearance of the blocks. Disabled pensioner, William Linton had unintentionally started the fire in his flat after dropping a lit cigarette. The fire melted the uPVC windows, then spread to the exterior of the building along the newly applied strip of cladding, which spanned the full height of the building around the windows. Mr Linton died in the fire.

Following the Gannock Court incident, a House of Commons select committee was formed to investigate combustible cladding on tower blocks. The report concluded that the types of cladding systems used on Knowsley Heights and Garnock Court had allowed a path for the fire to travel through quickly. They stated, "We do not believe that it should take a serious fire in which many people are killed before all reasonable steps are taken towards minimising the risks." (House of Commons, 1999). Following this, Scottish Building Regulations were changed to ban combustible materials being used on residential high-rise buildings. Subsequently in England, the Building Regulations Approved Document B was amended to state that materials must be graded at least A2 – of limited combustibility to be used on high-rise buildings, (Approved Document B Fire Safety, 2015). In other words, flammable materials would still be legal to use on high-rise buildings.

2005: Harrow Court (17 storeys) – Stevenage. The fire was started by tea-lights that had been left to burn on top of a television set. The residents calling the fire brigade were informed of the 'stay put policy' due to the compartmentalisation construction of the flats which would act as fire containment for a period of time. Refurbishment works carried out during 1993/4 changed the original opening windows in the communal staircase to double glazed UPVC sealed units. This lack of ventilation meant the fire-fighters had to smash the windows open. The fire on the 14th floor had no operational dry riser; fire-fighters had to wedge open fire doors from the floor

below up to allow hose lines to this storey. The staircase that the hoses were routed up had insufficient fire doors; this made a clear path for the fire and thick smoke to travel. It is believed a combination of the smashed windows and open fire doors created a more intense fire. A resident and two fire-fighters died in the blaze, (Handscomb, 2017).

A two-year investigation of the fire resulted in the Fire Brigades Union (FBU) reviewing the 'stay put' policy in tower blocks. This policy is only effective when the construction of the building does not compromise the flats compartmentalisation, which helps delay fire spread. It is believed that sprinkler systems could have prevented loss of lives, as it would have detected and held off the fire spread. The review recommended the sprinkler systems be installed in all tower blocks. These recommendations were sent to the Department for Communities and Local Government as a matter of national significance. However, the 'stay put' policy advice remained unchanged and the sprinkler system advice was rejected. Instead, Approved Document B was amended in 2006 to be less stringent in the way materials are fire safety tested. The new edition no longer required the test to be performed in a laboratory; rather, a desktop simulation was now to be considered sufficient evidence. (BBC, 2018b).

2009: Lakanal House (14 storeys) – London. A faulty TV set resulted in a fire, causing 6 deaths. Two years previously, the building had undergone refurbishment. Cladding panels had been added that were intended to have a fire rating of 1 hour. The investigation shows they lasted just 4 minutes, (BBC, 2018b). A 'stay put' policy was in place, meaning 999 operators instructed residents to stay within their flats. In addition to the new cladding, false ceilings had also been added during the refurbishment, compromising the compartmentalisation of the flats and allowing the fire to spread.

The coroner's report of the fire concluded the cladding did in fact meet fire safety standards as prescribed in the Building Regulations Approved Document B, but also went on to say that the document is worded in such a way that it makes the guidance ambiguous and unclear. The coroner's report to the government Community Secretary recommended a retrofit of sprinkler systems in all high-rise buildings, a revisit to the 'stay put' fire policy and a redress of the wording of Approved Document B to make it clearer. The housing secretary at the time, Eric Pickles, forwarded these recommendations on to Local Authorities but did not expressly deem them compulsory. A review of the Building Regulations was again called for and overlooked, (Minton, 2017).

The fires reviewed in this summary were stark warnings of the sub-standard level of refurbishments being carried out on social high-rise buildings. It has taken another tragedy, the Grenfell Tower fire; detailed in section (5.0) of this paper, to show that there has still not been enough done in regulatory reform. Had the various governments in power implemented the advice given from these previous fires, it is very likely the scale of the fire at Grenfell would not have occurred, detailed in section (5.0). It is crucial that lessons are learned from these refurbishments, as the government has agreed to slash UK CO2 emission by 80% by the year 2050. 4.5 million homes are part of the social housing sector, which the government is looking to tackle first, (Syal, 2016). Local authorities would have to approach these refurbishments with a more robust strategy, to ensure these ambitious CO2 emissions targets are met without creating further poor building refurbishments that lead to tragedies.

### 2.3 The Hackitt Report

Dame Judith Hackitt's report, produced in response to the Grenfell Tower fire, was released in 2018. Her findings opened with, "there is a need for a radical rethink of the whole system and how it works. This is most definitely not just a question of the specification of cladding systems, but of an industry that has not reflected and learned for itself, nor looked to other sectors." As revealed in section (2.3), the report's opening statement acknowledges that the government and construction industry have failed to learn from past mistakes. Oddly, the recommendations would only apply to "new and existing high-rise residential properties which are 10 storeys high or more". It was not made clear why Hackitt decided that the new recommendations will apply only to 10-storey or higher buildings. After examining 'Building a Safer Future Independent Review of Building Regulations and Fire Safety: Final Report' (2018), the following summarises the main points:

*Joint Competency Authority, Gateways, and Clarity of Roles* - The report looks to form a 'Joint Competency Authority (JCA) that will be made up of multiple disciplines including Local Authority Building Standards, fire and rescue authorities and the Health and Safety Executive. The aim of the JCA will be to give clarity to roles and responsibility at the necessary time its needed, to check that building progress meets safety and quality standards before it can be signed off onto the next stage of the build. This idea has been named the three 'gateway points'. The first being to demonstrate at planning stage that there is adequate access for the fire brigade to access the building. Secondly, the dutyholder will be able to show the safety risks of the building and ensure that these risks are being managed. Finally, the dutyholder must be able to demonstrate to the JCA that the signed-off design is in fact the one that is to be constructed before handover to the contractor is given, i.e. no material deviations.

*Testing and specification of materials, Procurement, and Fines* – Materials used on the building, whether standalone or combined in a system, must have specific testing to approve their compatibility working together. Plain language statements must explain where they are appropriate for use on specific areas of a building. To further strengthen this mindset, the JCA will have the power to pursue prosecution and enforce fines on those who do not show intention to adhere to creating safe and reliable buildings from inception. Tender information should detail how the building will be produced, demonstrating that they are not using cost-cutting methods that compromise safety. This should be included in a digital record of the building.

*Golden thread of information* – This section of the report is where Hackitt brings recognition to the positives of implementing a digital record, indicating a preference to using BIM, and making it a legal requirement for all clients, principal designers, and principal contractors involved to keep such records up to date. These digital records would hold vital information on the building such as materials, size of the building, and maintenance information. A fire and emergency file has also been suggested. This would contain full plans of the building including evacuation routes, details of passive safety measures such as compartmentalisation, and fire doors.

It could be argued that the government has encouraged the 'race to the bottom' culture through further minimisation of material safety testing required, something that the Hackitt report brushes over. Approved Document B's requirements for material testing has gradually declined



over the last few governments, (<https://www.gov.uk/>, 2016) Presently, materials and systems are no longer required to be signed off with a physical test, instead 'data testing' is considered sufficient to give the material/system approval for use. This deregulation has improved time-saving and cost cutting but ultimately is a direct contributory factor in the fires detailed in section (2.3) and later in the case study.

It came as a surprise to the industry that there was no specific banning of combustible materials in the report. Hackitt's justification is, if materials and knowledge are applied properly, this should not mean combustible cladding needs to be banned. This led on to comments on the competency levels of members of the construction industry. The government's actions should also be questioned here, who have consistently slashed regulation on testing and left guidance in an ambiguous format, it leaves the door wide open to unscrupulous behaviour. Overall, these recommendations are a positive start, but that is all they are currently - recommendations, and as seen previously, past regulatory reform recommendations have largely been ignored.

#### **2.4 Building Information Modelling (BIM) Opportunities and Constraints**

Although BIM is a frequently used buzzword in the construction industry now, it appears there are still misconceptions around its full potential. For clarity, the Centre for Digital Built Britain's (n.d.), definition is, "At its core BIM uses 3D models and a common data environment to access and share information efficiently across the supply chain and so boost the efficiency of activities around asset delivery and operation. By helping the entire supply chain to work from a single source of information, BIM reduces the risk of error and maximises the team ability to innovate." These advantages have already been recognised by the government and as such, in 2016, the BIM Level 2 Mandate, ([Bim-level2.org](http://Bim-level2.org), n.d.) was introduced, whereby all centrally funded construction projects must meet PAS 1192 standards in order to be considered for tender, which are accessible from [Bim-level2.org](http://Bim-level2.org). It is believed the Mandate has persuaded the AEC industry to move to BIM with the NBS National BIM Report (Waterhouse et al., 2018), showing BIM adoption has risen from 13% in 2011 to 74% by 2018.

To ensure that BIM is truly collaborative, it needs to be interoperable with the various BIM platforms on the market. This is made possible by exporting information into an open source industry foundations classes (IFC) file format. ([Bim-level2.org](http://Bim-level2.org), n.d.) This format also forms an essential part of the requirement of BIM Level 2. With this interoperability in place, Designers can easily handover the building's essential data on spaces and equipment. This information is passed on as 'data-drops', using a COBie file format which holds exported schedule information from a BIM project. The COBie data is then passed to the contractor who will then be responsible for filling out specific information on the designers outline design, such as; manufacturer, model, installation dates, warranty information; parts and supplies; and maintenance schedules, (<http://www.bimplus.co.uk/>, n.d.). These data drops occur at particular milestones in the project, which could be aligned with Hackitt's gateway points.

Digitising the building data into BIM allows for a smooth flow of asset information to be easily accessible and structured concisely throughout planning, delivery and operation. However, a main barrier for implementing BIM retrospectively to existing social housing is that data handover in the past has notoriously been poor; older buildings have a greater likelihood of

missing building information including as-built and building modifications information. This is demonstrated in David McGough's thesis, (2015), where the modelling of an existing building being created for his thesis was hindered by missing handover information for a façade that had been added later in the building's life. His research budget did not stretch to be able to survey this part of the building, making the model incomplete.

Nevertheless, even when existing data is available, it cannot always be relied on. To make sure the BIM is an accurate representation, the existing data should always be corroborated with new extensive building survey data. Creating geometry for existing stock will be a lengthy process but will be sped up greatly by laser scanning (LiDAR), this is a great visual tool and will accelerate up the modelling process, as it will give real world dimensions, positioning and can also identify services in walls etc, further adding photometry can create a life like look to the model (McGough, 2016).

### **3. RESEARCH REVIEW AND METHODOLOGY**

A single case study approach has been taken for this paper, using the Grenfell Tower fire as its focus. The event was a shock to a developed country in the 21st century and should never happen again. Looking at the tower exclusively, the complex variables will be examined to ascertain what led to the building's failure.

Case study research is often seen as inferior because the research results yielded are hard to draw comparison to, and hard to measure (Yin, 2018). However, this form of research is ideal when the topic is focusing on contemporary and unique events, (Stella Cottrell, 2014), where "The goal is to understand 'the case' – what it is, how it works, and how it interacts with its real-world contextual environment." (Yin, 2018, p.134).

Case studies also receive criticism for research results being construed as sweeping generalisations; this research paper is in no way assuming that all high-rise social housing is comparable to the Grenfell Tower, but it is understood from the literature review that government statistics currently show a large amount of social housing is listed as inadequate, which is the group that Grenfell Tower would have sat in. So even though it is acknowledged that Grenfell is a unique case, certain variables may indeed be replicated in other social high-rise buildings all over the country.

### **4. RESEARCH METHOD**

Stella Cottrell (2014 p.34) states, "case studies can indicate a direction for how existing theory or workplace practice could be adapted to meet the needs of special cases". Using Cottrell's theory, the paper will investigate extant secondary data such as document and archival records, including newspaper articles, internet articles, other case studies, company or business records, survey data and government publications. From this, we can understand how the refurbishment of the tower was handled, and then reflect on how practice can be adapted for high-rise building

refurbishment. Ultimately, a recommendation will be formed on whether implementing BIM retrospectively to social high-rise building will, in fact, aid the process.

Grenfell is still a raw topic, with legal proceedings still surrounding the case, so it is important that a sensitive approach is taken. Research will therefore only utilise sources freely available to the public. The research will not involve approaching anyone for information, i.e. victims of the fire, or professionals who may not be able to divulge information due to legal or professional constraints.

## **5. RESEARCH RESULTS – CASE STUDY: GRENFELL TOWER**

Grenfell Tower was part of the West Lancaster Estate, an area that was severely bombed in WWII. During 1960s and 1970s, Kensington and Chelsea London Borough Council demolished the remains and rebuilt the area as part of the slum clearance initiative. The tower was built in 1974 by A.E. Symes of Leyton, London, designed by Nigel Whitbred, (RBKCC, n.d.). The concrete structure stood at 67 meters high, with 24 storeys, which is classified as a high-rise building in the UK, (<https://www.designingbuildings.co.uk>, 2018).

Although council owned, 14 of the flats in the tower had been bought under the Right to Buy Scheme, meaning the tower was mixed-tenure of both social housing flats and leaseholder flats, (Apps et al., n.d.). The building was managed by Kensington and Chelsea Tenant Management Organisation, (KCTMO). Residents of the tower that formed Grenfell Action Group, had repeatedly and vocally complained about their disappointment with the KCTMO's lack of concern for complaints made about the building, such as electrical power surges in 2013 which gave address to fire warning, (<https://grenfellactiongroup.wordpress.com>, 2016). The tower originally had two access/ egress points, but one was blocked up to prevent criminal activity. Removal of this second access reportedly made this route cramped. There was no sprinkler system fitted in the building, no external fire escapes and fire doors were insufficient. (Steel, 2018).

The tower's fire policy was to 'stay put' in the building – this was because each flat was its designed to be its own contained concrete shell, so that if a fire broke out in a flat, the compartmentalisation meant it would contain the fire, giving sufficient time for the fire brigade to arrive and extinguish it, (NFCC, n.d.) This was seen as sound advice, as the single communal staircase which lead to the cramped entrance/exit to the tower would mean fire fighters would have difficulty ascending the staircase if people were fleeing the building in concentrated numbers.

In 2012, plans to refurbish the building were addressed. Architects practice, E-Studio produced a Design and Access Statement that included the proposed works; new cladding and windows to be installed, a new foyer layout, and a new communal heating and fire alarm system. Additional to this, 9 new flats were constructed on poorly utilised maintenance floors. The KCTMO awarded the contract to Rydon Construction, who had quoted significantly under the Local Authority's build budget. A post-tender document shows Rydon were able to price competitively due to changing the material specification of the cladding, using "aluminium

cladding in lieu of zinc cladding" to make a saving of £293,368. (Symonds & De Simone, 2017), This cheaper aluminium composite material (ACM), was significantly more combustible than the zinc panelling originally specified. The Rydon CEO claims this was signed off by all parties involved, (Steel, 2018).

Changing a material in the specification, a 'material alteration' indicates the need for a material safety test as noted in Approved Document B. Rydon were the ones to deviate from the original material specification, so they had responsibility to safety test the new combination of materials. Speculation from the BBC's 2017 'Panorama' documentary raised doubts that this critical testing was not done. It is important to note that this lapse of judgement was further worsened by the manufacturer of the insulation used on Grenfell, Celotex. It was revealed that their product specifications for the insulation were misleading, claiming that the product was suitable for refurbishments, including buildings over 18m in height and would be suitable with a range of cladding panels. The Celotex insulation did, in fact, pass a safety test, but it has since come to light that a different formula was used after they had been granted the safety certificate. It has been questioned whether this new formula held the same fire-resistant properties, (BBC, 2018b).

After the refurbishment was completed in 2016, the KCTMO informed residents of the improved fire alarm system and fire escape plan. However, the information provided was self-contradictory, at one point stating that the existing 'stay put' policy was still in force, yet also advising that if the fire was not in their flat, but the individual deemed the fire might be close to them, that they should leave the building, (Apps et al., n.d.).

In the early hours of 14th June 2017, a fire broke out on the 4th floor due to a faulty electrical appliance. The fire melted through the uPVC windows and spread externally to the flammable cladding that encased the building. The refurbishments works stated that smoke alarms were fitted throughout, however, the survivors of the fire say they were not woken by the sound of a fire alarm, (Steel, 2018). Callers to the Emergency Services were told to 'stay put'. It was not until 2:47am that the 'stay put' advice was abandoned, and callers were told to make their best attempts to evacuate. By this time, all sides of the buildings were alight, including most of the upper floors. Large buildings are required to keep documents that detail the building layout and show locations of gas pipes, air vents, electrics, and dry-risers in the case of high-rise buildings, (Mitchelson, 2018). Station manager, Peter Johnson, was quoted in a BBC News article (BBC, 2018c) revealing that when the fire brigade arrived at Grenfell tower, the fireproof box in the tower's lobby did not have the necessary fire plan documents. This severely hampered the rescue mission. He explained that the fire fighters only had a photo of the building as guidance.

Many parties involved that held responsibility in the refurbishment of Grenfell. Like a lot of larger projects, parts of the construction process were subcontracted out, this in itself leads to uncertainties, Alwan, (2015) quoted Park & Kim's suggestion that this is why, "BIM integration in the housing sector is difficult, due to a fragmented construction sector and complicated stakeholder requirements." Ben Bradford, a fire safety expert, backs this idea up with his comment on Grenfell, "There's probably multiple failings that have occurred in this particular case," he said. "The work, in terms of fire stopping, often falls to a sub-contractor. They don't

always realise the critical nature of the components they're installing in the overall system.” (Davies, 2017).

72 people were reported to have perished in the incident, (BBC, 2018a). More than a year later, the Public enquiry ran by Sir Martin Moore-Bick is still ongoing. As yet, nobody has been held accountable.

## **6. DISCUSSION**

It is a sobering fact that all the building fires discussed in section (2.3) show stark similarity to the Grenfell Tower case study (5.0). It is clear there was systematic neglect throughout Grenfell's lifespan. With such failings, would implementing BIM retrospectively have prevented this disaster?

Although BIM is being used on new government centrally funded projects; this remit does not stretch to social housing, which is the devolved responsibility of Local Authorities. This is almost certainly why there is very little evidence of BIM being applied to social housing, and even fewer still for refurbishment works. This lack of data has limited the research findings of this report, meaning the conclusions are theoretical ideas, and have not been tested in practice.

Adding BIM as a new process to the social housing sector will be expensive, and will require adapting new ways of working, as well as bridging the skills gap. This BIM skills gap also applies to small subcontractors. If BIM were adopted in the social housing sector, would this mean smaller sub-contractors would be frozen out from the supply chain?

There is a recurring theme of 'stay put' advice throughout section 2.3 and 5.0, and its multiple recommendations for review suggests that passive fire prevention measures often are not checked after refurbishments. It is crucial to recheck this if it could mean a flats compartmentalisation has been compromised. In the case of Grenfell specifically, the contradictory 'stay put' advice suggests that there was no clear fire evacuation plan in place after the refurbishment. BIM is not a strong contender to combat this problem; it would be for the designer to assess whether the refurbishments completed affect the compartmentalisation.

Claims that the fire alarm did not sound suggest that the system was faulty. Asset management data within a BIM would flag the facilities manager when equipment needs periodic testing. If the system were to fail, information on the manufacturer, model and replacement costs would be available to view all in one place. This assistance is helpful on condition that the product or system needed for replacement is still available later in the building lifespan.

Failure to test materials robustly was certainly a main failing at Grenfell, E-Studio Architects had specified the materials, and as professionals, it was their duty to ensure the design is safe. Their original specification of the cladding had a significantly lower combustibility rating. The contract was awarded to Rydon, who subsequently changed the cladding specification for the cheaper, more combustible ACM cladding. It was this cost cutting exercise that meant their budget to complete the work significantly undercut the competition. Furthermore, it is likely this is why the council awarded them the contract.

Currently, BIM has the capability to identify clash detection of building elements in a project; very much a visual process. This however does not extend as far as identifying materials in systems that may not be suitable together. A material or system change could be represented in the model and highlighted for inspection for the Designer to review, however, the safety tests performed on materials and system to clarify this go beyond BIMs sphere of activity.

## **7. CONCLUSION**

In summary, the findings show that BIM cannot resolve all the failures demonstrated in the case study, but it is reasonable to conclude from the discussion that it would have enabled transparency to responsibility and flaws in design.

The Local Authority or Housing Associations would have a much better understanding of faults in their existing stock if they retrospectively implemented BIM. This would allow for mass planning of repair works and material ordering, or subcontracting services required. The BIM would include as-built information, alterations and maintenance requirements which would be made accessible and transparent to all the necessary disciplines involved. Sharing this data is vital, but it is also important to consider security of this data, which is now included in the PAS 1192 scope. Arguably, this adds further responsibility and levels of complexity. A legal requirement to keep this information up to date would ensure that the model holds accurate, data rich geometry. The visual representation would also be helpful to gain resident engagement where an interactive model of the proposed refurbishment could be demonstrated for end user to give feedback.

As social housing is not funded from the government's central pot, it has slipped the net of being required to meet the 2016 BIM Level 2 mandate. Phasing this in to make it a legal requirement for social high-rise residences to have a BIM would force local authorities and social housing associations to start actioning this now. Although BIM adoption is on the increase, there remains a skills gap to fully achieving BIM Level 2 requirements. Funding for training will be necessary at all levels of the team to be able to embrace BIM effectively into the current refurbishment framework, this would be a challenge to implement a new process into a not-for-profit organisation. Another draw on money would be the need for intrusive surveys of existing buildings to ensure that the BIM is replicated precisely to the physical building. Missing or incorrect data is where BIM can fall down – older buildings may have materials that are not manufactured anymore, or bespoke systems that cannot be traced.

The Hackitt report's recommendation of a fire and emergency file to become a legal requirement is a step in the right direction. However, this could be developed further by creating an interactive BIM of the building available for emergency crews to view on portable devices. This could incorporate a plethora of information that could be view in conjunction with all the relevant variables the fire brigade would need to know, such as staircases, lifts, location of dry-risers, vacant flats, vulnerable tenants or those registered with accessibility issues, roof opening points and many more could all be addressed in a model. A digital model would mean the information is accessible before firefighters get to the building, and aid planning of the fire

fighting. It would also be easier to keep up to date rather than physical copies that are stored in the building itself.

A BIM work-flow will only be successful for high-rise social housing if it is implemented with all bodies involved completing their required roles and in turn keeping the BIM up to date with accurate information. If Hackitt's advice of introducing a JCA body to ensure 'gateway points' are signed off at project milestones, this can be reflected in the BIM by adding project parameters that specify clearance to move on to the next project stage. For this to be effective, monitoring is needed by dutyholders 'on the ground' throughout the design, build and aftercare of the building.

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*Amendments and clarifications:* At the time of completing this paper, the Government announced that they have taken the decision to ban combustible materials on high-rise buildings and offer support to local authorities to carry out emergency remediation work. Information accessible at:

<https://www.gov.uk/government/news/government-bans-combustible-materials-on-high-rise-homes>

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# Has BIM Changed the Role of the Architectural Technologist?

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**Keywords:** Architectural Technologist, BIM, Architectural Roles

## ABSTRACT

*BIM (Building Information Modelling) is a process for creating and managing information that is being adopted increasingly by practices in the construction industry (Morton & Thompson, 2011). This recently introduced a method of working that has altered the way that the design team works and communicates with one another (Czmoch & Pekala, 2015). This paper will discuss if the role of the Architectural Technologist has changed since the adoption of BIM compared to the traditional approaches. The literature review suggests that the AT's role changes during concept and detailed design stages. The emergence of BIM has provoked a breakthrough in technology and increased the capabilities of software which is suggested to have had an impact on the Architectural Technologists and the design team (Latiffi & Fathi 2016). Eastman et al. (2011) highlights BIM software's capability to automatically generate construction details, support imported pre-determined objects from BIM libraries and this paper will carry out research to find out if these have impacted the way that AT's detail and if there is a reliance on software.*

## INTRODUCTION

Building Information Modelling (BIM) is defined as below by the NBS (National Building Specification):

*'BIM or Building Information Modelling is a process for creating and managing information on a construction project across the project lifecycle. One of the key outputs of this process is the Building Information Model, the digital description of every aspect of the built asset. This model draws on information assembled collaboratively and updated at key stages of a project.'* (NBS, 2016).

BIM was first included in the UK Governments construction strategy in 2011 with an aim to make it mandatory on all public sector procured construction projects in the UK (HM Government, 2012). The traditional approach used in the industry before BIM had several issues which lead to inefficiencies in timescales, quality and efficiency (Granero, 2017). Since the adoption of BIM in the UK, the construction industry and the roles within it, have adapted to suit (Latiffi & Fathi, 2016) Eastman et al. (2011) provide a further insight more specific to the Architectural Technologist (AT) when discussing the roles differences in Traditional and BIM approaches. Eastman et al. Concept, collaboration, effort and time, simulation and Architectural Detailing are

identified as significant areas where differences occur. This paper will carry out a literature review to explore if the AT's role changes in projects using the traditional and BIM approaches.

A literature review was deemed suitable to first, identify what literature currently exists to find out if there are any areas that are lacking research (Royal Literary Fund, 2018). After analysing existing research, it was found that most literature was more specific to the Architect as oppose to the AT, meaning that research on AT specific duties such as Architectural Detailing was lacking. A questionnaire aimed at Architectural Technology students, interns and professionals will also be used to gather qualitative and quantitative research to uncover if BIM has changed the roles and responsibilities of the AT and has it changed the way that construction details are completed.

The importance of this topic was established when it was discovered that there is a difference in opinion between literature and some recent blogs. Armstrong & Allwinkle (2017) and Morton & Thompson (2011) argue that Architectural Technology is ideally placed to take a central and integral role in the adoption of BIM. This is implying that the future of the AT is safe under the adoption of BIM. On the other hand, in a recent online blog, Hubbard (D.U) began by saying that automation is something that could replace and threaten job roles currently being carried out by humans. Hubbard (D.U) continued by saying that "BIM" due to its automated nature, could potentially automate certain tasks currently carried out by professionals in the design team in the future. Due to the growing adoption of BIM in the UK and the lack of research that currently exists on the AT's transition under traditional and BIM approaches, it is an important topic to explore.

### **Concept Design**

During the concept design of traditional projects, less effort and time for planning and drawing is allocated to the project (Eastman et al. 2011). This means that generally the AT can complete this stage quickly. Most of the effort is spent drawing using conventional 2D software (Czmoch & Pekala, 2014). The minimal planning and effort used in the traditional concept design means that any changes requested by the client will not cost the client a lot of money because the changes will be made by the AT and will not affect any other members of the design team. However, due to the lack of planning and effort spent in the concept stage, any changes requested in the detailed design stage will cost significantly more. Using the BIM approach, the AT will spend more effort and time planning and consulting with other members of the design team during the concept stage. The drawing time, unlike in the traditional approach, is significantly reduced as BIM software such as Revit, updates the elevations, sections and site plans once the plans have been altered (Eastman et al., 2011). The extra planning and consulting used in the BIM approach, results in changes during the concept stage being expensive as more individuals are involved, however, if changes are made during the construction Documents (CD) stage, costs are significantly less because the drawing work has already been completed.

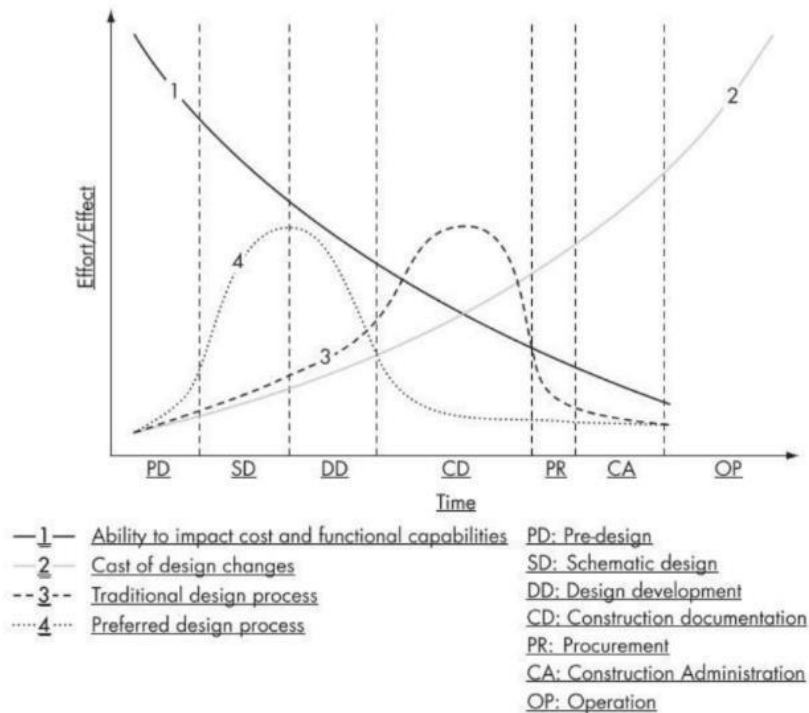


Figure 1: adapted from Eastman et al. (2011) which compares the stages in which time/effort is allocated and the resulting effects on 'cost of design changes' and 'ability to impact cost and functional capabilities'

### Detailed Design

During the detailed design stage of a project using the traditional approach, the format in which the drawings were completed would see the AT and the rest of the design team produce separate drawings. When the drawings are compiled, amendments are required to correct any unforeseen discrepancies which requires a lot of time and effort (Bataw et al. 2016). BIM on the other hand, uses a centralised model that is shared between the AT and other key members of the design team to share construction details and information simultaneously (Sagarka, 2016). Eastman et al. (2011) supports this by stating that BIM encourages Architectural Technologists to provide more details to the model. This means that the AT can take on more responsibility in comparison to indicative drawings used in traditional approaches to reduce liability.

Construction details can now be produced faster than ever as BIM allows standardised details to be automatically generated and imported from BIM libraries which eliminates the need to produce them yourself (Eastman et al. 2011). BIM involves a revolutionary shift away from abstracted drafting and moves towards drawing in accordance with the realities of building 'modelling is akin to actually building the building' Armstrong and Allwinkle (2017) cited Eastman et al. (2011). Comiskey et al. (2014) cited Simoni (2013) who states a potential disadvantage when saying that the use of BIM could 'hamper the creativity in the design process' if the user was not familiar enough with the software.

## Collaboration

According to Deutsch (2011) BIM has changed the way that information is shared.

Talking about the problems with the traditional approach, Sagarka (2016) states, 'before information can be shared, each member of the design team must wait for each other's design to be completed and therefore information is piled up in silos'. This is one of the disadvantages to the traditional approach as information reaches members of the design team at a slower rate which leads to delays in projects. Eastman et al. (2011), highlights another issue with the way in which information is shared in the traditional approach when saying that the relationship between the Architectural

Technologist and the engineer disjointed as the Architect produces drawings for 'design intent' purposes only. This is also inefficient because the engineer must wait for the Architectural Technologists drawings before the structural drawings can be completed. BIM uses a system in which each member of the design team inputs information simultaneously into one model rather than several drawings. This increases communication which leads to significant time saving and efficiency. When working with the BIM approach, information is shared by each member of the design team as it happens which means that the information is always up to date (Sagarka, 2016).

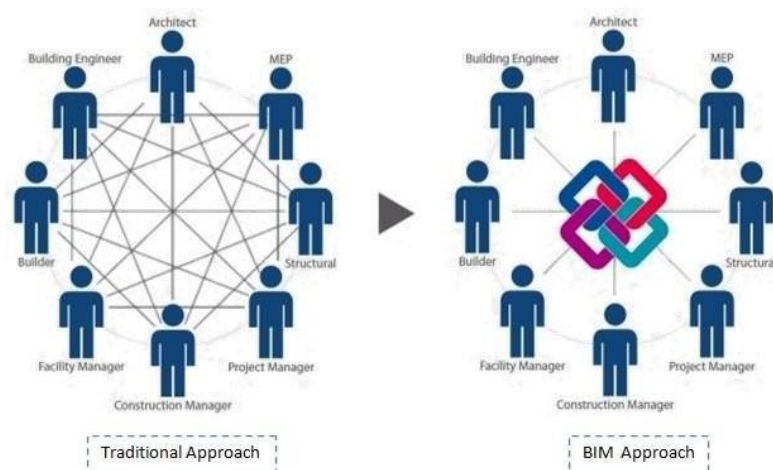


Figure 2: adapted from Sagarka (2016) to indicate how members of the construction team communicate with each other in both traditional (Left) and BIM approaches (Right).

## RESEARCH REVIEW & METHODOLOGY

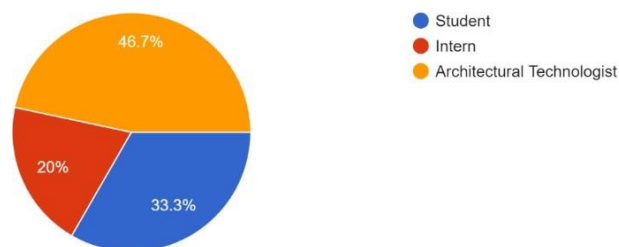
To gather research for this study a questionnaire was carried out. The questionnaire aimed to gather information specifically on how Architectural Technologists carry out the detailing elements within their role as well as any changes regarding roles and responsibilities that the participants may have experienced during their time as an intern, student or professional.

A Semi-structured questionnaire was adopted for this study to gain the benefits from both quantitative and qualitative question. Firstly, the speed in which questionnaires allow data to be gathered. Due to the narrow timeline in which the study was to be completed, research had to be gathered fast in order to meet the deadline of the study. Secondly, the questionnaire allowed participants to share their experiences both free and anonymously. Using structured and non-structured questions, the questionnaire enabled answers that could be measured to gather demographical information and answers that was not measurable to learn the participants feelings and opinions. By structuring the questions in this way, patterns and trends could be found between the answers provided and the participants demographic. As well as this, unstructured questions provided a foundation for the participant to open up and share their true feelings which could potentially open up new topics to research in the future. The questionnaire was anonymous to make participants feel more comfortable which encourages honesty and openness. This was another beneficial approach as it ensured that the answers given was not false or inaccurate of the participants true feelings (Sheffield University, 2014). However, limitations were discovered using questionnaires to gather research. Limitations linked to number of participants and the ease of use for participants to answer and return the questionnaire.

## RESEARCH RESULT AND DISCUSSION

### Question 1 – Which of the options best describe you?

This question was used for the questionnaire to attain qualitative data on the where the participant was in terms of their career. This provided a brief background on the participant to gauge the level of experience that they have. It is anticipated that an experienced Architectural Technologist would have different attitudes on the topic in comparison to a student fresh out of university. As a fellow student, it was expected that most of the participants would be students and interns. The aim was to find a balanced number of participants from each occupation to fill out the questionnaire to avoid being biased by receiving answers only from students for example.

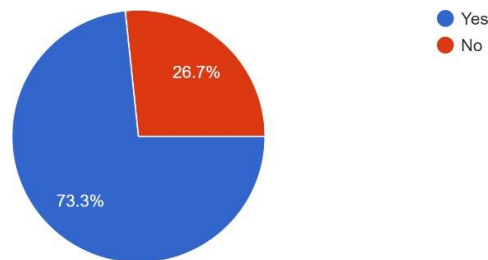


The results of this section of the questionnaire defied expectations as one of the anticipated challenges was finding an equal amount of professional Architectural Technologist to students/interns to participate in the questionnaire. The results showed that most of the participants was professional Architectural Technologists. This result benefits the research of the study because professional AT's are more likely to have more experience than the students

and AT's which means that they can provide more information regarding the AT's role when transitioning from the traditional to BIM approach.

### Question 2 – Are you currently working as an Architectural Technologist?

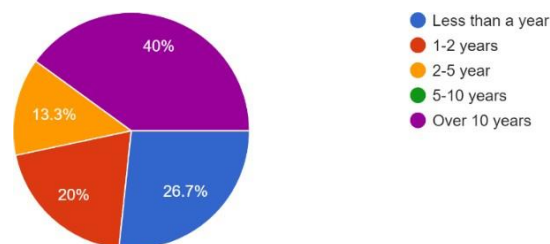
The aim of this question was to home in on the previous question to provide more information on the individual filling out the questionnaire. Perhaps the participant is by title is an Architectural Technologist but has not worked in the industry for years and therefore does not have a great deal of experience with modern day software of practices.



The results of this question were a success. Almost  $\frac{3}{4}$  of the overall participants that took part in the questionnaire are currently working in the industry as an Architectural Technologist. This is beneficial for the study because it means that most of the answers provided in this questionnaire came from sources that have real life experience in the industry as an AT. Meaning that the responses in this survey will address actual opinions, problems and benefits that AT's experience with BIM and the traditional approach.

### Question 3 – How many years' experience do you have?

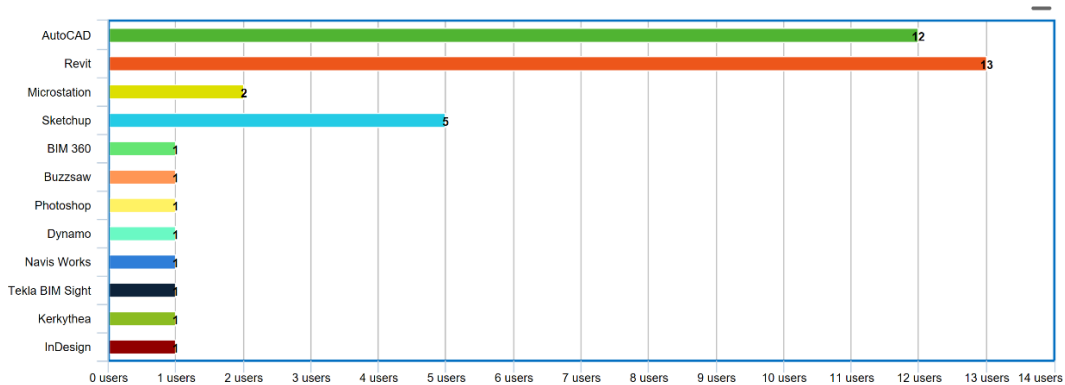
This question was selected to find out the length of time that participants had spent in the industry. This was an interesting question to ask participants as it enabled the opportunity to attempt to find out if participants with different levels of experience had different attitudes towards the BIM/traditional approach.



The results of this question were unexpected as the pie chart above shows that 40% of the participants had over 10 years' experience. This was a surprise because as a student in a university setting, it was easier to gain the feedback of students as oppose to professionals in the industry.

#### Question 4 – Do you use architectural software and if so which?

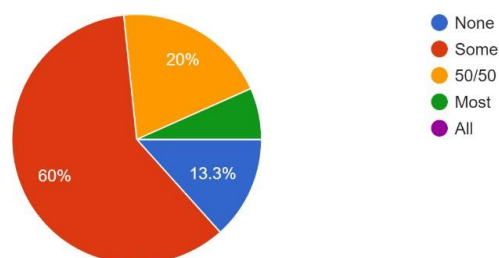
Question 4 was used to find out which software was the most commonly used by Architectural Technologists. The traditional approach is more known for the use of 2D software such as AutoCAD so it was interesting to find out if this software was still widely used since the introduction of new BIM software. It was expected that AutoCAD and Revit would be the most used software because it is well known that they are the industry leaders.



The results came out just as expected, AutoCAD and Revit were by far the most commonly used software with each almost level with one another. The surprising outcome of this question was the range of software used by Architectural Technologists.

#### Question 5 – How much of your overall detailing work is completed using imported objects from a BIM library?

This aim of this question was to find out how Architectural Technologists complete the detailed elements of their work. The introduction of BIM has brought automated elements that are at the disposal of the AT. Elements such as BIM library and the ability to automatically create details on software have created new ways in which AT's can detail. This question tries to find out.



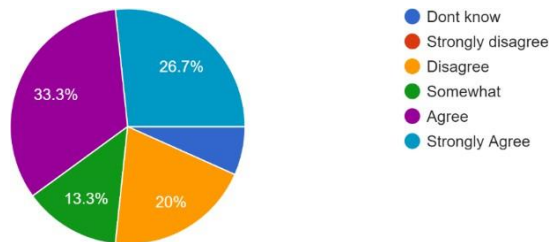
With the growing popularity of BIM and its importance towards collaboration, it was anticipated that imported manufacturers components would be widely used when detailing. The reason being that the communication of information is key in BIM and imports often include data on that component which is universally understood amongst other members of the design team. Also, the speed and ease of use that imported objects as described by Eastman et al. (2011). The findings indicate that



AT's have adopted the use of pre-determined objects from BIM libraries. However, the findings indicate that BIM objects are not the only way that AT's detail.

**Question 6 - Without the aid of BIM software, could you carry out detailing as effectively?**

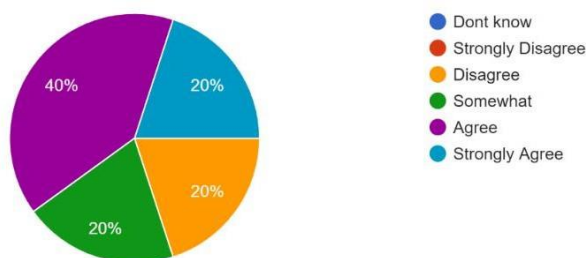
This question tried to determine the importance of BIM software when Architectural Technologists complete construction details. With BIM software and features such as the BIM library being relatively new to the industry, it was expected that the majority would disagree with this question and would be able to be just as effective without the aid of these features.



The results were relatively as anticipated with most participants responding with the belief that they would be confident without the aid of BIM software. These results partially support Simoni (2013) cited by Comiskey (2014), who said that BIM could potentially hamper an individual's design creativeness, as approximately 40% of respondents answered that they require software to detail effectively. This is a different view than Eastman et al. (2011) who stated that BIM increases the input of the AT in a project which increases their responsibilities.

**Question 7 – Do you believe that AT'S are becoming reliant on software to detail?**

Question 7 aims to build on question 6. Q6 aimed to get responses based on their own abilities but Q7 captures information based on their experiences working with another AT. E.g. Perhaps they have noticed a trend at work where AT's are becoming more and more reliant on software to generate details.



The responses on this one was very unexpected. It appears that generally, students, interns and professionals share the same view on this as the results show that on average participants agree or strongly agree that AT's are becoming more reliant on software. These results yet again link to Simoni (2013), cited by Comiskey (2014), who believes that BIM could hamper design skills. These results support the belief as over half of the respondents believe that AT's are becoming second to software.

### Question 7a – If you wish to give your reasons, please do so below

The next section was an add on to question 7 with aim to give the participants the opportunity to provide their reasons on why they chose their answer in the question previous. The results would provide qualitative data and the opinions of the respondents could potentially create a topic for a new study in the future.

- People nowadays find it quicker and easier to import models rather than start from scratch with a detail. Therefore, not necessarily understanding the ins and outs of a detail.
- Makes it easier
- It is much more time efficient & easier to change/manipulate details on computer software than by hand.
- Can produce drawings with no real involvement
- There is a growing problem with the level of technical ability within the industry.
- I consider that there is an over reliance on design software/ components for detailing - and there is often little understanding of the wider relationships between one element and the interaction with those adjacent to it.
- perceptions of BIM and BIM tools are directing ATs to use BIM software to detail.
- Many technologists design their details and avoid standard details packages

The results from this question showed that most respondents have similar views on the subject in believing that there is a 'lack of understanding', growing problem with the technical ability in the industry'. Some also indicate in their answer that yes there is a reliance, but it is one that offers benefits for time management and ease of use as reported by Eastman et al (2011).

### Question 8 – Have you ever experienced technical issues within a project in which auto generated/imported details were responsible?

Question 8 aims to establish whether the use of detail components or details auto generated by software causes implications when the project begins on-site. This is an important question as it gauges how successful these components are in terms of the using them on site.

- No
- Yes - parametric modelling software can sometimes cause glitches and result in elements of a model changing.
- Sometimes
- Not at the moment
- The information is lacking
- The inappropriate use of a manufacturer's details and the rolling of information between projects.
- I don't believe that the industry is at the point where details are fully automated. However, I have experience issues with 'standard' component details supplied by manufacturers not relating to the exact model being specific and causing coordination issues on site.
- no
- yes in a previous practice but that was down to user error - as is always the case.

The results found that the use of details from components or automated software have a very good success rate when the project starts on site. Some respondents said that the errors that do

occur are generally down to user error which indicate a potential lack of training or understanding of the software. Other answers include the components not always been specific to the model or lack of information. The answers given partially support the theory by Eastman et al. (2011) which said that the BIM approach invests more planning in the early stages of a project which reduce the effect of a problem occurring later in the project. The relationship between the feedback from the questionnaire and the theory between Eastman et al. (2011) reduce the reliability of this literature because a lot of respondents have reported issues arising on site which have been related to lack of information or problems with the manufacturer's details.

**Question 9 – Since the introduction of BIM, are there any responsibilities/skills that the AT has gained or lost compared to before the adoption of BIM?**

Question 9 aims to find out if there has been any noticeable change in the role of the AT since the arrival of BIM. It is expected that there has been a lot of change to the role in terms of managing software but perhaps the number of responsibilities has decreased as BIM allows each member of the design team to contribute simultaneously which would be expected to ease the pressure on the AT.

Perhaps an actual understanding of the construction detail itself. BIM provides everything completed for you.
I feel like if anything, you would loose your skills and responsibilities
Ability to hand draw
Gained communication between companies
Role revolves more around software expertise than technical
Unsure as I have only ever been working as a Technologist since BIM has been implemented.
Don't know
Not sure
I don't know because I am starting my career in the BIM era so cant comment
Very little technical input, they just connect pre detailed data together and blame the manufacturer if wrong
The ethos of BIM has been around much longer than it was labelled BIM. The current set of standards and associated culture have changed the way we work but it has not necessarily lost anything.

The results of this question received from students was unsuccessful as most of them have never worked in practice or have never worked in practice pre-BIM which gave them a disadvantage when answering this question. The answers received from professionals were indicated that if anything the AT has lost responsibilities due to BIM doing everything for the AT, losing the ability to hand sketch and the role requiring more of an understanding of the software rather than the technical side. The lack of responsibilities gained by the AT was unexpected as some literature in the review suggested that BIM would provide opportunities for the AT and create a more integral role in the design team.

## Question 10 – Where do you see the future of the AT in terms of responsibility and importance?

Question 10 was another open question that allowed respondents to express their own opinions and feelings. The responses appear to support literature from Armstrong & Alwinkle (2017) and Morton & Thompson (2011) who suggest that BIM will create more opportunities and significance for the role of the AT. The results also contrast with an online blog by Hubbard (D.U) who wrote that automation may be a threat to some of the roles that currently exist in the construction industry.

I think it's Architects who will lose responsibility due to the fact that construction is becoming ever technology based - however it is making the need for AT's less, and if a highly trained level.
I feel they will be on par with the traditional architect.
I think in the future the need of AT's will become more important but also easier to do due to the use of software.
Increasing
Taking more of a turn towards technician than technologist, with software knowledge being more important than architectural or technical understanding
There are speculations that the role of the Technologist will become obsolete however I do not agree. I feel the line between architects and technologists are being blurred somewhat and their roles/responsibilities are becoming more similar.
Might have more responsibility and be as importance as architect
They are extremely important in the architectural world, and responsible for a lot of the info on projects
I see the AT as a key person to go to when delivering an architectural project from start to completion
Believe in your knowledge and technologist will always have importance.

The answers of this could not be predicted as it was an open question and up to the participants opinions. However, many of the respondents appear to support of a lot of literature by believing that BIM will be beneficial for the AT's future. Armstrong & Allwinkle (2017) agree with the answers of this question as they believe that 'the prominence of BIM aligns closely with the specialisms of

Architectural Technology which will allow the role to grow and take a key role in the industry'. However, these differ from the view of Morton & Thompson (2011) who state that the role of the AT will 'evolve' into a multidisciplinary role which will be more team orientated and collaborative.

## CONCLUSION

The aim was to carry out a literature review of the research that currently exists around the topic. A wide range of research was available which allowed a range of views to be evaluated and compared within the study. The barriers to the research was that there was a lack of information that was specific to the Architectural Technologist. According to the literature, the role of the AT has changed under BIM for advantageous reasons. Armstrong & Allwinkle (2017) believe that the nature in which technical information is shared simultaneously makes the AT an integral member under BIM. Eastman et al (2011), describes BIM as encouraging the AT to provide more input and in turn take more responsibility within projects. Upon comparing the

results from the questionnaire to the literature found, the answers suggest that there is an agreement that the role of the AT is changing. However, there are differing views on how the role will change. Whilst most responses agree with Armstrong & Allwinkle (2017), that the AT has a growing influence under BIM, some believe that the AT will take more of a multi-disciplinary role while others believe that there is an increasing reliance on software to carry out technical tasks. To conclude, the findings suggest that the AT has changed since the adoption of BIM, one key change appears to be the importance to collaborate with others while the main change is seen in the way that detailing is executed and way in which software is used to aid with it. With suggestions from feedback in the questionnaire pointing towards a reliance on BIM software to carry out the specialism that is construction detailing.

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# Are Bananas the New Building Material?

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**Keywords:** Waste, Material, Bananas, Sustainable

## ABSTRACT

*Every year humans produce 1.3bn tonnes of food which is wasted, and this is around one third of food produced around the World. If any of this waste could be turned into a resources such as construction materials then this would reduce the CO2 produced from the waste that would have otherwise ended up in landfills or incinerated (Food and Agriculture Organization of the United Nations, 2018). Due to population growth, the amount of waste produced worldwide will steadily increase unless there are actions taken to reduce it. The greenhouse effect is a natural process that warms the Earth's surface, however as the concentration of greenhouse gases continues to increase the Earth's temperature is rising. This could result in major long- term consequences such as abnormal weather putting millions of lives at risk. The idea of reusing organic waste tends to be associated with it ending up as compost helping other foods to thrive by providing them with nutrients through decomposition, however, the use of some organic waste products can create low-cost building materials making them sustainable and more eco-friendly than traditional construction materials. Bananas today are one the most popular fruits in the World with approximately 100 billion bananas eaten around the World every day (BananaLink, 2018). The use of bananas biomass waste within construction materials may be the solution to the use of waste bananas, rather than them becoming compost or worst put into landfills. Using construction materials made from organic waste would exploit an untapped resource which would have a positive impact on the technical and environmental side of the construction industry turning organic waste into a source of value.*

*The aim of this research paper is to review the benefits of using banana biomass waste as a construction material compared to traditional construction materials. This research paper will go through various examples of construction materials that contain bananas and the benefits in comparison to traditional building materials.*

## INTRODUCTION

The amount of organic waste produced by humans is an ongoing global problem and due to the increasing population, this is bound to rise as the years go by. The production of waste is a natural phenomenon and the mass of waste produced can be affected by the cultural and social changes within people's lives. These changes produce a large mass of unwanted waste which has huge potential to be recycled to our own benefit rather than being incinerated or put within

landfills. The disposal of organic waste at landfills is a huge problem as we lose potential valuable resources furthermore, the decomposition of waste methane is created which is a greenhouse gas and 25 times more potent than carbon dioxide (United States Environmental Protection Agency, 2018). The contribution of methane towards the atmosphere adds towards the “greenhouse effect” which is described as the warming that happens when gases like CO<sub>2</sub>, water vapour, methane nitrous oxide and other gases in Earth's atmosphere trap heat (Lallanilla, 2018). These gases let in light but keep heat from escaping, like the glass walls of a greenhouse (National Geographic, 2018). The greenhouse effect is causing our climate to change causing glaciers to melt, causing sea levels to rise, and for the weather to have sudden changes meaning more intense storms, longer droughts and more rain in different areas of the World and these changes will affect our crops and the wildlife negatively. The extreme weather will affect humans causing the destruction of many homes and even the death of thousands. All over the World the generation rate of waste is rising and is expected to rise from 1.3 billion tonnes of waste to 2.2 billion tonnes of waste by 2025 (Global Waste Management Conference, 2018). There are already ways or recycling our waste through the production of compost putting the nutrients of organic waste to good use. Agricultural waste is waste which is produced as a result of agricultural operations. This research paper will focus on agriculture waste which is a growing problem in less developed countries where the waste is burnt resulting in environmental problems.

The use of natural materials in today is important not only for the environment but our health which is supported by a report by Arup in 2017 which demonstrates that the “use of natural materials would trigger a different approach in construction by allowing a number of benefits in respect to traditional material options having a lower CO<sub>2</sub> content, reducing health risk. Food waste used within building materials would contribute towards the economy giving food waste more of a purpose. Humphrey Danso (2018) believes studies on sustainable construction materials are on the rise with their environmental, social, and economic benefits. Studies into new sustainable resources will help with our future buildings incorporating element which at first you would not think would benefit one another. The materials consulting lead at ARUP summarised the need for more sustainable materials as, “As one of the World's largest users of resources we need to move away from our ‘take, use, dispose of’ mentality. There are already pockets of activity, with some producers making lower-CO<sub>2</sub> building products from organic materials. What we need now is for the industry to come together to scale up this activity so that it enters the mainstream. An important first step is to work with the government to rethink construction codes and regulations to consider waste as a resource, opening up the opportunity to repurpose it on an industrial scale” (Fitzgerald, 2017). The demand for low-cost sustainable materials is growing to the changes in today’s social and economic environment. The use of low-cost materials would reduce the affordability of housing, which would in turn help with the fact that we have over one billion people in the World that are either homeless or living in poor housing (Uddin, 2015). The use of natural building materials has many benefits for example being simple to produce, quick and easy to use meaning that there is less of a need for highly skilled labourers and finally environmental benefits.

Bananas are grown in over 150 countries, the average person eats 12kg of bananas per year and 105 million tonnes being produced in 2013 this makes them the most traded fruit and the fifth



most trade agricultural products making bananas one of if not the most popular fruit worldwide (BananaLink, 2018). With a growing population the number of bananas consumed is also likely to increase resulting in more banana plants planted in order to meet demand. The wastage produced from these plants could be valuable use, banana fibres are harvested from banana biomass (pseudo, stem, leaves, etc.) that have already been harvested which otherwise would



become waste if not utilised as it is not utilised in an industrial form. Banana fibre (see image 1) is a natural fibre which has a wide range of adaptations. Banana fibres technical properties are that it is high strength, durable, lightweight, low cost and has good acoustic absorption making it a good underused material with great potential (see table 1). Banana fibre can be developed to make products such as mats, rope, clothes, and twines. Banana fibre has many properties such as being weatherproof, UV protection, absorbs moisture, antioxidant and biodegradable (C. Vigneswaran, 2015). Banana fibre can be used to make reinforced concrete to provide toughness and ductility to the concrete. Banana fibre can also be used within thermal insulation as banana fibre not only has mechanical properties but also has thermal properties, making it potentially a good insulator. Banana fibres are generally a lignocelluloses material and the cellulose content serves as a deciding factor for the mechanical properties alongside the micro fibril-angle (Uddin, 2015).

Image 1: Banana Fibre

Property Measure	Value
<b>Physical</b>	
Diameter (m/m)	14.00 – 26.00
Density (g/cm <sup>3</sup> )	0.86 – 1.12
Water Absorption	0.41
<b>Mechanical</b>	
Tensile Strength	385.00 – 655.00
Young’s Modulus (Gpa)	24.50 – 36.00
Elongation Break (%)	1.80 – 2.60
<b>Chemical</b>	
Cellulose (%)	55.00 – 64.00
Hemicellulose (%)	12.50 – 18.50
Lignin (%)	8.60 – 10.50

Table 1: Physical, Mechanical and Chemical Properties of Banana Fibre (Solomon Ikechukwu Anowai, 2017)

## LITERATURE REVIEW

This literature review is divided into three sections, the first one analyses the extraction of banana fibre, the second reviews banana fibre in concrete and the third, banana fibre within the insulation and their benefits in relation to today's contemporary materials.

### Extraction of Banana Fibre

Banana fibre requires certain care for the extraction in order to avoid damage to the fibre. The previous method of extracting the fibre involved the banana plant sections that were cut from the main stem to be lightly rolled removing any excess water. Any impurities that were found in the fibre, which would involve pigments, broken fibres, etc to be removed manually by a comb and then the fibres were cleaned and dried. This technique is tedious, time- consuming and caused damage towards the fibre so in terms of use in the industry this technique was not suitable. Today there are machines (see image 2) that are



available for the extraction of banana fibre making the process of extraction much simpler by just placing a clean piece of the banana stem on the machine's platform. The machine avoided the breakage of the fibres and after the extraction is complete the material is then cleaned and dried in a chamber for 3 hours at a temperature of 20°C completing the process (My MSME, 2018). There is not yet a machine that can be used on an industrial scale to source banana fibre but could be developed by material manufacturers.

Image 2: Banana Extraction Machine

### Banana Fibre in Concrete

Concrete is normally a composite material composed of fine and coarse aggregate which is bonded via cement which hardens over time and is weak under tension with a brittle character. Fibre-reinforced concrete is concrete that contains fibrous material which in turn increases its structural integrity. Normally the fibres within the fibre reinforced concrete are small and discrete. The fibres that can be used are glass fibres, synthetic fibres, steel fibres, and natural fibres. The use of fibre reinforced concrete is mainly used in shotcrete, but can also be used in normal concrete. Fibre reinforced concrete and normal concrete are mostly used for pavements and used on ground floors. The expense for concrete that is reinforced with fibres is less expensive than hand-tied rebar but still increases the tensile strength of the concrete. Fibres that are added to concrete usually are used to control the shrinkage of the concrete preventing it from cracking whilst drying (The Constructor - Civil Engineering Home for Civil Engineers, 2012). The fibres reduce the permeability of concrete, and therefore reduce the bleeding of the water. Banana fibre has the potential to be used within fibre reinforced concrete as replacement of the conventional fibres used today which come at a greater expense and most are not eco-friendly. Air-cured banana-fibre-reinforced cement or plaster have physical properties of density and water absorption similar to those of wood- fibre-reinforced air cured cement or plaster (R.S.P Coutts, 1994).

Banana fibre is reported to have a tensile strength of 800 MPa, an elastic modulus of 32 GPa and total elongation of 3.7% these factors with its low density of 0.67-1.50 g/cm<sup>3</sup> make it a good engineering material for reinforcement (Foluke Salgado Assisa, 2015).

### **Banana Fibre in Thermal Insulation**

Thermal insulation is one of the cheapest and simplest forms of insulating an indoor environment keeping it at a comfortable temperature by reducing the amount of heat lost within the building. As half of our energy is in buildings and with Europe having its largest share of energy is through heating insulation is vital (XCO2, n.d.). Insulation “is a passive method of reducing the rate of heat flow across a building envelope which has a direct impact on the energy bill for maintaining thermal comfort which eventually leads to a decrease in greenhouse gas emissions and environmental pollution” (Ademola, 2016). The conventional non-biodegradable thermal insulation has led to environmental problems due to the non-environmentally friendly inorganic materials that are used such as; mineral wool, lightweight and cellular concrete, fiberglass, plastic foams, Styrofoam, fibreglass and expanded perlite all of which are the most commonly used materials for thermal insulation. Inorganic insulation materials may have problems for human’s health and cause environmental pollution due to them emitting toxic gases and particles. The use of the conventional thermal insulation has led to research being taken to look towards natural fibres which can replace these non- biodegradable materials as an eco- friendly alternative. Banana fibre is potentially a great replacement for today's inorganic insulation materials. Banana fibres come in good lengths which makes them able to weave into an insulation batt without the use of binders (Ademola, 2016). The main indicator of the quality of a thermal insulator is its thermal conductivity and if the banana fibre has insulating properties between 0.02 W/m. K to 0.06 W/m. K (Ademola, 2016).

## **RESEARCH METHODOLOGY**

The object of this research paper was to answer whether bananas are a new potential material in the construction industry and this data can be found on various publications and websites.

Both qualitative and quantitative research was used to understand the use of banana fibre within the construction industry and the attributes this material has with facts the back it up. The research was carried out through secondary research using reports, journals and web pages found online. The quantitative data helped back up the attributes this material possess via numerical data and the effect that organic waste has on the World and the scale of a problem it is. By using already carried out experiments would give a better insight to how banana fibre actually performs within concrete instead of just the theoretical idea of it.

## **RESULTS AND DISCUSSION**

For banana fibre in concrete, there was a test carried out by (Solomon Ikechukwu Anowai, 2017) going through the compressive, flexural and splitting strength of concrete with different amounts of banana fibre within them in different lengths (Table 2). The banana fibres that were extracted for this experiment were chopped to a length of 10mm, 20mm, 30mm and 40mm. The grade of the cement used was C 25N/mm<sup>2</sup> and the banana fibres were added to the concrete in their volume fractions of 0.25%, 0.5% and 1.0%. The mixtures were fed into the prepared steel moulds and compacted via a mechanical vibrator for 30 to 60 seconds. The specimens were left to cure for the desired days which was 7 and 28 days (Solomon Ikechukwu Anowai, 2017).

Specimens	Amount of Banana Fibre (%)	Banana Fibre Length (mm)
A (control mix)	-	-
B1	0.25	10
B2	0.5	10
B3	1.0	10
C1	0.25	20
C2	0.5	20
C3	1.0	20
D1	0.25	30
D2	0.5	30
D3	1.0	30
E1	0.25	40
E2	0.5	40
E3	1.0	40

Table 2: Composition of Cement (Solomon Ikechukwu Anowai, 2017).

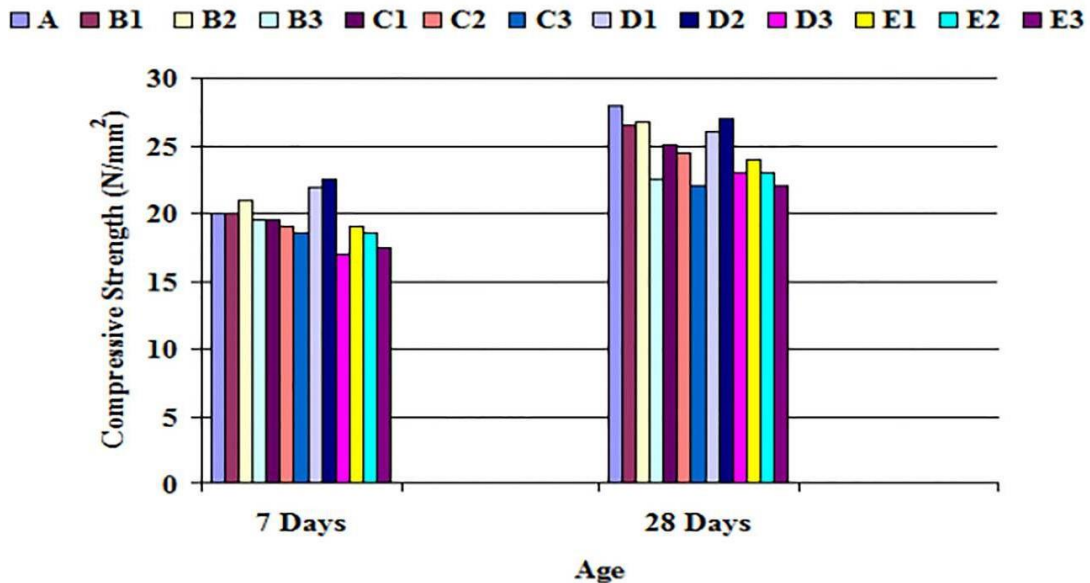


Figure 1: Compressive strength development of concrete reinforced with banana fibres at varying lengths and volume fractions (Solomon Ikechukwu Anowai, 2017).

In 7 days, the mixture D2 which had the banana fibre of 30mm and 0.5% volume fraction achieve the highest compressive strength of 22.50N/mm<sup>2</sup> which is 12.5% higher than A which had no banana fibre within it. In 28 days, however, the control mix (A) had a higher compressive strength than all of the mixtures. From the results, any specimens with a volume fraction above 0.5% the compressive strength decrease, this could be due to that the higher the percentage the harder it is to mix. These results show that 0.5% and 30mm (D2) are optimum for grade 25 concrete (Solomon Ikechukwu Anowai, 2017).

2:

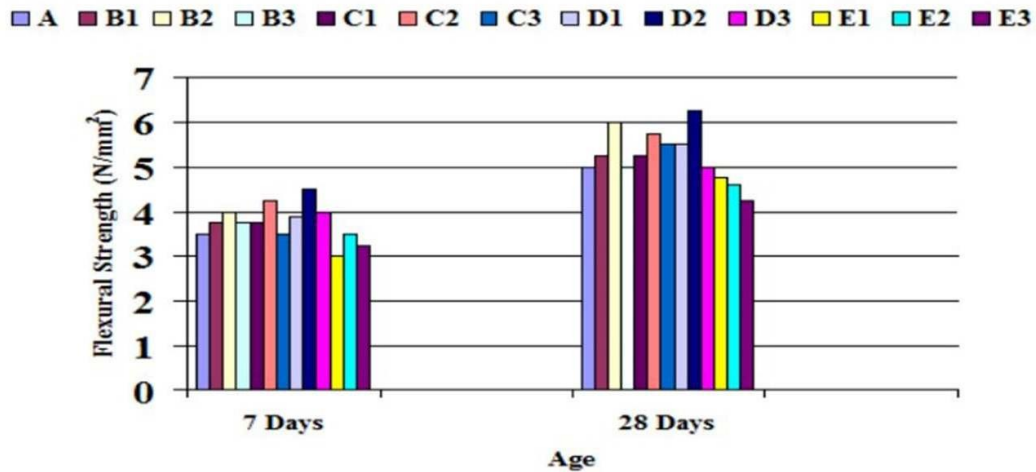


Figure Flexural

strength development of concrete reinforced with banana fibres of varying lengths and volume fractions (Solomon Ikechukwu Anowai, 2017).

The results for the flexural tests show that the addition of banana fibre within concrete increases its flexural strength. Mixture with 0.5% and length of 30mm (D2) had the highest flexural strength for both 7 days and 28 days with its maximum flexural strength of 6.25 N/mm<sup>2</sup> at 28 days of curing which is 25% more than the control mix (A) (Solomon Ikechukwu Anowai, 2017).

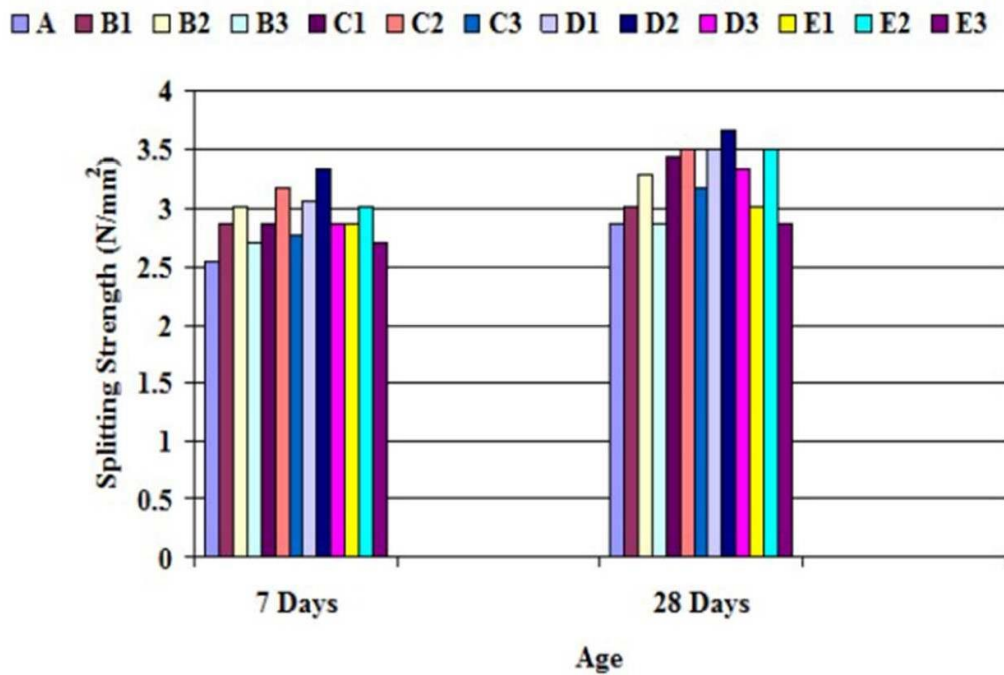


Figure 3: Splitting strength development of concrete reinforced with banana fibres of varying lengths and volume fractions (Solomon Ikechukwu Anowai, 2017).

The results for the splitting test show that the addition of banana fibre increases the splitting strength especially when it's put up to a quantity of 0.5%. From the results, the specimen with 0.5% fibre and length of 30mm (D2) achieved the highest splitting tensile strength in both 7 and 28 days with a strength

of 3.66 N/mm<sup>2</sup> which is 28% higher than the control mix (A). The tests showed that the mixtures that contained banana fibre developed small cracks under failure loads and showed more ductility unlike the plain concrete, which showed sudden failure.

Overall, the tests for the banana fibre in the concrete show that out of all the specimens D2 which had 0.5 % volume banana fibre at 30mm's came out on top on all tests. The control mix (A) did have the best compressive strength but it lacked in both flexural and splitting strengths whereas D2 thrived. The addition of banana fibre within the concrete added to its strength so the use of banana fibre could be an option to use over other inorganic products depending on the strength need for the concrete.

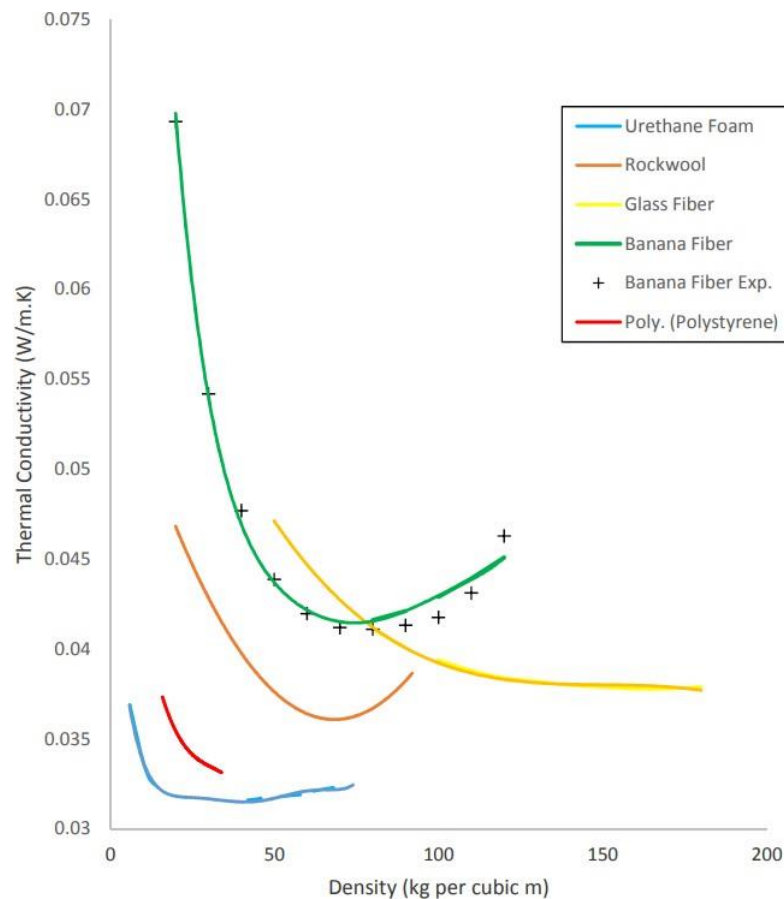


Figure 4: Comparative apparent thermal conductivity variation with density at 24°C (Ademola, 2016)

There was an experiment carried out by (Ademola, 2016) comparing the thermal conductivity of different thermal insulation materials with density at 24°C (See Figure 4). The banana fibre was extracted via a rotating machine (similar to one in Image 2) then the fibres were cut and allowed to dry under laboratory conditions for 5 days. The banana fibre was randomly arranged horizontally to form an insulation batt in a square polystyrene frame with a thickness of 38mm (Ademola, 2016).

The results showed that as the density of the banana fibre increased from 20kg/m<sup>3</sup> the thermal conductivity decreased to a minimum value of 80 kg/m<sup>3</sup> and then increased as density increased. Each test showed a linear increase in thermal conductivity with mean test temperature. At 24°C, the test showed the minimum thermal conductivity of banana fibre is 0.04130 W/m.K. at a density of 73.36 kg/m<sup>3</sup>. In figure 4 all the materials present a hook shape graph. Banana's minimum thermal conductivity is higher

than all of the other materials, however despite that its conductivity value is within the range to be used as a buildings thermal insulation which is from 0.02 W/m. K to 0.06 W/m.K. The benefits of using a naturally occurring biodegradable material, such as banana fibre is that it is environmentally friendly, cheap and there is an abundant supply of this raw material. However, there needs to be a consideration over the potential flammability of this material and the chance of insect attack and fungal growth over time (Ademola, 2016). Banana fibre in its current form would need to be treated to prevent the growth of fungus and the attack of insects.

## CONCLUSION

The aim of this research was to discover whether bananas can be used within construction materials so therefore banana fibre has a huge potential to be integrated within the construction industry. This is evident by the results of the experiments carried out, so banana fibre could become a new building material as long as its industrialised, however depending on what the banana fibre is used for it may need to be treated to prevent the attack of insect and the growth of fungus.

Overall there is huge potential to use today's organic waste within construction materials which would use a product that would normally have been incinerated or put into a landfill to decompose and pollute the environment. The use of organic waste in the construction industry would yield healthier products with a reduced environmental impact towards the construction industry, especially that these products have the potential to be returned to the biosphere at the end of their lifespan. To make the use of organic waste possible it would need a larger stakeholder engagement to support this concept making it a more attractive financial proposition.

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# Using Machine Learning for carbon-conditioning recycled aggregate concrete modelling

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**Keywords:** Machine learning, Statistical techniques, Carbon-conditioning recycled aggregate, Recycled aggregate concrete, Optimisation.

## ABSTRACT

*Environmental impact concerns are increasing in today's society globally. Greenhouse effect is known as a natural process that warms the Earth's surface. However, human activities in different industries are increasing the concentrations of greenhouse gases affecting the Earth's temperature. Carbon dioxide (CO<sub>2</sub>) is the most common gas emitted and rapidly increasing around the world. Australia's emissions have risen in the past three years and emissions in 2020 are projected to be 551 Mt CO<sub>2</sub>-e. The construction industry potentially can contribute to the decrease of CO<sub>2</sub> emission by the usage of sustainable materials such as carbon-conditioning recycled aggregate concrete. Recycled concrete is an eco-friendly material however it has not been typically used for structural applications. One of the reasons is the limited prediction models to obtain concrete mechanical properties, such as compressive strength. Since Machine Learning (ML) techniques have been used to computationally model the most varied types of engineering problems, this paper presents a study of some techniques to investigate how well they can model one of the main characteristics of recycled concrete aggregate (RCA), the compressive strength. The data set characteristics will be explained and what techniques can be used for parts of these information to achieve better results. The contribution to the industry is the construction of programs to facilitate further studies and the concrete mixture optimisation.*

## INTRODUCTION

Aggregate used in construction industry is one of the most widely consumed minerals. In the middle of the first decade in the 21st century, 16 European countries were recorded an average consumption of 6-10 tons / inhabitant / year. In the United States, the rate was 8 tons / inhabitant / year. The Asia/Pacific region registers as one of the largest producers in product sales, as construction activity is rapidly rising, particularly in China and India. China alone accounts for half of all new aggregate demand worldwide during the 2010-2015 periods (Concrete Construction 2012). Considering the environmental impact by the use of natural aggregates, construction and demolition waste aggregate is revealed as a sustainable and efficient alternative to produce recycled concrete (Tam et al. 2016). The planning and execution of concrete tests are important in the development of new materials. However, for each study, plenty of mixtures are demanded and time in the curing process. In addition, a significant effort expended performing mechanical tests (compression, tensile, shear, elastic modulus, etc.). Thus, the study of techniques aiming to facilitate the modelling of engineering problems can have advantages in making the

process less costly and leading more reliable results. For example, there is also the inverse problem, where is desired a mixture that will achieve a certain 28 days compressive strength.

In order to obtain alternatives to model the mechanical behaviour of concrete as an option to regression analysis has been found in the literature since the 1990s. Yeh (1998) studied the use of a backpropagation Artificial Neural Networks (ANN) to model the compression strength of high- performance concretes with better results than those obtained by regression analysis.

In an attempt to give a destination in the ashes of hospital solid wastes, Al-Mutairi, Terro and Al- Khaleefi (2004) studied its effects on property compression strength when these ashes are mixed with concrete. For this research, the author made statistical evaluations and used a prediction model based on ANNs.

Taking advantage of the trend, Tam, Tam and Wang (2007) used ANNs to improve mixture methodology to obtain a higher performance of RACs. Using ANNs and fuzzy logic (ANFIS – Adaptive neuro-fuzzy inference systems) techniques, Topcu and Saridemir (2008) modelled the compressive and splitting tensile strengths for recycled aggregate incorporated silica fume.

Studying RACs and their characteristics for structural applications and following an experimental design using similar RACs, Kotrayothar (2012) developed a significant amount of tests which will be used as data base of this work. This decision was made considering that the recycled aggregate is a heterogeneous material and the use of a database generated in similar conditions can achieve relevant ANNs results in comparison to the authors who sought to compose their databases by gathering information from the most varied sources. Continuing the research, Tam et al., (2016) developed a regression analysis to predict target characteristic compressive, tensile and flexural strengths from 44 mix designs.

Recently, the use of machine learning tools has been providing significant results in previous projects. In order to model the behaviour of the modulus of elasticity at 28 days of RAC, Duan, Kou and Poon, (2013) constructed two ANNs and compared them with their experimental results and the results obtained by conventional regression analysis. The training of the first ANN was based on a dataset with 324 records drawn from 21 international papers, while the training of the second ANN considered these same 324 records plus 16 datasets from experiments done by the authors. The authors chose 16 characteristics as ANN entries and obtained precise results for both networks, with low values of Root Mean Square Error (RMSE) and Mean Absolute Percent Error (MAPE). As an extension of the previous paper, they used the same ANNs based on the same data sources and with the same input parameters to explore in detail the applicability of using ANNs in modulus of elasticity of RAC.

Some researchers (Şimşek, İç and Şimşek 2016; Paul, Panda and Garg 2018) executed a reduced experimental program and with little representativeness in certain regions of the input parameters. Several authors (Dantas, Batista Leite and De Jesus Nagahama 2013; Duan and Poon 2014) seek previous data to improve their analysis.

This paper aims to model the compressive strength of recycled concrete using regression analyses and a machine learning technique such as Artificial Neural Networks (ANNs) to evaluate which method lead to a more precise response.

## **METHODOLOGY**

The methodology used in this work follows the determined flow:

- To organize the data to be used in the modelling problem focused on compressive strength;

- Train some multilayer perceptron (MLP) ANN;
- Use the ANN and compare their results with Regression Analysis (RA) results and the tests values.

The characteristics of the data used in the modelling, as well as details related to ANN and the RA results, will also be commented.

## Materials

Recycled aggregate samples collected from a south-eastern Australia centralised recycling plant was adopted to produce concrete. The recycled aggregate utilised within the paper neural network can be seen in Table 1.

Table 1. Aggregate Properties

Source	Natural aggregate	Recycled aggregate
Grading	Pass	Pass
Water absorption (%)	1.02 (10mm); 0.42 (20mm)	5.02 (10mm); 5.63 (20mm)
Particle density on oven-dried basis (t/m <sup>3</sup> )	2.59 (10mm); 2.47 (20mm)	1.44 (10mm); 1.30 (20mm)
Particle density on saturated and surface-dried basis (t/m <sup>3</sup> )	2.61 (10mm); 2.48 (20mm)	1.51 (10mm); 1.37 (20mm)
Apparent particle density (t/m <sup>3</sup> )	2.66 (10mm); 2.50 (20mm)	1.55 (10mm); 1.40 (20mm)
Aggregate crushing value (%)	21	34
Contaminant (%)	0	2
Flakiness index	28.27 (10mm); 22.52 (20mm)	15.12 (10mm); 9.78 (20mm)
Misshapen particle (%)	3.02	0.88

## Data characteristics used to model the problem

The data used in this work were obtained from laboratory tests. This type of procedure is usually expensive and time consuming. Thus, depending on the type of study desired, a previous analysis of the variables must be done in the construction of an experimental design that allows the construction of a surrogate mathematical model. The variables considered in the construction of the model are:

- Cement type: Discrete information of cement types (1 to 4);
- Admixture: Discrete information of admixture use or not (yes or no);
- Two-stage process: Discrete information of two stages use technics (yes or no);
- Aggregate type: Discrete information (NA, MRA and RCA);
- Water: Continuous information of water use in Kg;
- Cement: Continuous information of cement use in Kg;
- Sand: Continuous information of sand use in Kg;
- Water to cement ratio: Continuous information in percentage;
- Chamber property 1: Continuous information;
- Chamber property 2: Continuous information.

Even for the construction of a very simple model, by traversing each discrete variable at least once and each continuous variable three times (minimum value, maximum value and average value) the number of mixtures to be tested will be:

$$\text{Mixtures} = 4 \times 2 \times 2 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 = 34992$$

The detailed equation and mix design are not able to provide in the paper due to its confidential nature as this project is currently under commercialisation.

This number of concretes would be very difficult to obtain in the laboratory, besides not allowing the construction of satisfactory mathematic models since the continuous variables are not well represented.

To improve the distribution of the continuous variables and consequently the results obtained by models based on this information, it was decided to reduce the spectrum of the problem. In this way, a specific case will be studied of the discrete variables for a cement type, without the use of admixture, without the use of the two-stage process and for one type of aggregate.

The number of blends available is 49 laboratory tests. ANNs are expected to succeed in modelling the compressive strength property based on the information available on that data set.

### **Artificial Neural Networks**

The choice of the ANN approach comes from the good results that this technique has obtained in the most varied fields of knowledge to solve problems of classification, regression and time series prediction. This is because the technique copes well with non-linear and complex problems.

An ANN is a computational technique that constructs a mathematical model with learning capacity, generalization, association and abstraction based on information contained in data. The design of this technique was inspired by a simplified biological neural system where information is presented to the network that tries to learn its patterns in a repetitive process that must be stopped at an optimal time.

During this iterative process of learning, ANN adapts its characteristics and connections between neurons in order to reduce its error in the construction of its model based on this data.

After training, testing and evaluating the results of several ANNs: A Multilayer Perceptron neural network (MLP) were chosen to model the problem.

Additional information about ANNs, as well as other techniques can be found in references (Golub, G.H. and Loan, 1993; Haykin, 1999).

### **Regression Analysis**

In statistics, regression analysis is a set of statistical processes for estimating the relationships among variables and describes how an independent variable is numerically related to the dependent variable. Any statistics software has a module to calculate them and even spreadsheet programs. That's the reason why regression analysis is always the first choice to model data into an equation that rule one problem.

This study presents a multiple regression analysis based on the 7 (seven) mix design variables leading to the equation (1) aiming to predict the compressive strength of carbon-conditioning recycled aggregate concrete. Due to confidential details, the equation is not allowed to be disclosed. However, it is important to provide a static comparison to demonstrate the efficiency of the analysis using different methods to estimate the compressive strength.

## RESULTS AND DISCUSSIONS

To evaluate the MLP ANN model and the Equation acquired, some statistics error measures were used to compare properly the compression strength results. These numbers represent absolute error values, percentage error values and the correlation of these outputs when compared to the values measured in laboratory tests. Some general statistics, shown in Table1, will also be presented with the results ranges for each model, as well as their means and standard deviation.

Table 2. General Statistics for Compressive Strength

	Equation (1)	MLP_ANN	Experimental Data
Maximum value	41.78	40.64	43.19
Minimum value	25.08	24.50	24.22
Average value	34.93	34.87	34.93
Standard Deviation	4.73	4.81	5.04

It is easy to notice that equation and the ANN acquired good results modelling the problem, with small errors measures and a good correlation to the laboratory results, when it is analysed Table 2. However, the ANN obtained a smaller set of error measures, in addition to a better correlation, closer to 1.

Table 3. Error Models Statistics for Compressive Strength

	Equation (1)	MLP_ANN
Mean Absolute Error (MAE)	1.30	0.75
Min. Absolute Error	0.00	0.02
Max Absolute Error	3.74	3.22
Mean Squared Error (MSE)	2.90	1.19
Root Mean Square Error (RMSE)	1.70	1.09
Mean Absolute Percentage Error (MAPE)	4.01	2.33
Multiple R	0.94	0.98
R Square	0.88	0.95

The results showed that the MLP ANN tested provided accurate responses modelling the compressive strength with low errors (MSE, RMSE and MAPE) and a Rsquare (R<sup>2</sup>) close to 1. The MLP ANN model provided better predictions than the regression analyses models.

This better ANN performance compared to Equation (1) is also easily observed by analysing the graphs. Graph 1 shows that the results obtained by ANN are closer to the results obtained in the laboratory than those of Equation (1).

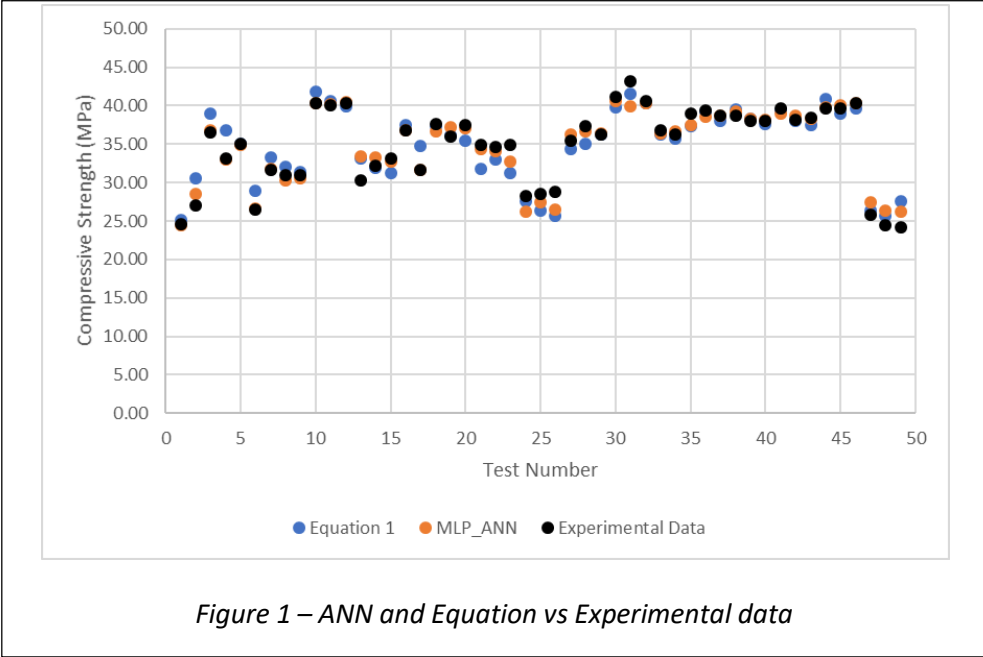
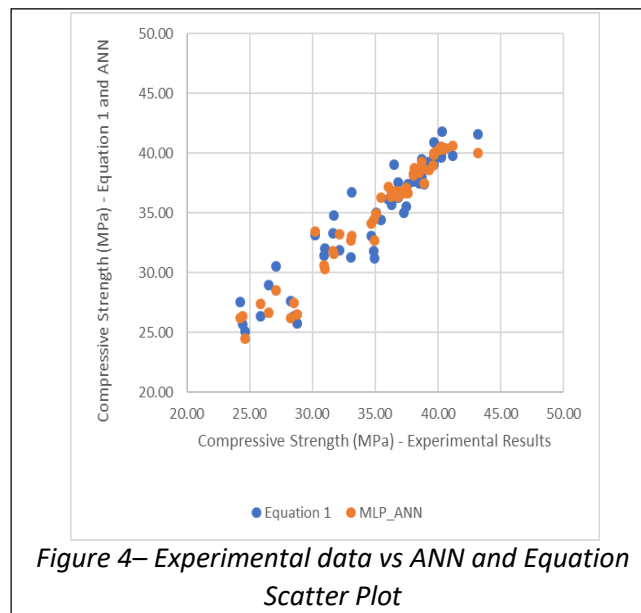
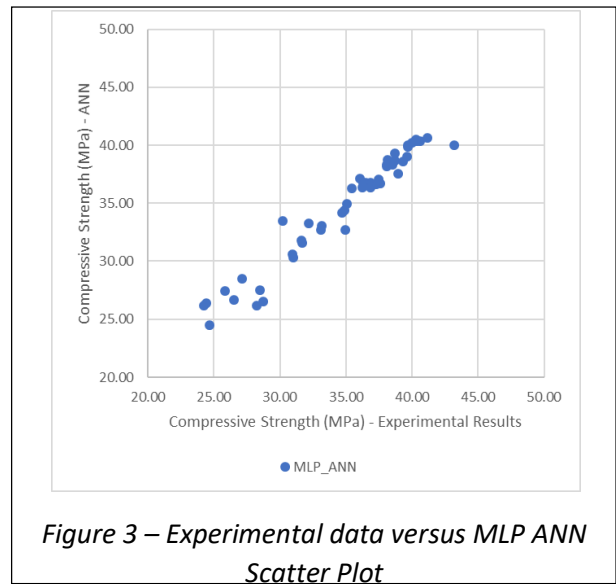
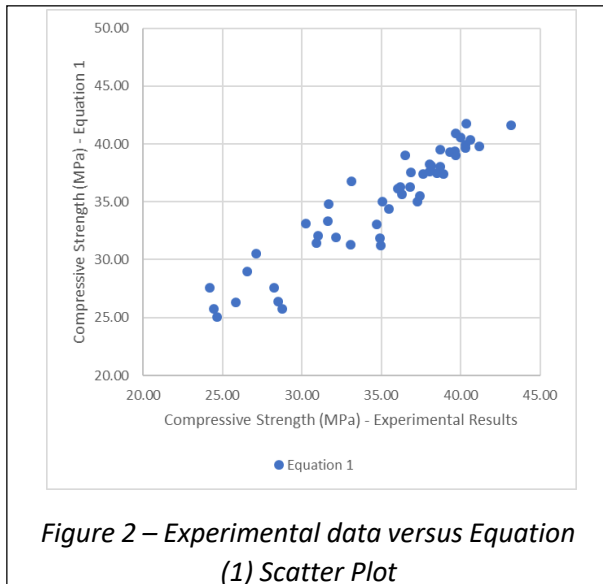
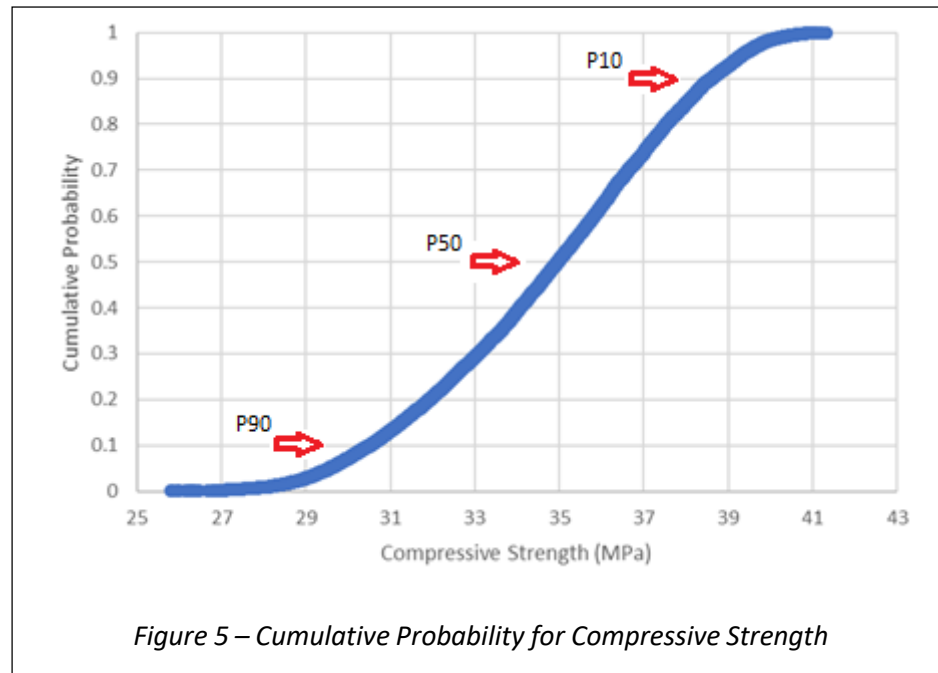


Figure 1 – ANN and Equation vs Experimental data

A useful visual method to analyse the model accuracy is using cross-plot graphs like the scatter plot confronting the results of each model in one axis against the experimental data results in the other axis of the plot. Thereby, for each point plotted it is possible to compare the value of the reference versus the value that was obtained by the ANN or RA model. So, the closer these values are, the more the points present the configuration of a 45-degree line and consequently, the greater the accuracy of the model. In this study, these graphs presented at figures 2 to 3, confirm the reliability of ANN techniques as an important tool to predict compressive strength of recycled concretes confirming the statistics measures of table 2.



For this type of concrete the CO<sub>2</sub> treatment in its aggregate and within the limits for each parameter in the construction of the ANN model, a Monte Carlo propagation with ten thousand ANN runs was made to construct a stochastic curve of answers for Compressive Strength. By importing these results into an Excel spreadsheet for the construction of figure 5 which presents a probabilistic value for compressive strength. For each probability there is a number presented in the graph for a value of the compressive strength. The main probabilities are: P90, P50, and P10, which respectively have 90%, 50%, and 10% probability as follows; if the focus is on mixtures with larger compressive strength, it usually emphasizes on P10 values where mixtures values exceed 38 MPa. For 50% probability for a given mixture to have values of 35 MPa or higher is known as P50. Finally, when the result of a mixture exceeds 30.5 MPa, it means a probability of existing 90% of mixtures with values above this value, known as P90.



## CONCLUSION

This paper investigated the use of ANNs for modelling the RAC compressive strength for a particular data set. The results showed that the MLP ANN tested provided accurate responses modelling the compressive strength with low errors (MSE, RMSE and MAPE) and a Rsquare (R<sup>2</sup>) close to 1. The MLP ANN model provided better predictions than the regression analyses models.

This research reveals the importance of obtaining a more accurate model aiming to predict concrete properties. The use of most innovative techniques of machine learning is expected in the future, aiming gains for the industry in relation to an increase of reliability of the model and in obtaining data, saving time and reducing costs. This study, focussing on compressive strength, demonstrate that the use of machine learning technics has a huge potential and can be adopt this approach to study other properties such as flexural strength, tensile strength, elasticity modulus, or durability.



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# Developing green building optimisation strategy for energy efficient building practices

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**Keywords:** Building Commissioning; Energy simulation; Measurement and Verification process; Monitoring and control systems.

## ABSTRACT

The use of advanced energy-efficient building practices is widely increasing in the international marketplace such as building commissioning process, energy simulation, measurement and verification, carbon dioxide monitoring and controllability of artificial lighting and ventilation systems. These processes should not be looked upon in isolation because after all, they aim at achieving almost the same green goals but acting on different sustainable criteria or life stages. It is also noted that a common obstacle for adopting such practices in the marketplace is their perceived high cost owing to the additional time and expertise required. Hence, the study assumes that their optimized integration is the cornerstone to be able to reach high building performance within planned time and cost constraints. This is performed through an integrated qualitative and quantitative methodology to develop an integrated model for the abovementioned green building practices. Relevant literature studies are cited, in addition to the result of an online questionnaire among worldwide practitioners to pinpoint interesting interrelations among some of these practices. Then the results are integrated into a causal loop diagram to define interrelations and problematic areas according to four assumed integration loops; L1: procedure, L2: temporal sequence, L3: pros and L4: cons. The study uses system modelling tools to represent the integration diagram proposed for such green building practices. The results of the study present mean of integrating advanced energy-efficient building practices as subcomponents of larger system integration model to reach higher building energy performance targets.

## INTRODUCTION

Adopting a green building process requires achieving system integration of several green building processes and practices that share a common aim of maximizing energy savings. This is considered a cornerstone of its success saving time and money, yet, it is a challenging process particularly with the several variables in hand and their dynamic and implicit interactions. Hence, the study investigates the integration of a number of energy efficient building practices such as; energy simulation, commissioning process (Cx), measurement and verification plan (M&V), carbon dioxide (CO<sub>2</sub>) monitoring as well as

managed and controlled artificial ventilation and lighting systems. It is notable that the contribution of these practices towards energy efficiency is often overlooked compared to other tangible factors with a direct effect on buildings' operational energy. Hence, a qualitative approach is used to individually discuss each method and its integration with other practices by means of literature review and practitioners' survey. The results provide valuable feedback comparing their perceived capital cost, additional time, expected savings, particular needed expertise as well as perceived risk and expected percentage error. Following on from this, a quantitative approach is used to deduct an integrative index for each method that represents its adoption rate and contribution to the building process and eventually, an integration model is developed to represent variables and interrelations. This pinpoints the importance of adopting dynamic system integration to optimise the interrelations of processes and practices to reach energy efficient building performance.

### **Arrangement of terms**

There are a number of factors affecting buildings' energy performance. This includes both operational and embodied energy use. The majority of research effort is concerned with optimising the selection of building elements, materials and systems with a tangible effect on energy consumption. Nevertheless, a number of green building practices may have a significant contribution as well. This includes the following;

- ❑ Energy simulation: this method takes place during the design phase to be able to manage the complication of the calculations as well as the multiple variables involved describing energy usage of buildings. Decisions related to energy, lighting and ventilation efficiency can be supported by computer simulation models, which provide efficient means to compare design choices and evaluate energy efficient design alternatives [1].
- ❑ Building Commissioning; this method takes place during the construction and operation phases. It is a rising concern in building management research as a response to the emerging emphasis on long-term performance and life cycle costs [2]. This is particularly evident for large and complex buildings; having significant loads on the mechanical equipment, variations in occupancy levels or extreme climatic conditions [1,3]. It requires early commitment and should be evaluated for the proper use of the process according to project type and condition. It can be tailored to numerous purposes according to the building type and condition. The cost of conducting a Cx process includes construction and soft cost implications. This includes performance tests, verification and validation checks. It also includes archiving operations and maintenance manuals, schedules, data sheets and warranties. Soft cost includes fees paid for the Cx agent and other design fees. Expected risk factors may be related to cost and quality of the Cx process especially with the lack of generally accepted industry guidelines and standards [4].
- ❑ Measurement and Verification process; this method takes place during building operation, nevertheless, it has to be carefully planned during early project phases to be able to include any mechanical system's modifications and this may include adjusting the set point of the building automation system (BAS). It raises the accuracy

and reliability for monitoring energy and resource consumption after construction and major retrofit. It acts as a feedback and adjustment mechanism for equipment performance, mechanical system or an entire building. It is also useful for performance contracting, energy service companies and demand resource certification. It could also discuss building life cycle costing which shall eventually bridge the gap between construction, operation and maintenance phases [2]. It requires significant capital cost; soft cost includes writing and implementing the M&V plan, and hard cost which comprises metering and submetering equipment. The feasibility and cost of this credit are associated with building type, size and complexity. It also depends on installing BAS and Building Management Systems. Common risks for applying M&V plan include missing energy management control system and past utility data, lack of building level utility meters and follow-up after project completion as well as poor qualifications of team members [3,4].

- ❑ Carbon dioxide level monitoring; this method takes place during the operation phase. It can be linked to central computer networks having fully automated control over all building facilities. It can be considered a part of an energy-efficiency management strategy. Installing CO<sub>2</sub> sensors has a dual advantage; they can sustain indoor occupants' comfort and wellbeing while achieving energy efficiency. This is optimized using demand control units in which ventilation rate is determined according to real-time occupancy and activity. Thus, the sensors' feedback is connected to an automated central ventilation unit.
- ❑ Controllability of systems; this requirement needs to be considered during early project phases to be integrated into the design drawings. Controllability of lighting and ventilation systems uses smart building technologies to provide high levels of occupants' control. This, in turn, increases their comfort and wellbeing and accordingly their work productivity [5]. Hence, the capital cost required for installing smart control building systems receive indirect payback, and this calls for the necessity of using life cycle cost analysis to account for long-term hard and soft cost implications [6].

After individually discussing each method, it is noted that the space for commonalities is widely open. Comparing building Cx against M&V plan shows the relative advantage of the latter over the former regarding the regular and long-term savings arising from optimization the design of the energy systems. They are common in sharing the whole building and system energy data and engineering savings estimates and often the data collected during the Cx process may be used in the post-installation M&V analysis. They provide a reference point to test the sufficiency of the energy model through energy savings and operational verification. M&V should optimally begin during Cx to validate its procedure. The Cx process requires conducting trend analysis to functionally-test equipment operations after installation. It is also important that the CO<sub>2</sub> sensors' calibration should be included in both the Cx and M&V plans. This corresponds to the operational verification requirement for the M&V process. Moreover, the Post Occupancy Evaluation (POE) may also be used to consider the qualitative aspects that evaluate building's performance in defined time limits. Also, it can confirm lifecycle performance projections; this can be very useful regarding new green technologies

to reduce risk and uncertainty. Also, some synergistic relations may exist between M&V, thermal comfort verification, and conducting a POE. This indicates that the system integration is the key to work within a defined budget to reach higher performance levels. This requires setting a plan, defining advanced tools and method, defining the work boundary, benchmark as well as any assumptions or normalization procedures.

## LITERATURE REVIEW

An updated literature search has been carried out using Science Direct database from 2010-2019. This included electronic books as well as research papers published in peer reviewed journals and conference proceedings. The search used the following keywords; energy optimization modelling, integrated energy efficient building systems and comprehensive building energy performance. A preliminary scanning step is performed to determine the extent and contribution of previous relevant studies; this is followed by a scoping step to outline the different perspectives undertaken as well as identifying relevant research gaps and limitations. Hence, Table (1) indicates that valuable research effort has discussed means of optimizing energy systems to reach building performance efficiency, yet the role of green building practices and the importance of their integration in these regards have been undervalued. This pinpoint possible interrelations of energy efficient green building processes and practices and the importance of studying them under the science of dynamic system integration.

**Table 1: Review of relevant studies**

Reference	Significance to the study
Azhar et al. (2011)	A suggested framework to investigate the direct and indirect role of BIM analysis to prepare LEED credits' compliance documents which save time and resources.
Norrström (2013)	The EEPOCH restoration research project includes a number of case studies adopting the systemic thinking approach for several aspects including energy efficiency.
Marinakis et al. (2013)	An energy-efficient integrated system for buildings' automation including real-time monitoring and energy use optimization.
Osma et al. (2015)	The BAS can monitor changing conditions in the surrounding environment and perform a real-time simulation of variables and analyze historical data to be able to adjust and respond to operational requirements of existing facilities.
Buonomano et al. (2016)	An integrated building model (DETECT 2.2) is developed to predict the energy demand taking into consideration a number of active and passive energy efficiency strategies.
Zibin et al. (2016)	BAS can provide the required data to carry an on-going Cx in mechanical systems, and hence an Automatic Assisted Calibration Tool is used to save the required time of carrying a trend data analysis and calibrate building energy models.

Wang et al. (2016)	A comprehensive methodology for energy performance diagnosis
Aste et al. (2017)	An analytical framework for BAS and control to guarantee building performance optimization.
Huang et al. (2017)	A new modelling concept that takes into account the systems perspective including the interaction of the building with its surrounding urban context.

## RESEARCH METHOD

This section investigates the interrelations of the aforementioned green building practices to be able to develop an optimized integration model for energy-efficient building performance. This requires working on dual tiers to cover the tangible and intangible integration aspects. In order to do so, the study suggests defining four loops of integration which demonstrates an iterative effect according to the consistent feedback about building performance as shown in Figure (1). These are; L1: procedure, L2: temporal sequence, L3: pros indicators and L4: cons indicators.

The quantitative tiers can be deduced from previous literature. These define the first two loops which represent the technical dependency of termed procedural occurrence

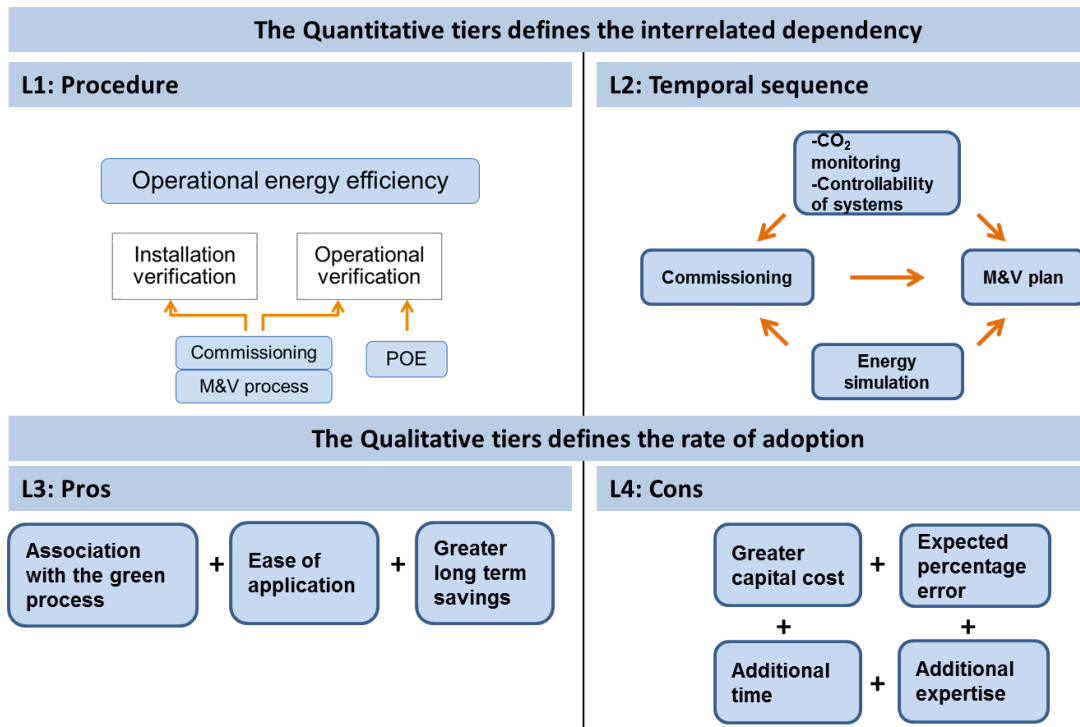
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(defining the dependency of one process to the other(s)), or temporal occurrence (defining the temporal sequence of one process in relation to other(s)).

The qualitative tiers investigate the rate of adoption of such green building practices and pinpoint opportunities for integration in relation to practitioners' perception and experience of their pros and cons. Hence, an online questionnaire is created and distributed on 09/21/2018 via professional networks on the following link <https://lnkd.in/gs3h3c4>. It investigated practitioners' views regarding a number of key qualitative aspects and received fifteen responses. The results in Table (2) are used to develop their corresponding integrative index as shown in Table (3). This normalization step enables having a common measuring unit for these qualitative aspects of the model's data input process.

**Table 2: Summarizing the results of the online questionnaire**

<p>A horizontal bar chart with a scale from 0 to 4. The bars represent: Energy simulation (green, ~3.2), Commissioning (blue, ~3.1), M&amp;V Plan (yellow, ~3.3), CO<sub>2</sub> monitoring (teal, ~2.8), and Controllability of systems (orange, ~2.7).</p>	<p>A horizontal bar chart with a scale from 0 to 4. The bars represent: Energy simulation (green, ~3.2), Commissioning (blue, ~3.1), M&amp;V Plan (yellow, ~2.9), CO<sub>2</sub> monitoring (teal, ~3.1), and Controllability of systems (orange, ~2.8).</p>	<p>A horizontal bar chart with a scale from 0% to 40%. The bars represent: Energy simulation (green, ~38%), Commissioning (blue, ~15%), M&amp;V Plan (yellow, ~8%), CO<sub>2</sub> monitoring (teal, ~22%), and Controllability of systems (orange, ~15%).</p>	<p>A horizontal bar chart with a scale from 0% to 40%. The bars represent: Energy simulation (green, ~42%), Commissioning (blue, ~15%), M&amp;V Plan (yellow, ~8%), CO<sub>2</sub> monitoring (teal, ~20%), and Controllability of systems (orange, ~15%).</p>
<p>Association with the green process</p>	<p>The ease of application</p>	<p>Greater capital cost</p>	<p>Greater long-term savings</p>
<p>A horizontal bar chart with a scale from 0% to 40%. The bars represent: Energy simulation (green, ~22%), Commissioning (blue, ~8%), M&amp;V Plan (yellow, ~38%), CO<sub>2</sub> monitoring (teal, ~22%), and Controllability of systems (orange, ~8%).</p>	<p>A horizontal bar chart with a scale from 0% to 40%. The bars represent: Energy simulation (green, ~30%), Commissioning (blue, ~8%), M&amp;V Plan (yellow, ~22%), CO<sub>2</sub> monitoring (teal, ~22%), and Controllability of systems (orange, ~15%).</p>	<p>A horizontal bar chart with a scale from 0% to 40%. The bars represent: Energy simulation (green, ~38%), Commissioning (blue, ~15%), M&amp;V Plan (yellow, ~8%), CO<sub>2</sub> monitoring (teal, ~15%), and Controllability of systems (orange, ~22%).</p>	<ul style="list-style-type: none"> <li><span style="color: green;">■</span> Energy simulation</li> <li><span style="color: blue;">■</span> Commissioning</li> <li><span style="color: yellow;">■</span> M&amp;V Plan</li> <li><span style="color: teal;">■</span> CO<sub>2</sub> monitoring</li> <li><span style="color: orange;">■</span> Controllability of systems</li> </ul>
<p>Additional extra time</p>	<p>Additional expertise</p>	<p>The expected percentage error</p>	



**Figure. 1: Integration of Green building practices (source: author)**

**Table 3: The deducted integrative index of each discussed green building practice**

	Variables	Energy simulation	Cx	M&V	CO <sub>2</sub> monitoring	Systems' control
L3 <sub>n</sub>	L3 <sub>1</sub> . Association with the green process	3.23	3.20	3.31	2.79	2.71
	L3 <sub>2</sub> .Ease of application	3.17	3.17	2.92	3.17	2.69
	L3 <sub>3</sub> .Long term savings	4.20	1.40	0.70	2.10	1.40
L4 <sub>k</sub>	L4 <sub>1</sub> . Capital cost	3.80	1.50	0.77	2.30	1.50
	L4 <sub>2</sub> . Extra time	2.30	0.77	3.80	2.30	0.77
	L4 <sub>3</sub> .Additional expertise	3.00	0.77	2.30	2.30	1.50
	L4 <sub>4</sub> . Expected error	3.80	1.50	0.77	1.50	2.30
	Total integrative index*	0.31	1.46	0.40	0.60	0.74

\*Total integrative index  $f(x) = \frac{\sum_{i=1}^n x_{L3_i}}{n} - \frac{\sum_{i=1}^k x_{L4_i}}{k}$



Then, a causal loop diagram is developed using Vensim PLE 7.1 software to act as an efficient method of defining the interrelations and problematic areas of a hypothetical office building with the following assumptions as shown in Table (4):

Occupancy: 50% male and 50% female Five occupants per 100 m<sup>2</sup>

Floor area= 1500 m<sup>2</sup>

Required lighting energy=250 kWh/m<sup>2</sup>

Required ventilation energy=250 kWh/m<sup>2</sup>

The rate of occupancy change=50 persons

**Table 4: Data input, Vensim PLE7.1**

Variable	Equation	Units	Notes
Artificial lighting requirement	Lighting level*floor area*integrative index of system control	kWh	250*floor area lighting level hence, assuming 100 kWh /m <sup>2</sup> /yr, then it equals 100*floor area.
Artificial ventilation requirement	Ventilation rate*floor area*integrative index of system control and CO <sub>2</sub> monitoring	kWh	For office buildings average energy consumed per occupant =250 kWh/m <sup>2</sup> of treated floor area [16].
Energy consumption	The rate of occupancy change*(artificial lighting+artificial ventilation)	kWh *persons	For the purpose of simplification, only artificial lighting and ventilation were considered.
Energy simulation	Energy consumption* energy simulation integrative index	kWh *persons	
Cx	Energy simulation* Cx integrative index	kWh *persons	
M&V plan	Cx*floor area/rate of occupancy change*M&V integrative index	kWh *m <sup>2</sup>	

## RESULTS & CONCLUSION

The study discusses energy efficient processes and practices such as energy simulation, Cx, M&V plan, CO<sub>2</sub> monitoring and controllability of systems. The results show a proposed optimization model exploring their interrelations through a causal loop diagram of dynamic system integration as shown in Figure (2). This indicates the predefined loops of integration

in terms of procedural and temporal dependency as well as their perceived rate of adoption in relation to their pros and cons. The effect of increasing the building floor area and number of occupants can also be considered. It can either be used as a standalone application or in integration with other energy analysis software programs to provide a comprehensive idea about system integration; not only considering the proper design of materials and systems but also the effect of energy efficient practices. This demonstrates significant relations to invest in, and how changes in the interconnections of this system may exhibit different behaviours towards efficient building performance. It would also establish a cross-sectoral information platform which would improve access to information, deliberation and coordination.

The proposed model can be used to track the effect of changing occupancy and/or floor area on buildings' energy performance taking into consideration the interrelations of the discussed green building practices. This shows that the energy consumption shall increase as a result of users' increased energy demands of artificial lighting and ventilation levels. Accordingly, this shall affect the data input of the predefined operational energy values for the energy simulation. This requires further checking using the Cx process to guarantee that it matches the design limits, and a more comprehensive checking is provided as part of the M&V process to take any required amendment actions and provide a continuous monitoring and feedback mechanisms. Figure (3) shows runs comparison for energy consumption parameter in cases where occupancy doubles (S1) and floor area doubles (S2), respectively. This shows a linear exponential trend of increased energy consumption.

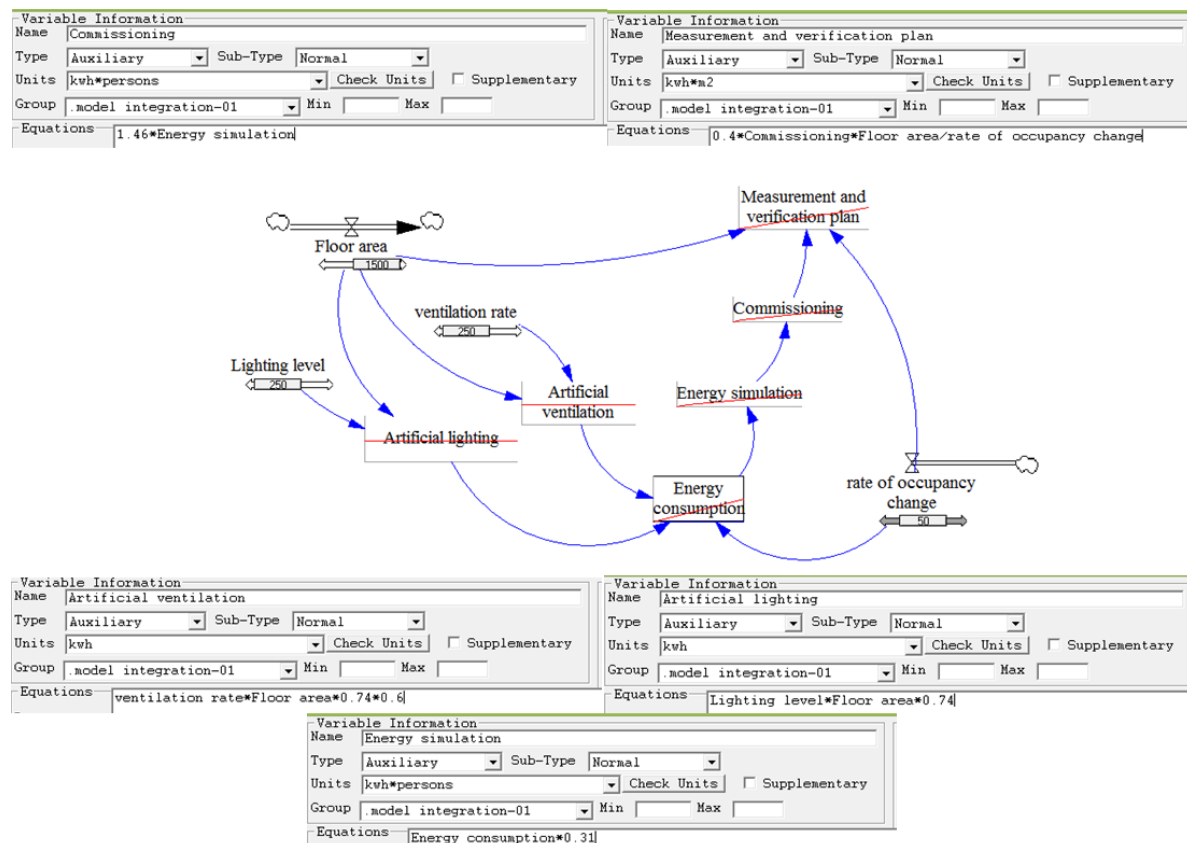


Figure. 2: The proposed optimization model showing input data and equations

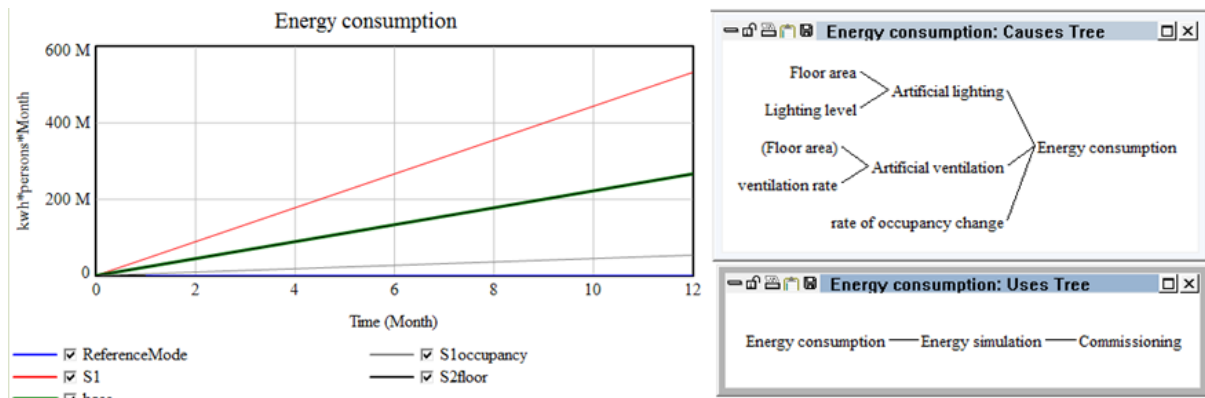


Figure. 3: The proposed optimization model showing input data and equations

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# Case studies of the 2014-15 Floods in Malaysia: The Role of Communities in the management of natural hazards

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## ABSTRACT

*Flooding is one of the most dangerous natural hazards in Malaysia occurring nearly every year during the monsoon season and affecting almost 4.82 million people, which is around 22% of the total population of the country. The floods that hit Malaysia between December 2014 and January 2015 were the worst disaster in decades when 21 people were killed and 200,000 people were affected or displaced. During these events, many local members in rural and urban areas volunteered to help vulnerable people within their local communities. However, lack of facilities, equipment and poor communication and coordination with local authorities and other government agencies meant their efforts were often ineffective and many flood victims continued to endure harsh realities post-disaster. The aims of this paper are; 1. To showcase community learning on risk management that took place during the 2014-2015 events and identify ways in which the community response to flood can be improved, and 2. To critically review current state-led policies and strategies for risk communication and education and post-disaster asset management. The study is based on a social survey of 80 households in Kelantan state and Temerloh in Central Pahang, Malaysia where many communities affected by the worst flooding in 2014-2015 are located. Survey results are used to identify community hazard learning, the adaptation needs of communities and the limitations of current local authority policies. While it is clear that households and volunteers in small urban areas and villages gained valuable experience and learning that has enhanced their ability to protect themselves and their assets. local authorities and agencies need to prevent people from developing new buildings near flood-prone areas.*

## INTRODUCTION

The impact of disasters has been dramatically increasing over the past decades in Malaysia because communities and their assets have been more exposed to the impact of natural hazards. Flood events that hit Malaysia between December 2014 and January 2015 were the worst disaster in decades where 21 people were killed and 200,000 people were affected or displaced (Aziz et al., 2016). During these events, many local members in rural and urban areas volunteered to help vulnerable people within their local communities. However, lack of facilities, equipment and poor communication and coordination with local authorities and other government agencies meant that their efforts were often ineffective and many flood

victims continued to endure harsh realities post-disaster. Since the adoption of the Sendai Framework for Disaster Risk Reduction SFDRR (2015-2030), the Malaysian authority is trying to implement the initiative of Community Based Disaster Risk Reduction (CBDRR) and Malaysian Civil Defence Forces have been given the authority to train general public about disaster emergency and hostile attack. However, moving Disaster Risk Management (DRM) from central level to national and local levels face many challenges because the Malaysian public generally rely on the government's response during a disaster. The field study in Malaysia covered five districts located in two states. All chosen districts are considered flood-prone areas because of their geographical locations within the Kelantan River Basin and at the junction of the Pahang River and the Semantan River. Interviews and meetings conducted with district chiefs and a number of local authorities' agencies members in addition to a questionnaire given to residents to reflect on their experience before, during and after the flood occurrence. The study showcases local community experience during the 2014-2015 events and identifies ways in which the community response to flooding can be improved. There is also a critical review of current state-led policies and strategies for risk communication and education and post-disaster asset management.

## **OVERVIEW OF FLOOD HISTORY IN MALAYSIA**

Malaysia is vulnerable to natural hazards including floods, forest fires, tsunamis, cyclonic storms, landslides, seismic activity, epidemics, and haze (CEDMHA, 2016). Flooding is one of the most dangerous natural hazards in the country and occurs nearly every year during the monsoon season which is characterised by heavy and regular rainfall from October to March, along with flash flooding which occurs because of inadequate drainage infrastructure in many urban and flood-prone areas (Wahab, 2013). Flood events affect almost 4.82 million people which is around 22 per cent of the total population of the country (D/iya et al., 2014). Flood-prone areas in Malaysia are estimated at about 29,800 square kilometres, which is 9 per cent of the total land area, and flooding affects approximately five million or 21 per cent of the total Malaysian people (DID, 2007). Inadequate drainage systems are unable to cope with the excessive rainfall during monsoon seasons and this has also intensified flooding problems in Malaysia (CEDMHA, 2016). However, a series of floods seen in the Johor state of Malaysia in 2006 are believed to be extraordinary events that are closely related to new weather phenomenon and global climate change (Hussaini, 2007).

The main cause of river flooding in Malaysia is the incidence of heavy rainfall during the monsoon season and a resultant large concentration of water runoff which exceeds river capacity (Hussaini, 2007). However, a report in 2007 by the Malaysian Ministry of Natural Resources and Environment stated that in recent years, rapid development within river catchments have resulted in higher runoff and deterioration in river capacity; and increased the flood frequency and magnitude (Hussaini, 2007). The report shows that there is about 60 per cent of Malaysian population residing in urban areas where flash flooding is perceived to be the most critical flood type since the mid-1990s (Hussaini, 2007). Also, there are other causes of flooding attributed to the high tides which are occasionally aggravated by heavy rains or strong wind in the coastal areas (Chan, 2012). Nevertheless, concerns are raised about an increasing occurrence of other flood-related disasters such as debris flood flow, mudflow and landslides in mountain streams and hill slopes and tsunami-induced coastal

flood disasters (Chan, 2012). A research study on the coastal flood phenomenon in Terengganu, Malaysia concluded that flood occurrence in Malaysia is a result of a combination of factors; high intensity rainfall which is the primary cause of flood in Malaysia, low water current in the river regime, back water phenomenon during high tides and velocity and direction of wind that opposes the direction of river flow (Barzani Gasim et al., 2007).

## **Description of the Study Area**

The study area focused on regions that were affected by the worst floods in December 2014 and January 2015 including the state of Kelantan on the northeast Malaysia and Temerloh in the central area of Pahang. Both regions have a tropical climate with temperatures from 21 to 32 °C and intermittent rain throughout the year (CEDMHA, 2016). Flood events in these regions have affected subsectors such as housing, health, education and cultural heritage including direct impact and indirect impact. This includes people displacement, demographic changes, insecurity and health effects (Abu Talib et al., 2018). The field study area comprises five sample districts located in two regions, including four districts in the rural state of Kelantan in the northeast of Peninsular Malaysia, and five villages in Temerloh. All sample sites are considered flood-prone areas, with some sites located within the Kelantan River Basin which discharges into the South China Sea and other sites situated at the junction of the Pahang River and the Semantan River (Chan, 1995). The field study included interviews with members of local authorities, community leaders, and groups of flood victims in addition to questionnaire forms given to local people. The field study observed the escalating damage bill in these districts that can be attributed to uncontrolled development within the floodplains over the past decades, and also witnessed the impact of flood frequency and magnitude which resulted in social-economic disruption and created much discomfort to local residents. Figure 1 shows an area highlighted in red which indicates the locations covered by the study in Kelantan and Temerloh, including many meetings and interviews conducted in the Malaysian capital Kuala Lumpur, map source (Picture Tomorrow, n.d.).



Figure 1: Highlighted area in red shows the location of the study area, Kelantan and Temerloh regions.

## State of Kelantan

Kelantan is a rural state in the northeast of Peninsular Malaysia, Kota Bharu is the riverside capital and home to royal palaces such as the wooden Istana Jahar (Rashid & Amin, 2014). The field study covered four districts which were affected badly by the 2014/15 flood events including; Kota Bharu, Pasir Mas, Kuala Krai and Gua Musang. Flood events in December 2014 lasted for more than one week of continuous rains in the state. This was unprecedented as they created the largest flood recorded in the century (Alias, N. E. et al., 2016). The result of this intense, heavy rain between 14th and 19th December created imbalance between the input and output of water discharge in the channel in the short term and the rivers exceeded the danger level by 17th December (Yahaya et al., 2015). The water level exceeded the carrying capacity of the tributaries of the Galas and Lebir Rivers because of increased water volume that surged into the main Kelantan River, causing water to flood the banks in the surroundings of many cities including Dabong, Gua Musang, Manik Urai and Kuala Krai (Yahaya et al., 2015). Also due to the geographical location adjacent to the coast of the South China Sea and the expansion of settlements on the river flood plains the situation was exacerbated by tidal impact from the coast (Yahaya et al., 2015). Some news reports on 29th December 2014, show that during the flood, large parts of Kelantan were flooded, causing displacement of more than 151,072 residents and 10 people were killed on 29 December 2014 (Yahaya et al., 2015).

## Temerloh District

Temerloh is a district in central of Pahang, the large state in Peninsular Malaysia and it is the second-largest town after Kuantan, situated at the junction of the Pahang River and the



Semantan River, and located about 130 kilometres from Kuala Lumpur along the Kuantan-Kuala Lumpur trunk road (MPT, 2016). The district of Temerloh area is 2,251 square kilometres, consists of 10 parishes and its population is 165,451 people, including 71.4 per cent Malays, 15.8 per cent Chinese, 7.8 per cent Indian and 5 per cent others (Aziz et al., 2016). A study by Ngah et al. (2016) shows that there has been rapid development in Temerloh in recent years and numerous housing estates have been built around the river banks which make the residents vulnerable to flooding when it occurs. Although the district is a flood-prone land and regularly affected by major flood events, the impact of the 2014 floods in comparison with previous years is more severe because of higher population density near floodplains (Ngah et al., 2016). As from 25th December 2014 the Pahang River at Temerloh rose rapidly at about one meter a day and many residents were caught unprepared, and by January 2015, all major roads in Temerloh were affected except the old road from Temerloh to Kuala Lumpur, making most towns and villages inaccessible (Ismail, K. et al., 2017).

The field study covered five villages within the district, which were hit by major flood events between December 2014 and January 2015 and resulted in more than 20,000 flood evacuees and more than 6,450 people displaced (Ismail, K. et al., 2017). The field study focused on the condition of the areas affected by flooding and explored the views of victims about problems they faced and the support they received from local authorities and community leaders. Although the Temerloh district was the worst district affected by flooding with the second-highest number of Disaster Rescue Centres (DRC), the number of communicable diseases reported from this district was only 339 cases, which is 5.7 per cent of the population (Ismail, K. et al., 2017). This was explained by the fact that medical and health activities were temporarily paralysed since many of the staff were themselves affected by flooding (Ngah et al., 2016).

## **RESEARCH METHOD**

A literature review was performed to review published academic and consultancy work to obtain detailed knowledge and informative data. This developed a broader understanding of the natural hazards in Malaysia, and highlighted some challenges to adopting a new approach to empower local communities and stakeholders to manage risk. The review included the flood history in Malaysia and the impact on society and economic sectors. Additionally, to identify how local authorities responded and managed disaster during the 2014/15 flood events, and assess to what extent local communities' response was effective. Furthermore, a mixed-method approach using questionnaires and semi-structured interviews was adopted for this research to gather primary data from two major areas affected by flooding in Malaysia namely; Kelantan on the northeast of Peninsular Malaysia and Temerloh in central Pahang. Two samples of semi-structured interviews were chosen to gather information and data for this research (Mcewen et al., 2018). First, a key actors sample which focused on interviews with local authorities including Malaysia Civil Defence Force members to understand how local authorities have integrated with the local communities and support their effort to be engaged, particularly in the events of flooding. Secondly, a local level sample which includes interviews with local volunteers and residents.

Interviewee Number	Organisation /Profession
Interviewee 1	Professor at Faculty of Social Science and Humanities, the National University of Malaysia
Interviewee 2	Group of flood victims, Pasir Mas District
Interviewee 3	Director at Policy Planning and Coordination Division, Malaysia Civil Defence Forces
Interviewee 4	Member of the Policy Planning and Coordination Division, Malaysia Civil Defence Forces
Interviewee 5	Member of the Communication and Rescue Organisation in Pasir Mas
Interviewee 6	Volunteer at the Communication and Rescue Organisation in Pasir Mas
Interviewee 7	Volunteer at Malaysia Civil Defence Forces in Gua Musang District
Interviewee 8	Group of flood victims, Gua Musang District
Interviewee 9	Head of department at Malaysia Civil Defence Forces in Gua Musang District
Interviewee 10	Head of department at Malaysia Civil Defence Forces Temerloh District
Interviewee 11	Researcher at International Islamic University of Malaysia
Interviewee 12	Community leader at Kampung Paya Dalam, Temerloh District
Interviewee 13	The district Chief, Temerloh District and Land Office
Interviewee 14	Chief assistant, Temerloh District and Land Office
Interviewee 15	community leader at Kampung Megat, Temerloh District
Interviewee 16	Head of department at Malaysia Civil Defence Forces in Temerloh District
Interviewee 17	Officer at Malaysia Civil Defence Forces in Gua Musang District
Interviewee 18	Head of Department, Mercy Malaysia

The semi-structured interview process focused on engaging with experts from a wide range of disciplines that deal with the post-disaster conditions, provided flexible conversations with each participant based on his or her expertise area, and make it possible to navigate a complex nature of disasters within the limited data collection period (Lee, 2014). It is critical to narrow the focus of the research before conducting the interviews by formulating specific questions to generate data (Kitchin & Tate, 2013). Also, for semi-structured interviews with key actors a list of questions was prepared beforehand, but additional questions were asked as the interviews progressed, and all interviews were tape-recorded and transcribed. These interviews were carried out at the end of the research period, and their purpose was primarily to clarify information and issues that influenced the research. Interviewee Sampling: the criteria for selecting participants was based on selecting individuals who were qualified to give constructive responses to research questions. It is notable that the interview participants expressed a preference towards being interviewed as an “individual” participant rather than as a representative of an organisation. All interviewees were offered anonymity to encourage open and frank dialogue, and the permission of individuals to quote their responses was obtained. The interviews focused on broad themes:

1. To assess the community learning on risk management that took place during the 2014 events and identify ways in which community response can be improved
2. To identify to what extent local communities could participate on DRM/DRR in order to reduce disaster impact and their vulnerability
3. To critically review current state-led policies and strategies for risk communication and education and post disaster asset management

### **Local Communities responsibilities during 2014/15 events**

There are many regions in Malaysia vulnerable to natural hazards including floods and landslides (CEDMHA, 2016), and although flooding occurs as a result of cyclical monsoons and inadequate drainage system, the 2014 flood events in both regions; Kuantan and Kelantan on

the east coast of Peninsular Malaysia, are considered as extraordinary events because the water level of three major rivers rose dramatically above the sea level (interviewee 1).

### **1- In Kelantan State:**

The geographical location of Kelantan state adjacent to the coast of the South China Sea and major settlements built around flood plain areas are the reasons behind the exposure of local people to small frequent flooding which occurs every 2-3 years on average while large floods are generally less frequent (Yahaya et al., 2015). In the past, the majority of local people lived near the flood-prone area or low-lying areas as they learnt how to live with the annual flood events and have traditionally managed to live with water by adopting a simple architectural design for their houses to reduce the effects of flooding (Yahaya et al., 2015). However, during the field study, horrifying stories were heard about local people's experiences during flooding, including families who were surrounded by water and did not know where to go. They managed to use fireworks to alert rescue teams but they waited for more than six hours to be rescued (interviewee 2). Meeting with flood victims made it clear that a lack of flood risk awareness within local communities is the main reason that people ignored the warning messages that they received from local authorities' agencies to evacuate their homes. Also the lack of an adequate number of well-equipped relief centres is another reason that local people did not know where to go during flooding (interviewee 2).

*"In Kuala Krai, hundreds of the flood victims residing in the low floodplains fled to nearby mountains and were trapped there for several days. The estimated loss is about MR 2.8 billion. The actual losses are higher considering loss of economic productivity, compensation to victims, reconstruction, among others." (Yahaya et al., 2015, p55)*

However, as Kuala Krai is the district most affected by flooding aftermath, MCDF is delivering a special programme to local communities in this area along with Mercy Malaysia to train and raise public awareness to disasters (interviewee 3). Also, with pressure from the increasing population, poorer families expand their settlements in the floodplains which increases their vulnerability and the numbers of victims in severe flood events (interviewee 4). Nevertheless, Weng (2004) in a study about integrating official and traditional hazard management in Malaysia, stated that a lack of understanding of the social and traditional mitigation measures and knowledge of local people by the government and local authorities is the reason behind ineffective disaster management. In this respect, there is a need for local vulnerability assessment to minimise exposure to risks and to develop the individual, social and institutional capacities to withstand natural hazards and reduce disaster risk impact (UNISDR, 2004).

*"Although modern scientific knowledge for disaster risk management is invaluable, it is essential to recognise the role of traditional and local knowledge in enhancing the resilience of local communities. Lessons can be derived from the traditional and local practices that have been applied by communities over centuries to cope with disasters." (Ngwese et al., 2018, p15)*

On the other hand, in the Pasir Mas district, it was noticed that local people and volunteers at the local Communication and Rescue Organisation were trying to avoid negative comments or criticism of local authorities or government efforts to manage disasters in their district. Surprisingly, during the field study visits to various locations in the district, many flood victims mentioned that during the 2014/15 flooding, there was a lack of local government agencies including MCDP to support flood victims, and only local volunteers and international NGOs with Mercy Malaysia helped them on the evacuation and rescue operation.

It is clear from the questionnaire respondents that residents of the Pasir Mas district are not engaged with any activities organised by local authority's agencies. For instance, the results indicate that 59 per cent of local people in Pasir Mas were not aware of any activities planned by MCDP whereas the respondents in Kuala Krai and Gua Musang within the same state show a high percentage of activities awareness. This indicates that local authorities in Pasir Mas lack communication and coordination with local people. Also there is a lack of resources and funds for MCDP's activities to educate and raise risk awareness and provide services at a local level. However, this district provides good examples of how to empower local people by developing their own traditional knowledge on managing risks to enhance the resilience of their local communities. For example, in this district, each village has a group of volunteers who are trained members of the Communication and Rescue Organization (CRO), and their duties are to support local people during emergencies. CRO members are also dealing with community leaders in villages and rural area to pass alert messages to local people and managed to create links of communication and coordination between them and other agencies and national and international NGOs (interviewee 5).

“Local people in general have learnt from their past experience with flood events how to protect themselves and their assets. We also as team of local volunteers try to learn from our past mistakes and make things better when disaster happens again.”  
(i5, Manager at the Communication and Rescue Organisation, Pasir Mas)

Furthermore, after the 2014 flood events in the Pasir Mass district many people adapted living with water and approached simple architectural design solutions for their houses by elevating the structure above the base flood to protect their properties, also store food and their own boats to be able to evacuate during severe flood events. interviewee 6 explained that although most of the people in this region have the experience, skills and preparation to cope and deal with severe flooding events, sometimes people become stuck in their homes in villages and need to call for help.

In the Gua Mjusang district, most people surveyed said that they did not receive any training to raise awareness to flood risks by local authorities or NGOs before the 2014 disaster. However, volunteers from MCDP are making huge efforts to educate the general public and emergency kits are being provided to many households in this district (interviewee 7). Interestingly, in Kelantan state, the survey information shows a high percentage of respondents who are relying on the national television or radio to be alerted for potential flood events. However, in the Gua Musand district, more than 50 per cent of the respondents said that they keep informed by social media and local agencies along with national television. Nevertheless, these tools are not utilised yet to educate and raise awareness of the general

public in Malaysia, as people, in general, seek valid information from respected sources, including community leaders, radio, national television and websites before they take any actions (Societies, 2011). In addition, although the questionnaire shows that the majority of the respondents understand how to act when they receive a flood warning, there are still nearly 30 per cent of the residents in these districts who do not receive early warning messages as an advance notice of flooding to be able to leave their homes in time and save their lives. Research by (Alias, N. A. et al., 2018) about flood disaster management in Malaysia, concluded that there is still uncertainty over if or how recipients of warning messages will respond, as their actions are often ineffective and many people will do something else which results in less time to save their belongings. Furthermore, although local authorities' agencies are trying to achieve a level of preparedness within local communities, a lack of funds, ineffective communications and a lack of capacity in relief centres are still the main obstacles in the management process of disasters (interviewee 9). Also, sometimes local communities misunderstand certain information delivered by local authorities because of the lack of communication and this has resulted in the spread of uncontrollable viral information that may affect flood victims' actions during disasters (Alias, N. A. et al., 2018).

With regard to local people, access to the internet and the use of social media is important to keep people connected during and after disasters and to share news, photos, videos and information about flood events in Kelantan state. The questionnaire shows that there are about 70 per cent of the respondents have access to social media. However, 30 per cent are not connected because they lack access to the internet. Therefore, local authorities and Malaysian central governments need to improve their communication channels to keep local people connected in cities, villages and rural areas to build resilient communities. Empowering local communities through social media should include sharing information, discussing and planning what is being done to manage the risks and what they can do next, and also raise risk awareness to support people during and after a disaster (Duffy, 2012).

## **2- In Pahang State**

In this state, local people experienced the worst flooding in 43 years, as during the 2014/15 flood events 81,927 evacuees were forced to leave their homes and move to disaster relief centres (Aziz et al., 2016). Also, there were 7,052 households and 29,204 victims affected by flooding in the Temerloh district in the centre of Pahang, which was seven times worse than the previous severe floods in 2007 (Alias, N. A. et al., 2018). The flood had a huge impact on the main administrative buildings in Temerloh which resulted in disruption of administrative and commercial activities as well as public utilities and basic amenities including electrical, water supply and telecommunication systems (interviewee 10). However, it was remarkable that a number of medical and health teams were arranged to execute control and preventive activities to avoid potential disease outbreaks (Rafidah , et al., 2016). Nevertheless, lack of public awareness and preparedness level were not the only reasons for poor emergency responses, as poor leadership, inadequate equipment, disruption of electricity supply and telecommunications together with transportation problems were among the main factors in the ineffective disaster management (Rafidah et al., 2016). Kuantan, the state capital of Pahang, had experienced severe flood events in December 2013, and local people are generally accustomed to flood events every year due to the monsoon season (Chong et al.,

2014). However, the flood events in December 2014 had not been anticipated and local people and local authorities were unprepared to deal with such a level of a disaster. The level of distribution was huge and many houses were washed away (interviewee 11). The unexpected flooding events in this district caused chaos to the affected community with 23,549 evacuees placed in 61 disaster relief centres (Aziz et al., 2016). However, interviewee 11 explained that many areas in the northern part of Kuantan experienced unusual rainfall and although local people did not receive warning or information from local authorities, most people were well prepared.

“I believe that people were somehow prepared during 2014 flooding and that reflected on the number of victims who are evacuated to relief centres and the total number of people who passed away because of the disaster. People managed to save their lives with a great support from local volunteers at the Village Development and Security Committee<sup>1</sup> (JKKK) as they notified and helped local people to evacuate.”  
(iRA3, a research, Deputy Dean, Malaysia International Islamic University)

In terms of training and raising public awareness to flood risks in the Temerloh district before the 2014 flood event, the results of questionnaire questions indicate that the majority of the residents hardly received any training to be able to deliver first aid during emergencies in comparison with percentage of respondents in the other three districts. However, it was stated by interviewee 12 that there were many training sessions provided by local authority's agencies for local people but not all the people were concerned enough or willing to attend. In this respect, during the field study in this district, it was clear that MCDF are building a good relationship with residents, mainly in villages and the rural area. Additionally, it was explained by the Temerloh District Chief that there were many challenges faced by local authority's agencies in 2014 because of the lack of resources, communication skills and coordination between local authorities' agencies and local communities (interviewee 13). However, the District Chief confirmed that many changes are happening and the disaster management teams are in charge, also the Disaster Operation Control Centre now includes representatives from MCDF, Police, Fire Department, Public works Department, Welfare Department, Health Ministry and a number of local community leaders for better communication and coordination. During the meeting with local authority's agencies in the Temerloh district, evidence was presented by the District Chief Assistant that the region is ready and well prepared to face any flood events in the future and local people are generally prepared and the awareness of the flood warning system is better than it used to be before the 2014/15 events (interviewee 14).

With regard to the sharing of flood knowledge, local people in the Temerloh district collect information about river level and observe the duration of rainfall, also, some people conduct their own research and analyse their collected data about river water levels to understand and predict when flooding is going to happen (interviewee 15). However, it is unfortunate that this knowledge and data is not taken seriously by local authorities because they say that this information needs to be inspected, investigated and verified by experts in this field (interviewee 4). In addition, in both states, although Malaysian people generally believe that disasters relief and management are the responsibility of the federal government and local

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<sup>1</sup> The Village Development and Security Committee is known in Malay language as Jawatankuasa Kemajuan dan Keselamatan Kampung (JKKK).

authorities' agencies (Chan, 2012), after the flood events in 2014/15, most people in these states are now registered to receive alert warning messages, and people who are not registered receive the information about potential flooding through their community leaders in villages and rural areas (interviewee 16). It is also evident that people are aware that they have to be evacuated or taken to rescue centres when disaster alerts are released because the rescue groups and other relief agencies cannot reach them in time when a disaster event is ongoing (interviewee 17).

*“The communication between the affected residents and the relevant government agencies is crucial, particularly during a flood event, as services such as evacuation and rescue operations, and the setting up of temporary shelters for the victims, must be established immediately.” (Zahari & Ariffin, 2013, p5)*

In terms of volunteer work, it is undeniable that volunteers play an important role in helping flood victims and providing optimal health services to affected populations (Rafidah et al., 2016). However, some volunteers' efforts failed because DRM procedures lacked proper guidelines in managing and coordinating volunteers during and after disaster, also some volunteers were not reporting to the Disaster Operation Room (DOR) before they started serving the public and some were poorly equipped or trained (Rafidah et al., 2016). Also, volunteers' missions were affected by many challenges as they used privately owned four-wheel drive (4WD) vehicles as transport during major flood events in these two states to reach the affected areas. However, accessibility via roads was not possible because of flooding (interviewee 6). Therefore, although there is a high demand for rescue boats, local authorities need to provide these facilities to local volunteers and NGOs to reach areas most affected by natural hazards in the future. Also, the Disaster Relief Coordination Centre (PDRCC) should prepare and provide maps of safe and accessible routes to volunteers and medical teams to ensure the efficiency of their rescue and volunteers safety (Rosli et al., 2016). With regards to volunteers role in the post-disaster phase, Zubir & Amirrol (2011) in their study about Flood Risk Reduction through community participation, found that there is a significant link between emergency responses and the existence of sound volunteer management systems. Therefore, governments should invest in building a good relational structure between volunteers, social networks and civil society to increase the efficiency of post-crisis recovery. In this respect, Mercy Malaysia, the main national volunteer organisation in Malaysia, is making efforts to involve local communities in managing the risks to rebuild communities after a disaster and raise their awareness on how to prevent risks in the future (interviewee 18). Engaging the general public with local agencies and NGOs, improves their ability to respond to natural hazard emergencies effectively and enhances the disaster management procedures (Chan, 2012).

## **CONCLUSION**

The study shows that there is a lack of management procedures and funds to reduce the impact and magnitude of enormous flood events. In this respect, empowering the public awareness to flood risk and the benefits of local flood knowledge could be achieved by enhancing local communities' knowledge and awareness of risks. The survey carried out in

Kelantan and Temerloh was used to identify community hazard learning, the adaptation needs of communities and the limitations of current local authority policies. The outcome shows that local people have existing measures to reduce the impact of flood on themselves and their assets. However, lack of funds to train local people results in a large number of people who are not ready for severe flood events. In terms of the level of preparedness and the warning system, approximately half of the residents received flood warning messages which is a relatively low figure and indicates that a significant proportion of the people are vulnerable in these regions. However, the percentage of residents with some level of awareness of safety measures is relatively high and shows that local people have their own measures to mitigate flood risks. It was also noted that there are a number of districts which lack connection with local authorities' agencies and local people rely on local volunteers for rescue operations during flood events. In other districts it is clear that local agencies, for example MCDF, are making good links and communication channels for local people which make it easy to deliver messages and raise risk awareness.

With regards to community awareness, there is a need for local people to participate in disaster reduction interventions and give their input on preparedness initiatives in order to make emergency planning more effective at a local level. Moreover, local people should be involved in decision making on policies and strategies in order to be able to take control over the disaster event by utilising their knowledge and experience to improve tools for managing disasters. Also, local communities should be provided with appropriate tools and facilities for emergency responses which will support local authorities and local actors to reduce disaster risks. In addition, when studying the role of local communities during the 2014/15 flood events, it become clear that to enhance the resilience of local people, community leaders in villages and small towns should be involved with local authorities because they can provide information and cooperation on the ground and they can be responsible for distributing disaster relief goods and help in the reconstruction phase. Moreover, raising people's awareness of risks should be added to education programmes in schools and utilise social media, local and national TV networks to deliver information and education material to the wider population and help build better capability and more resilient communities.

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# Exploring resilient characteristics, social-ecological resilience and adaptive capacity: An environmental volunteering case study

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**Keywords:** Environmental Volunteering; Social-Ecological Resilience; Impact Measurement; Focus Group Interviews.

## ABSTRACT

*Engaging in civic ecology practices like environmental volunteering has been shown to offer a range of benefits, such as food production and social connectivity. There has been a growth in studies exploring the potential impact that engaging in these practices has on people's social-ecological resilience. However, none have fully explored those characteristics which can promote and support such relationship. The study aims to provide further understanding about social-ecological resilience and examines how engaging in environmental volunteering has the potential to promote as well as strengthen social- ecological resilience. This relationship is explored through the lens of four characteristics regarded as key attributes fostering resilience in social-ecological systems: activity, self- organisation, connections and skills and knowledge. To examine these characteristics, the study used focus groups interviews, hybrid thematic and descriptive analytical methods. This study is reported from the perspective of local community groups in Greater London (UK) who engaged in environmental volunteering activities as a case study. Overall, this study finds there to be variability in these characteristics explored amongst local community groups. This suggests that the relationship between social-ecological resilience and environmental volunteering is rather complex.*

## INTRODUCTION

Recently the UK government has set out several campaigns to encourage resilience building in communities (Steiner and Markantoni 2014). These campaigns are guided by the view that communities have the ability to take responsibility for their own actions as well as drawing on their skills, connections and expertise to develop solutions to local challenges (Steiner and Markantoni 2014). In response, there has been a growth in studies exploring the potential impact that engaging in environmental community-based practices has on people's social-ecological resilience (e.g. Tidball and Krasny 2007; Dolan et al. 2015).

This article reports a study which implements a cross-sectional research design, using focus group interviews. The study aims to examine those characteristics which can promote and support social-ecological resilience of those who engage in environmental volunteering. It is reported from the perspective of local environmental community groups in Greater London.

## Social-ecological resilience, civic ecology and environmental volunteering

Social-ecological resilience is described as the capacity of social-ecological systems (e.g. biosphere and communities) to maintain its structure and functioning despite any perturbations and other stresses (Folke et al. 2016). The concept itself draws on two systems: social and ecological (also termed the biosphere). Social systems are those systems integrating human dimensions, such as community, economic, societal, political and cultural. The biosphere refers to the global ecological system which integrates all living beings (e.g. humans) and their relationships with their interactions with Earth's dynamic systems, i.e. the water cycle. When integrated, social-ecological systems place emphasis on the interconnectedness between them, where both systems shape, are shaped by and evolve together, from local to global scales (Folke et al. 2016).

There has been a gradual increase in the number of studies examining the relationship between resilience and social-ecological coupled systems (e.g. Norris et al. 2008; Kelly et al. 2015). Of these relationships, there has been a growth in studies exploring the impact that engaging in civic ecology practices has on local urban communities (e.g. Dolan et al. 2015).

Civic ecology can be defined as community-based practices to monitor, conserve, manage and create green infrastructures in urban cities, such as community gardens and allotments (Krasny et al. 2014). Environmental volunteering is a type of civic ecology practice (Seymour and Haklay 2017) and has been shown to offer a range of benefits (e.g. Krasny et al. 2015). These include strengthening ecosystem and social outcomes (e.g. food production and social connectivity) from individual communities to larger ecosystem system scales due to each scale's interactive nature and feedback loops (Barthel et al. 2010; Krasny et al. 2015; Folke et al. 2016). Such social and ecosystem outcomes generated from civic ecology practices have also been suggested to foster local urban resilience through its ability to develop personal and collective capacity (e.g. adaptive co-management) in response to environmental change and sustain themselves (Krasny and Tidball 2007; Kelly et al. 2015). However, whilst recent studies have provided useful insights into the relationship between resilience and social-ecological coupled systems, they remain largely generalised in scope and have not yet fully explored selected characteristics which can promote and support such relationship in-depth. Nor have they used collaborative approaches (e.g., focus groups) and provided useful feedback to the community-based groups themselves so that they may use it to strengthen their future social-ecological resilience and related benefits (e.g., ecosystem and social outcomes).

It is therefore anticipated that our current understanding of those characteristics, which could help support the development of social-ecological resilience, would be better understood if we identify which enablers to implement as well as barriers to consider. This in turn would allow community-based groups (e.g., environmental volunteering groups), to better develop their civic ecology practices to encourage these characteristics. This would also be valuable in assisting practitioners in socio-ecological and ecosystem service fields in their understanding of how characteristics emerging from the engagement in these civic ecology activities may strengthen ecosystem and social outcomes. Therefore, this article aims to explore this gap in knowledge.

## **Social-ecological resilience and the Green Impacts project**

The Green Impacts project was a two-year research funded project (April 2012 to April 2014), undertaken by sustainable development consultancy, Resources for Change (see [www.r4c.org.uk](http://www.r4c.org.uk)), and UK environmental charity, The Conservation Volunteers (see [www.tcv.org.uk](http://www.tcv.org.uk)). It explored how social-ecological could be generated or enhanced when people engage in environmental volunteering.

In particular, the study focused on the following characteristics: activity, self-organisation, social connections, and skills and knowledge. These four characteristics were selected for this study have been highlighted by other researchers as key attributes fostering resilience in social-ecological systems and have received most attention in this research area (e.g. Krasny and Tidball 2007; Folke et al. 2016).

Activity refers to the engagement and regularity of a person's involvement in an activity or interaction within a community group. Within social-ecological resilience, the type as well as level of activity that one or more members of the group engage in can facilitate and support social systems whilst serving as a source of input to carry out activities to manage and sustain ecological systems (Krasny and Tidball 2012). These can include meetings, local events and group activities.

Within social systems, self-organisation can refer to a group of peoples' abilities to work together towards a collective goal, having the ability to make decisions, manage resources and readily adapt to changing conditions. Within social-ecological resilience, self-organisation can be viewed as an adaptive governance process (e.g. learning by doing), leading to the resilience of both social and ecological systems in response to change. This can encompass a host of activities, e.g. developing objectives and managing resources (Krasny and Tidball 2007).

Skills and knowledge are two separate yet relating concepts. Knowledge refers to factual information and theoretical concepts learnt through sensory input (e.g. reading and listening), whilst skills is the ability to apply knowledge to situations developed through practice (e.g. problem solving and driving). Within social-ecological resilience, skills and knowledge that one or more person possess in a group can be viewed as tools for promoting or supporting social and ecological systems that can leading to action and advocacy (Tidball and Krasny 2007). These can be both technical or interpersonal and include communication, administration, practical woodland management and ecosystem functioning.

Finally, social connections or networks are the relationships you have with those around you, such as co-workers, friends, family and stakeholders. Within social-ecological resilience, social connections are those who create and support social systems whilst serving as a source of input to carry out activities to manage and sustain ecological systems. These can include funders, environmental volunteers, project officers and local business partners (O'Sullivan et al. 2015).

## **RESEARCH METHOD**

To examine those characteristics which can promote and support social-ecological resilience of those who engage in environmental volunteering, focus groups interviews were used.

### **Participants**

Participants were recruited through gatekeepers and email recruitment strategies (manually searched for online using a search engine. There are various strengths to these methods, including accessing unknown or hard to reach populations, diffusing knowledge about the study, fostering collaborative with participants, as well as overall cost-effectiveness (Bryman 2012). The study sample comprised of 70 voluntary consenting participants from 13 local environmental community groups consisting of between 4 to 10 participants per group.

These local community groups are all not-for-profit organisations and charities that engaged in environmental volunteering activities within Greater London (UK). Greater London was selected as a study location due to the distances travelled, time and resource availability of the authors.

### **Research design and data collection**

A snapshot and cross-sectional research design was used to explore the four selected characteristics. 13 focus group interviews were conducted for an hour and a half duration (n=20 hours) with local community groups from January to September 2013. Focus group interviews were held at community centers and offices used by local community groups, due to time availability of participants.

The focus group interviews were separated into two parts: icebreaker and group discussion. Ice breaker sessions were used at the start and asked participants volunteers to say their name and a little bit about themselves as a way of introduction. This is a pre-intervention strategy used to engage volunteers in understanding the objectives of the study, as well as allowing us to become acquainted with them and increasing group interpersonal interactions (Kilanowski 2012). The focus group discussion followed directly after the ice breaker session, to collect data to explore the four characteristics we outlined in the previous section. The following four open ended questions were used to initiate the focus group discussion: how active would you say your group was, how self-organised would you rate your group, how connected would you rate your group as, and, what level of skills and knowledge would you rate those in your group? Each question was with researchers from UK academic institutions and other non-governmental organisations with a good level of knowledge on social-ecological resilience and environmental volunteering as well as experience of conducting similar interviews, to enhance face validity (Patton 2002). This feedback strengthen the questions, ensuring they were clear, neutral and sensitive in nature, making alterations where required (Bryman 2012).

The groups were then asked to collectively rate themselves for each of the four questions according to how much activity and self-organisation they perceive themselves to be engaged in as a group as well as the quality of their connections, skills and knowledge they collectively have. Each question was rated using a 5-point Likert scale with a total score of 20, 5 being the

most and 0 being the least (Joshi et al. 2015). As ratings were based on a group consensus, it is uncertain whether data generated might be subject to group effects (e.g. dominant group members, and other group dynamics). Rating scales for characteristics 'activity' and 'self-organisation' were based on their perceived frequency of occurrence (1 = "never", 2 = "rarely", 3 = "sometimes", 4 = "often", 5 = "always"), whilst for 'connectivity' and 'skills and knowledge' scales were based on their perceived quality (1 = "very poor", 2 = "poor", 3 = "fair", 4 = "good", 5 = "excellent"). Outcomes of scales were therefore not comparable across each of the four characteristics. A probing technique was also used throughout to encourage elaboration or explanation, using 5 focused follow-up questions (e.g. "Can you tell me more about that?"). The technique has been shown to increase the richness and depth of responses (Doody and Noonan 2013). The technique also allowed us flexibility to focus on promising avenues of conversation that might not have otherwise been in the list of questions (Bryman 2012). All data collected was made confidential and anonymised, before being stored in compliance with the Data Protection Act (1998). Focus group interviews were audio-recorded and transcribed (Patton 2002).

### **Data analysis**

Data analysis using a mixed method approach consisting of two main parts: descriptive summary of groups' self-reported ratings for the four characteristics, and a hybrid thematic coding analysis of focus group interview transcripts (see Fereday and Muir-Cochrane, 2006 for full method). Descriptive summaries were performed using R (Version 3.1.1) and qualitative analysis using Atlas.ti (Version 8).

Groups' self-reported ratings were summarised and descriptions for the four characteristics using a descriptive approach, due to the nature and scale of data collected. This flexible approach was used to reveal and visually represent the underlying features of the dataset, using both graphical (e.g. bar charts) and non-graphical (e.g. descriptive) summaries (Jebb et al. 2016).

The hybrid thematic coding analytical approach was conducted by the author and a fellow PhD student, both with expertise in social-ecological resilience. This technique enabled flexibility to explore emerging data that was new or expanded on the predetermined codes that might not have otherwise been captured thereby enriching study findings. The technique also facilitated a systematic approach, assessing to what extent engaging in environmental volunteering has the potential to strengthen social-ecological resilience as well as whether the four characteristics explored were contributing factors (Fereday and Muir-Cochrane 2006). Intercoder reliability was measured using a simple proportion agreement method due to the large-scale variations in coding, and exploratory nature of the study (see Campbell et al. 2013 for full method). Intercoder agreement scores of 79% percent were identified which is deemed acceptable. This was achieved using a mutual codebook and interrater agreement between coders on coding categories and level granularity (Campbell et al. 2013).

## RESEARCH RESULTS

### Social-ecological characteristics of local community groups

General descriptive summaries of the local community groups' (n=13 groups) self-reported scores for each of the four characteristics explored are found in Figure 1. Most groups (n=9) perceived the amount of activity they engaged in to be very high, describing themselves as "always" active. Few groups (n=4) perceived their activity levels across a broad spectrum of "never" and "often". By contrast, groups reported mixed scores for their overall amount of self-organisation they perceived themselves to be engaged in, again across a broad spectrum from "never" and "always". Further, no groups reported their level or quality of connections and skills and knowledge to be "poor", instead perceiving these characteristics to be "fair" to "excellent".

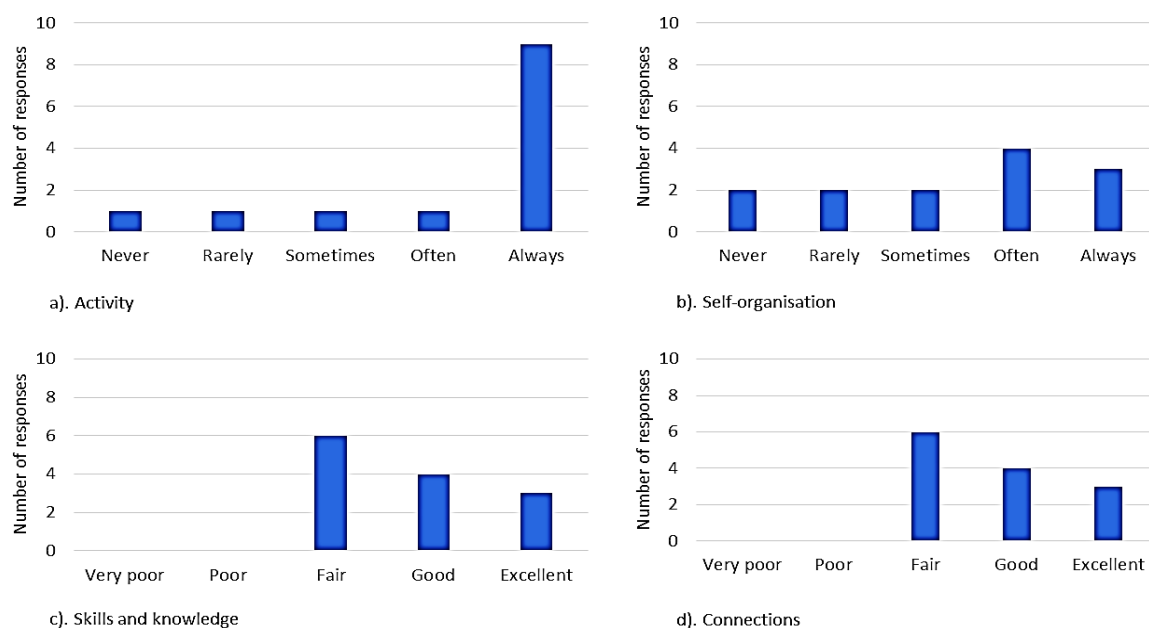


Figure 1. General summary of local community groups' scores for each characteristic.

Summarised descriptions of the four characteristics explored for the local community groups' (n=13 groups) are found in Table 1. Groups were involved in various types of activities within each of the characteristics explored. Number of activity types per characteristic ranged from 2 to 11. The frequency of activity types varied across the different groups. Similarly, there were mixed responses between groups in terms of the number of connections they had with local services, ranging from none to 10. There were also mixed findings in the number of group members being involved in the different activitytypes.



**Table 1. Summarised descriptions of the four characteristics explored for the local community groups.**

<b>Characteristic</b>	<b>Types of activities</b>	<b>Description</b>	<b>Frequency, number or quality</b>	<b>Number of group members involved</b>
Activity	Environmental volunteering sessions	Group members engage in a wide range of practical conservation and outdoor-based activities. These include food growing, pond weeding, dry stone walling, and coppicing trees.	Ranges from 2 days a week to monthly	All members
	Events	Educational learning programmes for schools, guided walks and fairs to sell local produce (e.g. vegetables or homemade chutneys).	Ranges from monthly to every 6 months	1 or 2 members of the group
Self-organisation	Fundraising and finance	Financially resource and manage the daily running of these groups. This can include applying for funding grants, organising membership fees and raising charitable donations.	Weekly to 6 months	1 or 2 members of the group
	Meetings	Organised meetings are used to discuss topics relating to the management of the local community groups. These include events, activities and resources. These usually involve most group members, with some groups including external stakeholders, governing bodies and funders to attend.	Ranges from weekly to monthly	4 to 10 members
	Management Plans	Written documents which provide a detailed description of group's goals, objectives, activities and resource management plans. These plans are usually reviewed at meetings (see above) and assigned to one or more members of the group.	Yearly to every 20 years	1 or 2 members of the group
Connectivity	Contractors	People or firms that are hired by the group to provide materials or to perform activities. These include building materials (e.g. wood), hired equipment and those licenced to coppice trees.	None to 6 connections	1 or 2 members of the group
	Local services	Schools, colleges, governmental ministers (MPs), education outreach programmes and local businesses (e.g. garden centres) which provide goods or services (waste management) to the community or town.	None to 10 connections	4 to 10 members

	Other non-governmental organisations	Independently run charitable trusts and community-led organisations. These includes friends of the local park, resident associations and rehabilitation groups.	None to 3 connections	4 to 10 members
Skills and Knowledge	Public relations, communication and media	Communicated key messages about their work or advertise upcoming events to local newspapers and through social media platforms. This is usually done by one or more members of the group who have pre-existing skills and knowledge in this area.	Ranges from non-experienced to experienced	1 or 2 members of the group
	Finance and resource management	Financial and resource organisation within the group, including overseeing the management of a funding grant and the allocation of equipment required for the group's activities. This is usually by one member of the group who has been assigned the role of 'treasurer' who have pre-existing skills and knowledge in this area.	Few members are experienced	1 or 2 members of the group
	Horticulture and conservation	A wide range of gardening and habitat management activities, including food growing, community gardening, pond weeding, dry stone walling, and coppicing trees. These activities are mostly undertaken by all members of the local community group, some with pre-existing skills and knowledge with others learning from these members.	Ranges from non-experienced to experienced	4 to 10 members
	Administration	The general organisation of the local community groups, including computing, organising, scheduling and recruitment. This is usually by one or two members of the group who has been assigned the role of administrator who have pre-existing skills and knowledge in this area.	Few members are experienced	1 or 2 members of the group

## Local community group responses

Overall, the 13 local community groups presented mixed responses to the interview questions. All groups reported to be engaged in a variety of different activities or interactions both within the group as well as the local community. However, differences were identified in the amount of activities each group engaged in. Reasons for these differences in activity levels related to a number of factors, such as issues surrounding landownership, financial resources, seasonal variability and ability to self-organise. For example, most groups (n=11) reported that they engaged in regular amounts of activities on a weekly or fortnightly basis, with one participant commenting:

*'We carry out various activities every Tuesday and Friday as well as the first and third Sundays of every month. Our activities centre on conservation, environmental education, and sustainable agricultural techniques due to them recognising that children are future guardians of the environment. We also organise Green Fairs in which organisations can come and demonstrate different skills or sell locally made organic products'.*

By contrast, few groups (n=2) noted having a low amount of activities. For instance, one participant stated:

*'We meet once every three to four months to have discussions. However, as four members are family or close friends, they sometimes talk about the green 'off the record' in-between this time. We work on the garden on a seasonal basis'.*

There was variability in group's ability to self-organise in relation to acquiring resources, decision making processes, as well as strategic aims for the future of the group and its activities. For instance, some groups have a future management plan in place which is supported through a regular funding source or self-sufficiency (e.g. membership fees). By contrast, others have no set aims or objectives relating to various reasons, such as no formalised decision-making processes, permissions for use of land, and lack of regular and consistent members:

*'It's hard to imagine the future ... There is no secure or regular funding in place or funding applications. [We] do not have plans in place to recruit new members because there is no membership'.*

All groups presented a good degree of awareness of their skills and knowledge base. These varied widely from those transferable skills and knowledge associated with some group members' existing employment, such as "teaching" and "project management", to those more specific to their groups' activities, including "conservation management", "horticulture", and "volunteer mentoring and co-ordination". Similarly, most groups recognised their ability to make a wider contribution to their local environmental and community work, with one commenting:

*'[We] serve the local community by providing herbs and lots of edible plants and educating young people who visit on school trips as well as those who have fallen out of school ... liaising with local shops and businesses for prizes for the summer events which they organise'.*

Most groups highlighted areas that they felt there was room for improvement, such as particular skills and knowledge as well as how these characteristics are distributed within the group themselves as well as those external stakeholders they connect with. For instance, as one participant stated:

*'We feel that more conservation knowledge is desired because knowledge of the plants specific to our reserve is limited. But logistics and cost limit our ability to do this. Also we feel somewhat uncomfortable with public relations and using newspapers, so more development of public relation skills are needed'.*

Finally, all groups reported a good degree of awareness of their social connections, both within the groups themselves as well as those external to the group. Examples of connections included family, friends, schools, other local community groups, funders, members of the councils, housing associations and contractors. However, differences were identified in the amount of connections each group had. Reasons for these differences in the amount of connections related to a number of factors, such as time availability, size of the group as well as how connections are distributed within the group. Of those groups who presented a wide range and amount of connections, many individual connections were shared equally across the group. Conversely, those groups reporting a low amount of connections identified the need to expand their connections and outreach as well as distributing connections more widely within the group to ensure their long-term sustainability.

*'Two of the group have the majority of the connections and each of these group members have different points of contact. This will be helpful in acquiring different skills and knowledge. Potential contacts are limited, but we could use them to meet the needs for working on the greenspace. These [potential contacts] could be the local garden centre, scouts, guides, local flower shop and national lottery funding. If these contacts are used effectively as well as our existing contacts our group could achieve its main aim of becoming an enjoyable space in a short amount of time'.*

## **DISCUSSION**

Overall, the study finds there to be variability in those characteristics (e.g. skills and knowledge) regarded by some to be key attributes in fostering social-ecological resilience (Krasny and Tidball 2007) amongst those local community groups who engage in environmental volunteering activities. This suggests that the relationship between social-ecological resilience and environmental volunteering is rather complex. Such knowledge is useful for practitioners, policy makers and researchers from the civic ecology field (e.g. environmental volunteering sector) not only for providing an understanding of existing behavioural characteristics of these local community groups and how these may relate to their overall social-ecological system outcomes. This knowledge could also be used to help design civic ecology practices to increase their long-term social-ecological resilience, identifying which enablers to implement (e.g. meetings and management plans) and barriers to consider (e.g. retention and funding resources) within those characteristics explored. Additionally, the collaborative approaches (e.g., focus groups) used in this study could also be viewed as valuable to relevant practitioners, providing useful feedback

methods to local community groups. Such approach could be used to strengthen those enabling characteristics in social systems (e.g. social connections), thus enhancing the environment's resilience and related benefits (e.g. social-ecological resilience). Further discussions about those four characteristics explored are outlined below.

In general, most groups perceive the amount of activity that one or more members of the group engage in as relatively high and centred on those activities which can facilitate and support social-ecological systems (Krasny and Tidball 2012). These findings resonate with similar studies (e.g. Krasny and Tidball 2007; Kelly et al. 2015; O'Sullivan et al. 2015). However, few groups reported a low level of activity. Reasons for these differences in activity levels relate to various factors, including issues surrounding landownership, sustaining motivation, financial resources, seasonal variability and ability to self-organise (e.g. Kelly et al. 2015). Further, differences were observed between groups relating to the types of activities they engaged in, covering a wide spectrum. These variable responses were often linked to those contextual factors as outlined above (e.g. financial resources and landownership). Such knowledge can be valuable from a project management perspective when planning for activities (e.g. weekly or monthly) which can lead to the promotion of social-ecological resilience. Through understanding their existing interactive activities and engagement behaviours, such approach can assist local community groups for planning for future goals they wish to attain and whether they are attainable.

In relation to self-organisation, our findings presented differences between groups in the amount and types of contributing activities they perceived themselves to be engaged in. These differences often related to contextual factors or a groups' existing practices to implement plans to increase their degree of long-term management and self-sufficiency (Steiner and Markantoni 2014). These included acquiring resources, decision making processes as well as strategic aims for the future of the group and its activities. Several factors might explain these trends, including community competence, adequate tangible support, use of co-produced knowledge, adaptive co-management system as well as flexibility (Norris et al. 2008; Tengö et al. 2014). Through evaluating self-organisation as such this could enable civic ecology practices, like environmental volunteering, to implement plans to increase their degree of long-term management and self-sufficiency. This can include adequacy of recruitment and retention, as well as the allocation of equipment and training resources (Steiner and Markantoni 2014). This is supported by research which shows that a group that is effective in self-organising has the resources in place to deliver its aims and have plans in place to gain new resources, as they are needed (O'Sullivan et al. 2015, Kelly et al. 2015).

Finally, groups were found to rate themselves similarly for their levels of social connectivity, skills and knowledge, ranging broadly from "fair" to "excellent". First, groups varied in the numbers of social connections they currently engage with. Reasons for these differences in the amount of connections related to several factors, including time availability, size of the group as well as how connections are distributed within the group (e.g. Krasny and Tidball 2007; Houston et al. 2015). Further, of those groups who presented a wide range and amount of connections, many individual connections were shared equally across the group. Conversely, few groups reported a low amount of shared connections, recognising their need to share these more equally. This importance to have a wide range of social connections external to the group that are shared more equally within a group has also been noted by

others (Tidball and Krasny 2007; O'Sullivan et al. 2015; Houston et al. 2015). This can permit groups to be more effective in working towards a collective goal, leading to the resilience of both social and ecological systems in response to change (Tidball and Krasny 2007). Second, all groups were acutely aware of their skills and knowledge base, both those within the group

as well as those of external stakeholders they connected with. Skills and knowledge varied widely from those transferable (e.g. teaching and project management) and interpersonal (e.g. networking), to those more specific to their groups' activities (e.g. environmental conservation and volunteer co-ordination). Further, most groups recognised areas for improvement. In particular, they highlighted the need to increase the distribution and sharing of skills and knowledge within the group. This view is shared by other resilience scholars (Krasny and Tidball 2007; Kelly et al. 2015), who comment on the importance of diversity when fostering social-ecological resilience as well as having the right set of skills and knowledge (e.g. environment specific and local knowledge).

### **Study limitations and future research**

There are two main limitations relevant to this study. First, findings observed were case specific to local community groups in the Greater London region that engaged in environmental volunteering. As these groups share goals with other environmental volunteering organisations in urban regions across the UK, findings observed in this study can be applicable to other similar environmental volunteering. However, it remains uncertain whether these findings can be applicable to local community groups in rural populations. It is therefore recommended that further work using the methods applied in this study would be beneficial to explore the social-ecological characteristics presented by other similar local community groups in rural regions. This would therefore enable one to determine whether these findings are more widespread amongst urban-rural populations.

Second, due to the nature of workshop discussions it is uncertain whether data generated might be subject to group effects (positive and negative), particularly as volunteers were already known to each other. Reasons for this include dominant group members, peer pressure and other group dynamics and may be responsible for incomplete or biased information processing. Future research therefore needs to identify potential influences of group effects by both measuring separate individual and group effects as well as through implementing additional methods (e.g., one-to-one interviews with participants).

### **CONCLUSION**

This study provides further insight on the nature of social-ecological resilience amongst local community groups within Greater London (UK) who engage in environmental volunteering, a type of civic ecology practice. This can be particularly useful to volunteering services and local community groups to create programmes which encourage those enabling characteristics to foster the development of social-ecological resilience. This knowledge would also be valuable in assisting practitioners in socio-ecological and sustainability fields in their understanding of how characteristics emerging from the engagement in these activities may promote ecosystem and social outcomes.

The study also identifies areas that warrant more research. For instance, this study serves as a case study focusing on the Greater London region. Future research should make further comparisons across the UK to explore those characteristics presented by local community groups that engage in environmental volunteering in other rural and urban regions. Similarly, future research therefore needs to identify potential influences of group effects by both measuring separate individual and group effects as well as through implementing additional methods (e.g., one-to-one interviews with participants).

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# Studying resource exchange through actor interactions in the smart city service ecosystem, using the service dominant logic

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## ABSTRACT

The detrimental effects of rapid urbanization have led to the urgent need to reconstruct the way in which cities operate and utilize resources. Smart cities have emerged as a possible solution towards more efficient urban environments. They are considered imperative for a sustainable future. While there is a plethora of research focusing on the technological, as well as the urban aspects of smart cities, there is a dearth of literature on the organisational and managerial issues arising by this rapidly emerging concept. Service dominant logic is applied as the theoretical framework, which views the target domain as an ecosystem. This research studies the interactions in the smart city ecosystem, that is, how smart city actors, namely the university, government, industry and civic society, exchange resources between them through interactions at organisational level. In order to identify these resources, exploratory qualitative interviews with 17 senior staff from representative organisations from the university, government and industry have been performed, while interactions with the civic society have been drawn upon from collected data of the other three groups. These were used to map the dyadic interactions that occur between organisations within the smart city ecosystem.

Early indicative findings of this study, suggest that university actors use urban data sourced from citizens and planning authorities, and funding from industry, to analyse and develop models and theories, while industrial actors appear to use this output and user data to create consumer services. The government appears to be both a regulator and an active player, by addressing emergent topics and providing funds and data. The civic society data has behavioural influence on the institutional norms under which the ecosystem operates.

The mapping of resources exchanged between these actors allows for a more efficient management of smart city organisations and consequently to managerial and organisational urban innovation, which may lead to the improvement of quality of life and well-being for citizens.

## INTRODUCTION

The world is facing unprecedented levels of urbanization (Dirks and Keeling, 2009). Half of the world population resides in cities, while ten per cent (10%) lives in only 30 metropolises (Dobbs et al., 2011). In 2008, 75% of the European population lived in urban areas, while this

percentage is expected to rise to 80% by 2020 (United Nations, 2011). Moreover, the urban population is expected to double from 2.6 billion in 2010 to 5.2 billion in 2050 (United Nations, 2011). Cities are already facing numerous challenges that are bound to increase due to rapid urbanization.

The concept of smart cities has emerged as a possible solution to these challenges. A smart city is a city that may aim to make itself 'smarter', more sustainable, efficient, equitable and liveable (NRDC, 2012). It uses information and communications technologies to make the infrastructure and services of a city more interactive and efficient (Belissent, 2010). A significant part of the existing literature on smart cities focuses on their technological aspects (Letaifa, 2015), while there are only few studies that address their organisational and managerial aspects (Chourabi et al., 2012). Technology is a means to achieve smart city and not necessarily the most critical factor (Paquet, 2001). Technology and other resources must be used in an intelligent and coordinated manner in order to transform urban centres to integrated, habitable and sustainable environments (Barrionuevo et al., 2012). The way in which smart cities operate by offering a balanced centrality between technology, institutions and citizens, can be described as a holistic urban system or an ecosystem, which supports value co-creation amongst all city stakeholders (Letaifa, 2015). The "smart ecosystem" of a city may provide multiple advanced, user-centric and user co-created services to its citizens (Yovanof and Hazapis, 2009). This ecosystem generates value through the use and re-use of information (Komninou, 2008). The mechanisms through which value is created, as well as, the ways in which value is managed in smart cities, has received little attention in the smart city literature, along with other managerial and organisational aspects.

By recognizing the research gap in the literature related to the management of smart cities and principally the lack of studies on smart city management for the realization of value, this research uses Service Dominant Logic (S-D logic), in order to study the resource exchange mechanisms of smart city organisations. S-D logic provides a theoretical framework that allows studying how smart cities actors operate both between each other and as an ecosystem. This facilitates a better understanding of the way in which resources are exchanged between them, and how these resources can be better managed. As the majority of smart city projects are publicly funded, more efficient management of resources will lead to more efficient public spending. This paper will firstly present the S-D logic, the theoretical framework through which resource exchange will be studied, followed by the levels of interaction and types of resources exchanged, the methodology, the findings and analysis.

## **LITERATURE REVIEW**

### **Service-Dominant Logic**

The Service-Dominant Logic (S-D logic) is a theory developed by Vargo and Lusch as part of service marketing (Vargo and Lusch, 2017), but has been evolved to a generic service theory that allows researchers to study service ecosystems in various sectors such as construction (Fuentes et al., 2019), healthcare (Hardyman et al., 2015) water supply networks (Ojuri et al., 2018) and others. S-D logic suggests that all economic activity is best perceived in terms of service-for-service exchange instead of the traditional goods-for-goods or goods-for-

money exchange (Vargo and Lusch, 2017). It proposes shifting the focus of studying exchange in terms of units of output, to the way and mechanisms by which value is created through interaction between various stakeholders (Akaka et al., 2013). This interaction occurs through the integration of resources between agents, and application of competences (Vargo and Lusch, 2008). Interactions between agents (or actors) do not occur in isolation but rather within a network of actors. These networks are called service ecosystems (Vargo and Lusch, 2016) and are composed of three levels in which interactions occur: the micro, the meso and the macro level (Chandler and Vargo, 2011).

### **Levels of interaction**

Service ecosystems operate at the micro (individual), the meso (intermediary) and the macro (institutionalized) level (Chandler and Vargo, 2011). At the micro-level, actors realise the interactions needed to facilitate their interdependence (Akaka et al., 2015) by combining resources. Service exchange in the micro level is direct between actors (Chandler and Vargo, 2011). At the meso-, the indirect service-for-service exchange occurs (Chandler and Vargo, 2011). Here, Actor A is exchanging services with Actor C not through a direct relationship with each other but through both interacting with actor B. The macro-level is the domain of wider societal structures and activities, where enduring institutions and rules on community formulation at micro and meso level are assembled (Lusch and Vargo, 2014).

### **Resource Exchange – Operant and operand resources**

Interaction is the enabler of the exchange of resources. Resources can be defined as tangible or intangible entities, at the disposal of an organisation, that enable it to create efficiently and/or effectively a market offering that possesses value for particular market segments (Hunt, 2000). For enterprises, resources have been recognized as a key element to achieve growth (Penrose, 2009) and competitive advantage (Hunt, 2002). Constantin and Lusch (1994) classify resources as operand and operant, where operand resources require an action to be performed upon them (for example goods and money) and are generally considered as 'hard' or tangible resources, while operant are acting on other resources (for example knowledge and skills) and can be considered as 'soft' or intangible or cultural resources and include the competences, capabilities, and dynamic capabilities of the actors. From an S-D logic perspective, operant resources appear to have a primacy over operand due to their capability to generate strategic benefit and sustained competitive advantage through attributes such as value, rareness, and substitutability (Arnould, 2008). Nevertheless, value creation is mediated by operand resources (Akaka et al., 2015) and the importance of natural or national resources, or the need for import and export of tangible goods is not decreased (Lusch and Vargo, 2006).

### **Resource exchange through interaction between smart city actors**

The current -limited- literature suggests that operant and operand resources are combined by the smart city societal actors in order to achieve a common result, a smarter city. The three main organisational and institutional actors in smart cities, are the universities, industries and governments (Cocchia and Dameri, 2016), a synergy commonly referred to as the triple helix model (Leydesdorff and Deakin, 2013) of smart city actors, which evolved into

a quadruple helix by acknowledging civil society is one of the key actors (Parsons, 1963). This advanced model considers the four helices to operate in a complex urban environment, where the interrelations between universities, industries and the government are formed by civic society and social capital (Lombardi et al., 2012). Numerous resources can be identified in the smart city literature. Operand resources include technologies (Barrionuevo et al., 2012), such as information and communication technologies (ICT) and web 2.0 technology (Toppeta, 2010), as well as sensors and automated systems; a city's hard infrastructure (Caragliu et al., 2011) and data and information which are typically infused in the city's infrastructure (Nam and Pardo, 2011) in order to facilitate the provision of services. Additionally, they include financial and environmental capital (EIP-SCC, 2013) such as energy and raw materials. Operant resources include human capital (Caragliu et al., 2011) such as a skilled labour force (Kourtit and Nijkamp, 2012), social capital (Caragliu et al., 2011) such as culture and societal values and entrepreneurial capital force (Kourtit and Nijkamp, 2012), which comprises of leadership, knowledge and education among others. This exploratory research goes beyond identifying the resources in smart cities and studies how they are exchanged, what actors enable this exchange and how they affect the programmes/projects. This facilitates greater understanding of the significance of each resource and ultimately, how the resources of the smart city can be better managed.

## **METHODOLOGY**

In this research the use of the service dominant logic allows to study how smart city actors operate between each other and as a whole. By studying the interactions between smart city actors in the micro and meso level, the resource exchange mechanisms of the smart city service ecosystem, can be analysed. In order to identify these interactions, 17 exploratory qualitative interviews with senior staff from representative organisations from the industry, government, university and civic society actor groups, have been performed. The interviewees are part of programmes or projects based in various locations around the UK and range in value between £ 1.2 million to £ 20 million. The majority of the interviewees are part of governmental institutions, as smart cities programmes and projects fall under the jurisdiction of councils due to their size and scope. As seen in table 1, eleven come from various levels of governmental institutions, three of the interviewees come from the industry, two from universities and one from civic society. Three of the interviewees are part of different organisations within the same smart city programme, two work for the same ICT department in a council, two work for the same transport department in a council and two for the same university led alliance.

Thematic analysis was used in order to identify, analyse and describe patterns, or themes, within the data collected (Braun and Clarke, 2006). Themes were identified both at the manifest level, where directly observable information are used, and at a latent level, where underlying phenomena were examined (Boyatzis, 1998).

Type of actor	Position	Sector
<b>Industry</b>		
For profit	CEO of software provider and consultancy	ICT and public engagement
For profit	Head of infrastructure in consultancy	Infrastructure
Industrial alliance	Business advisor	ICT
<b>Civil society</b>		
Charity	Programme manager in community centre	Community engagement
<b>Government</b>		
Local government	Programme lead in council	Innovation
Local government	Department lead in council	ICT
Local government	Department lead in council	Transport
Local government	Project manager in council	ICT
Local government	Project manager in council	Transport
Local government	Project lead in council-led programme	Smart homes
Council and university funded organisation	Project manager in council-led programme	Across sectors
Gov. Funded institution	Project manager in regional programme	Across sectors
Council founded company	Senior consultant	Across sectors
Local authority trading company	Innovation manager	Healthcare
Council and university funded institution	Director	Data analytics
<b>University</b>		
University led alliance	Partnership manager	Across sector
University led alliance	Funding advisor	Across sector

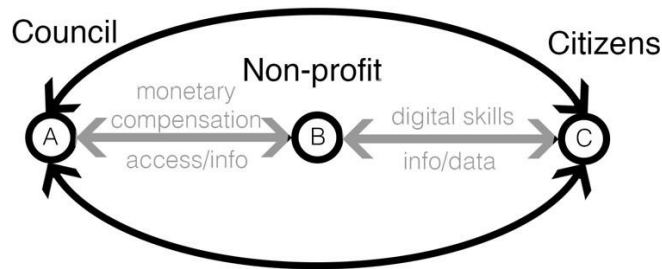
**Table 1 Characteristics of the interviewees divided by actor group. Created by the author.**

## FINDINGS

The data retrieved from the 17 interviews indicate the existence of a complex ecosystem consistent of at least 181 dyadic interactions between the smart city actors. The programmes/projects which the interviewees are part of, even though distinct between each other in terms of governance, owner and scope, appear to share certain similarities in the way in which resources are shared between the actor groups.

The resource exchanged most commonly between actors appears to be -in order of frequency- human capital and more particularly skills, followed by social networks/connections, financial resources such as funding and compensation, public benefit and more particularly job creation, data/information, access, technology, visibility and environmental benefits. Councils and other governmental agencies employ their human capital in order to run the smart city programmes/projects. They offer connections, access and funding to their partnering organisations, in order to receive skills and knowledge. These organisations are either non-profit or industrial partners. Non-profit organisations possess specific types of skills, such as educational, managerial or digital and often offer at the same time access to

other actors, such as citizens. For example, in a council-led programme, the council is offering financial compensation to a non-profit organization that in return provides access to residents of a specific area. The non-profit aids with the recruitment of participants in the project and additionally provides them with digital skills education. In return, the participants provide data and information in the form of feedback back to the organization and indirectly the council (figure 1). These types of indirect resource exchange appear to be quite common in the ecosystem.



**Figure 1 Example of indirect resource exchange. Created by the author.**

The second most common resource exchanged between actors, is connections through social networks. These connections create future opportunities for the actors that receive them – usually industrial actors-, such as early access to biddings, favorable bidding conditions, developing working relationships with the programme/project team and meeting/collaborating with diverse organisations . In exchange for these, the actors provide human capital, data/information, technology and very rarely financial compensation.

Connections through social networks are usually offered by publicly funded alliances that operate in two ways. Firstly, these alliances create networking opportunities for their members through frequently organised events and secondly, through individual consultations they directly introduce partners with common scopes to each other. They additionally help organisations establishing consortia and identifying and applying for funding streams. Usually, such agencies do not receive monetary compensation in return, but are rather interested in the creation of public benefit and specifically jobs in their locality.

The third most common type of resource exchanged is financial, in the form of either programme/project funding or monetary compensation for services provided.

Programme/project funding is typically provided both to councils and university and very rarely to the industry, and comes from national governmental agencies such as UKRI (UK Research and Innovation) or European funds such as Horizon 2020 or the European Regional Development fund. The types of programmes/projects that appear to attract more funding are those created through consortiums of public organisations, universities and few industrial actors, while actors that apply individually appear to face more difficulties in securing public funding schemes. In some cases, external organisations are founded by councils in order to manage the programme, or deliver the programme objectives. In return, these types of interaction enable the creation of jobs in the locality and other types of public benefit such as decrease in public spending in the medium to long term related to healthcare and transport costs.

The monetary exchange that occurs from programmes/projects towards industrial actors is frequently at a discounted rate in exchange for technology, advisory services or data/information. For example, three of the programmes gather data/information from citizens through external industrial partners, that provide digital platforms and workshops. In a few programmes the industry is offering technology and human capital without any direct monetary gain and get in return the aforementioned connections. In very limited cases, the programmes/projects receive technology, human capital and monetary compensation -usually in the form of funding- from industrial actors.

## **ANALYSIS**

The findings of this exploratory study appear to be overall in line with the literature but provide a deeper insight into the reasons why these types of interactions occur. The most significant finding of the study is the central role of alliances/consortiums in enabling smart city programmes. These alliances combine different types of resources from different actors to deliver the programmes.

Literature suggests that industrial actors create or are part of exploratory alliances in order to benefit from sharing resources (Möller et al., 2005) and that they frequently enter in such alliances with various public actors such as universities and research centres, as well as with different city-scaled governmental players, with the scope of augmenting the probabilities of developing new technologies and services (Sandulli et al., 2017). While industrial actors do indeed enter in alliances in order to develop new technologies and services, this study suggests that this occurs in very few cases and that their main benefit comes from creating connections with public actors, who are their main clients. These connections are created through collaboration. In order to be able to collaborate these organisations presuppose a cultural willingness to share information among their partners (Fawcett et al., 2011). This cultural willingness to information sharing appears to be a type of institutional arrangement within the smart city service ecosystem and enables industrial partners to participate into pilot studies part of programmes, which allows them to develop skills and gives them access to networks of new clients. Additionally, this collaboration acts as an advantage for the bidding stage of the scaling up of the pilot. As the interactions within the alliances/consortiums between the smart city actors become more multidimensional and more interconnected, collaboration transforms into operant resource which is more difficult for competitors to acquire or develop (Madhavaram and Hunt, 2008). When the smart city actors use collaboration to improve their efficiency and effectiveness, it becomes a source of competitive advantage (Barney, 1991).

Moreover, the interviews demonstrated that the availability or willingness of an actor to offer a specific resource largely affects the final outcome of the programme/project. This is particularly relevant to three resources: access, technology and human capital. Access to local government and more specifically councils, appears to be imperative for smart city programmes, due to their urban nature. This resource appears to have been an issue for certain publicly funded projects in the past, resulting in delays and in one case termination and the loss of public funds. Technology used in specific projects, such as electric or autonomous vehicles and 5G, is not widely available and can be offered by limited suppliers.

These suppliers -usually multinational firms-, choose the location of their testbeds-pilots according to the market of the location and collaboration possibilities they offer. If collaboration is not facilitated by local actors, the technology provider will choose a different location or even a different country. This might lead to further loss of future jobs and other types of public benefit. This demonstrates that the uniqueness or rareness (Arnould, 2008) of the resources, operant and operand, has an apparent significant effect on smart city programmes and projects and thus can be a source of competitive advantage for the actors.

## CONCLUSIONS

The need for the development of alternative urban management models has increased in the past years due to the detrimental effects of rapid urbanisation. While smart city has emerged as one of the most popular solutions, there is limited research on its organizational and managerial aspects. This exploratory study researched the exchange of resources between the different types of smart city actors, namely the government, industry, university and citizens, through mapping and analyzing their interactions at a micro level.

The data collected through 17 qualitative interviews with senior members of smart city actor groups demonstrate that:

- The most common resource exchanged is human capital, followed by connections enabled through collaboration and money/funding;
- Connections enabled through collaboration create future opportunities for the actors that engage between each other. These collaborations are usually mediated through publicly funded alliances or consortiums that undertake the curation of this aspect of the programme/project;
- Funding is typically provided in councils and universities but very rarely to industrial actors. Consortiums between public actors, universities and some industrial players are almost essential to secure funding from public resources;
- The ability of the actors to work between each other in these alliances, establish collaboration as a composite or interconnected operant resource that may bring competitive advantage to the actors that utilise it efficiently;
- The resources: access, technology and human capital, have a significant impact on the development of smart city programmes and projects, according to their uniqueness and can be sources of competitive advantage.

Future research will use this study in order to inform further work, focusing on deeper understanding of the significance and characteristics of the main resources used and will explore how the way in which they are combined can be better managed.



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# **A Literature Review on Social Lifecycle Assessment Studies: Potentials, Challenges and Literature Gaps**

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**Keywords:** literature review, social life cycle assessment, sustainability

## **ABSTRACT**

*This literature review was conducted to understand the potentials and challenges of S-LCA methodology to utilize the method within a holistic sustainability assessment framework that covers ecologic, financial and social impacts of products. Findings of the literature review were used to develop a S-LCA methodology to evaluate sustainability of building materials. While the methodology development study was focused on building materials, literaturereview covers S-LCA studies from different industries and since the findings were to beutilized as quantitative inputs for the designated methodology, the literature review was conducted in a systematic way.*

*Society keeps companies responsible of their social impacts on various stakeholders. Many different tools to evaluate social responsibility schemes have been developed and utilized by companies in corporate level. With these tools, a step to standardization of S-LCA has been taken. While these tools were focused on managing production processes, individual S-LCA studies were conducted and tested worldwide in 2000s.*

*Since there are no global standards for S-LCA method and framework individual S-LCA studies in the literature are investigated. To understand the development of the method, studies are examined in chronological order. The stakeholder and impact categories in the literature were collected whenever they are available to create the framework of the designated S-LCA methodology.*

## **INTRODUCTION**

Since there are no global standards for S-LCA method and framework individual S-LCA studies in the literature are investigated. To understand the development of the method, studies are examined in chronological order. It is possible to divide the studies according to their types before and after UNEP/SETAC Life Cycle Initiative Guidelines (2009) about S- LCA. Moreover, some new attempts take place in the literature that aim to combine LCA, S- LCA and LCC in one Life Cycle Sustainability Assessment (LCSA) after the release of UNEP/SETAC Life Cycle Initiative's (2011) LCSA guidelines. The stakeholder and impact categories in the literature were collected whenever they are available to create the frameworkof this study in following chapters. While doing so, studies that focus on certain aspects or

stakeholders of S-LCA are excluded. To conduct a systematic literature review at this stage, first 100 papers in Google Scholar search with “social” and “LCA” keywords were selected. Most of the papers were acquired from first 5 pages of Google Scholar search results (approximately 90% of total studies). In the next 5 pages following the first 5, studies mostly mention social aspect as a requirement of any sustainability assessment and some of them even address S-LCA method as we use today; but they conduct only E-LCA in the end.

## **BRIEF HISTORY OF S-LCA**

Although various aspects of social responsibility were the subject of action by organizations and governments as far back as the late 19th century, the term “social responsibility” has come into widespread use in 1970s. Since attention to social responsibility has been focused primarily on business in the past, “corporate social responsibility” is a more familiar term to most people than “social responsibility”. The early social responsibility concept is centered on charitable activities and subjects like labor rights and fair operating practices have a much older history. Other subjects like human rights, environment, consumer protection, corruption, *etc.* are added overtime which constitute backbone of current S-LCA structure (ISO, 2010).

Discussions on how to deal with social and economic assessment of products throughout their life cycle started in 1980s. One of the first initiatives was Project Group of Ecological Economics within Öko Institut in 1987 and SETAC workshop report on a conceptual framework for LCIA in 1993. Both initiatives worked on creating a holistic approach to combine social and environmental aspects of life cycle assessment as well (UNEP/SETAC LCI, 2011).

In the early 2000s, life cycle thinking became more popular globally after mentioned in the *World Summit on Sustainable Development Declaration in 2002 by UNEP*. There, it is also mentioned that *some of our choices may have socio-economic impacts as well and these impacts may affect all actors throughout the life cycle chain and eve society* (Paragahawewa et al., 2009).

In 2000s, many authors argued about social life cycle assessment or tried to carry it out. These studies include an indicator assessment study by Brent and Labuschagne (2006), a social life cycle framework study by Dreyer, Hauschild and Schierbeck (2006), an application experience of S-LCA method in New Zealand (Grießhammer et al., 2006) and S-LCA methodology studies (Jørgensen et al., 2008; Klöpffer, 2003). The first step for standardization of S-LCA method was “Guidelines for Social Life Cycle Assessment of Products” of UNEP/SETAC Life Cycle Initiative in 2009. It was a directive for S-LCA studies that is derived from LCA method which is also based on ISO 14040 and 14044 standards for LCA (Reitinger et al., 2011). Although stakeholders, subcategories and indicators are mostly defined in the guideline, no consistent or specific method is proposed (Hsu et al., 2013).

In its early stages, S-LCA is generally compared to conventional LCA and it is considered that it has a great potential to add a further dimension to LCA (Paragahawewa *et al.*, 2009). Elements of social responsibility assessment reflects the expectations of society at a certain time and are therefore liable to change (ISO, 2010). Studies that were conducted before publication of

international guidelines lack a global methodological structure but some main elements of S-LCA were introduced in them such as impact categories and functional unit.

## **S-LCA STUDIES AFTER INTERNATIONAL GUIDELINES**

Starting from 2007, a series of guidelines were published each year which are PROSA (2007), SEEBALANCE (2008), UNEP/SETAC (2009) and ISO 26000 (2010). S-LCA studies mostly based their structures on these guidelines after release of each. These guidelines were utilized in this study as well to form a framework. In this section, the guidelines are highlighted as milestones.

**PROSA:** PROSA (Product Sustainability Assessment) (Öko-Institut e.V, 2007), is probably the oldest tool that have been created to assess social and economic aspects of product lifecycle. First guideline was created in 1997 by Öko-Institut and it took the current shape in 2007 edition. The first version of the methodology was rarely used back in 90s unlike its counterpart; E-LCA methodology (Öko-Institut e.V, n.d.). Though their structures are somewhat different, S-LCA guideline of UNEP & SETAC and S-LCA part of PROSA guidelines share many common building blocks since they affected each other during the creation process. On the other hand, PROSA is a fundamental tool that gathers all three main types of sustainability assessment studies under one guideline and connect them on pairwise comparison charts.

As it happens, PROSA is an improvement tool rather than a comparison tool. The last stage of the assessment structure requires a strategy planning to heal detected hot spots. Still, impact categories can apply to various types of S-LCA studies and it has been the first methodological framework that affected many studies back then.

**SEEBALANCE:** An important method that was introduced on LCSA in 2008 is SEEBALANCE (Social, Economic, Environmental Balance) method (Schmidt et al., 2008). The method is constructed by selecting major hot-spots about social sustainability in the literature and defining the methodological concept that is originated from classical LCA. It includes six stakeholder categories. Apart from common stakeholders of S-LCA, (employees, local community, society, suppliers/partners and end users) the method introduces “future generations” category to include some environmental impacts within the same framework.

SEEBALANCE framework is included among other sources to create the framework of this study. Also, an economic analysis like LCC has been suggested that was conducted within the life cycle scope of a product to enable weighting among companies that are involved in production of the product.

**UNEP & SETAC LCI:** UNEP & SETAC Life Cycle Initiative (2009) guideline was one of the first attempts to create a S-LCA directive. Thus, it had a quite definitive structure. Each step is narrated in detail and weaknesses and future improvements were pointed out wherever possible. Though it does not have a definitive indicator list for each of its defined impact categories, it points out how to define them depending on the framework. However, suggested indicator definition process depends mostly on subjective approach of the assessment performers based on an elaborate research on the related industry. Thus, it needs to be performed by a group of qualified professionals to reach reliable results. Thus, indicator definition process depends on former studies that were performed by such experts on the

field. UNEP/SETAC (2011) also published holistic LCSA guidelines two years after its S-LCA guidelines. When their holistic methods were compared, SEEBALANCE and UNEP/SETAC's LCSA have completely different hierarchic structures. (Figure 1)

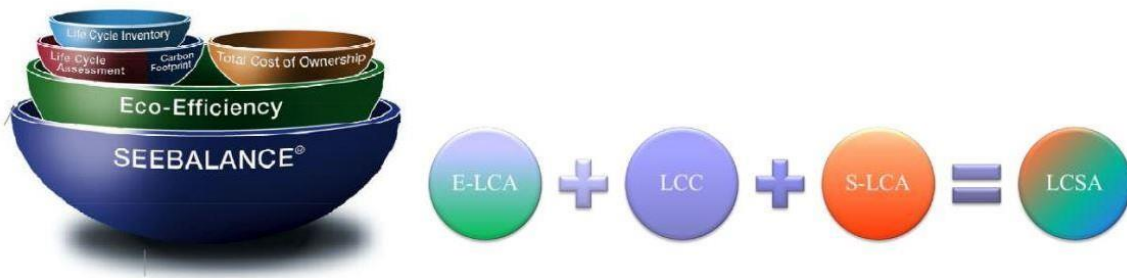


Figure 1: Comparison of SEEBALANCE and UNEP/SETAC methods in terms of hierarchy (Muller & Saling, 2011; UNEP/SETAC, 2011)

In 2010, various frameworks were created with different scopes and inventories. One of them is a social impact characterization study that reduces impact categories to four main categories under human rights topic according to International Labor Organization (ILO) conventions to render the suggested method simple and feasible for companies. It mainly focuses on characterization of indicators for these four categories which are forced labor, discrimination, freedom of association and collective bargaining and child labor (Dreyer & Hauschild, 2010). Another study combines separately conducted LCA, LCC and S-LCA studies with a final weighting system to obtain a single score comparison table (Finkbeiner et al., 2010). It does not use stakeholder approach for S-LCA but it categorizes social impacts in local, national and global sectors. Also, the study focuses on graphical visualization methods of the results to render them legible to both expert and non-expert audiences. On the other hand, this study's social sustainability part is not comprehensive in comparison with other S-LCA studies in the literature.

Apart from framework creation and testing, there are some methodology evaluation studies that were published in 2010 as well. Firstly, a research to understand "sustainability" and "LCA" concepts were conducted to propose a method to combine them within a LCSA framework (Heijungs et al., 2010). It basically uses the framework that was suggested in ISO LCA standards with some modifications. For example, inventory analysis and impact assessment steps were combined and they were performed together. Reductionist approach of classical LCA is questioned and some primary reviews are made about performing a holistic sustainability assessment without going into detail. Secondly, another study from Jørgensen and his colleagues (2010) is a critical study that aims to increase the reliability of the assessment by questioning social consequences of a product that occur out of product's life cycle scope. It introduces additional indicators to measure social impacts of other social consequences. Third study was created by Jørgensen and his colleagues (2010) as well. It conducts a specific review on two subjects; current indicators' validity to determine "wellbeing" of children as a stakeholder and validity of child labor presence as an indicator to give an idea on social areas of protection (AoP). The article analyzes all concepts and terminologies mentioned within these subjects in detail and compares their usages in case S-LCA studies. Such a scientific social study should be applied for each indicator to evaluate their relevance, validity and proper forms should be suggested wherever possible.

ISO 26000: ISO also published its 26000 directive in 2010. ISO 26000 directive is composed of guidelines to evaluate a company's socially responsible behavior to its related stakeholders to ensure a sustainable community. Although it is not an overall assessment tool of a products lifecycle phases, it is referred as one of the limited number of social sustainability assessment directives in UNEP & SETAC guideline. The directive covers health ecosystem, social equity and good organizational governance aspects of sustainability. Thus, it covers environmental impact categories that are deducted from this part of the assessment. Although schematic overview of this directive has a different structure from a LCA, it follows a similar path. Namely, first five clauses cover the first step (goal and scope definition) of LCA with further extensions to understand the sustainable development and social responsibility terms. On clause 7, impact categories and sub-categories are defined in detail.

Unlike UNEP & SETAC guideline, ISO 26000 directive implements a different structure by linking stakeholders and impact categories instead of using stakeholders as a superior level of categorization. Sub categories of each impact category are defined and described in detail. Using this information, a similarly structured table to UNEP & SETAC guideline is created. Stakeholders are defined with respect to descriptions of impact categories in this study and other guidelines' classification methods of intersecting impact categories.

## **HOLISTIC SUSTAINABILITY ASSESSMENT ATTEMPTS**

In 2011, UNEP/SETAC's LCSA guidelines were published and studies mostly aimed to inherit a holistic LCSA method since then. Most of these studies questioned how to combine all three assessment methods in one single method.

Study of Ciroti and Franze (2011) covers a detailed complete life cycle assessment of a notebook. Particularly, social hotspots were detected on production and informal recycling phases. Some assumptions were made to simplify the assessment process like presuming raw material locations according to national statistics. E-LCA was conducted as well. The framework and inventory for S-LCA is adapted from UNEP/SETAC guidelines (2009). Since the framework were not derived from the guidelines identically, impact category and stakeholder lists were evaluated while creating the inventory for this study. Another study about past, present and future of S-LCA analyzes its historical development and its state at the time of the study (Guinée et al., 2011). Also, it claimed that LCA studies would be conducted as LCSA studies in 2010s.

Zamagni's study (2012) conducts a literature review on "sustainability" and "LCA" terms and offers some recommendations for LCSA for practitioners. Firstly, it points out the maturity difference between LCC, LCA and S-LCA that leads to inconsistency among them. It recommends focusing on that topic to practitioners. Secondly, it questions if it is feasible to conduct a single LCSA instead of three sustainability assessments and encourages it. Finally, it promotes practitioners to question if uncertainty is inevitable for LCSA and how can it be managed.

A framework that is unusual to LCSA practitioners was introduced in the study of Macombe and her colleagues (2013) about S-LCA of biodiesel production. In the research, a social life

cycle assessment was conducted via complementary approach, which was performed by adding social impact categories to LCA. The stakeholder system was defined as a hierarchic system with different level categories namely; company, regional and state levels. The paper concludes by claiming that a social life cycle assessment with suggested method is not yet possible and assessment framework requires many researches on different parts of the assessment like system boundary definitions. On the other hand, framework of a S-LCA study that is conducted in the same year on palm oil biodiesel is used as a reference to create this study's framework (Manik et al., 2013). The framework follows UNEP/SETAC guidelines and stakeholder approach. Another borrowed framework is of Foolmaun and Ramjeeawon's study (2013) on comparative S-LCA of polyethylene terephthalate bottles. The study conducts separate comparative environmental and social LCA studies that are focused on their disposal phases. In impact assessment phase, reference values consisting of midpoints, max values and min values were used to create a scoring table. Correspondingly, scores higher than mid-point were categorized as positive impacts and scores lower than midpoint are categorized as negative impacts proportionately with their difference.

Aparcana and Salhofer (2013) conducted a literature review on current S-LCA methods to create a framework. The inventory was mostly composed of semi-quantitative indicators. The study focuses on creating a framework rather than testing it. Later in 2017, another study was conducted by the same practitioners to apply their framework. Data was mostly collected via interviews. A simple binary grading system was used to transform qualitative information into quantitative data (Aparcana & Salhofer, 2017). A study on S-LCA as a management tool by Arcese, Lucchetti and Merli (2013) applies S-LCA to tourism sector for the first time according to its claim. It uses the framework of UNEP/SETAC (2009) directly and thus, it is not used as a Reference to avoid iteration. Indicators were mostly determined via interviews to detect hot-spots of the sector. The study was conducted successfully and it claims that S-LCA can be conducted in tourism sector comprehensively by using UNEP/SETAC (2009) guidelines. The last article about S-LCA in 2013 is obtained as conference proceedings. The authors realized the gap that is left in UNEP/SETAC guidelines (2009) about impact assessment phase and suggested a method to fill this gap. For each quantitative indicator, they introduced performance reference points (PRPs) which are country-specific statistics to use as references for each indicator. The assessment is concentrated on "worker" stakeholder category (Hsu & Hu, 2013).

Considering the studies that are conducted in 2014, it is possible to state that S-LCA method that was suggested in UNEP/SETAC guidelines (2009) has reached to a certain maturity and started to be used widely. Most of the frameworks that were published in 2014 have been used to build this study's framework. To begin with, a study on application challenges of S-LCA tests its method on a holistic sustainability assessment of different fertilizer products (Martinez-blanco et al., 2014). The study conducts a complete S-LCA by studying all material production processes. It points out lack of definition of social targets to base the results on. Since number of the methodological obstacles faced were too high, the study could not be completed with an interpretation phase. Another study on subcategory assessment methodology reviews studies up to UNEP/SETAC guidelines (2009) and evaluates most of them as incomplete or subjective (Petti et al., 2014). The study itself aims to propose an objective method for sub-category evaluation phase of S-LCA. The paper suggests a sub- category



assessment method for sub-category classification during impact assessment phase. It conducts a four-level assessment system for companies according to their promotion and fulfillment of defined basic requirements. The paper also encourages application of its own framework on various assessment studies all around the world to test it. Framework of the study is deemed original and used as a reference for this study.

A significant study that conducts both S-LCA and E-LCA separately in 2015 has been conducted on welding technologies (Chang *et al.*, 2015). The functional unit is defined as 1-meter weld seam. S-LCA study is focused on remuneration satisfaction of workers and potential health risks of selected welding technologies. The study aims to acquire results rather than creating and testing a framework. Thus, no suggestions or challenges about the method are included.

Another significant report of 2015 on S-LCA methodology is published by Joint Research Centre which is composed of different studies and approaches and it consists of five chapters (Sala *et al.*, 2015). The first part forms a baseline to inventory assessment, by selecting six of United Nations' 2030 sustainable development goals on social issues and two on governance of the transition towards sustainable development are selected. In this chapter, S-LCA, LCA, social impact and social benefit concepts are investigated to detect differences and similarities between them. On the second part, necessity of conducting S-LCA is questioned in business, policy making and NGO levels. Also, S-LCA examples for them are investigated. For business point of view, the argument focuses on SEEBALANCE method and its previous applications mostly. Third section summarized history, present state and future expectations about S-LCA method. Also, it investigates different S-LCA studies that are conducted in different levels (micro and macro) for different products. Fourth section introduces Social Hotspot Database (SHDB) method which simply aims to provide access to best available social risk and opportunity information at the most granular level possible as well as to provide methods and tools to calculate and simplify this information down to a single grading method. Last section introduces positive impacts and indicator categories in S-LCA by sharing the results of a systematic literature review.

Finally, three significant studies that are published in 2017 are detected. First one is Aparcana & Salhofer's (2017) attempt to test their own framework on a case study which is already mentioned in previous paragraphs. Second one is another study from Jørgensen and his colleagues (2017) that questions relevance and feasibility of conducting a S-LCA study from company point of view by conducting a S-LCA study for a company through interviews. According to the results, companies mostly disagree that their social responsibility is limited with the suggested S-LCA framework which leads to question S-LCA's coverage. Also, companies mostly don't find it feasible and possible to conduct a full life cycle assessment of a product with all chain actors. The last study is an attempt to test common LCSA method on a case study about photovoltaic modules for the first time (Traverso *et al.*, 2017). Result comparisons are done in both S-LCA and LCSA levels. The study points out S-LCA indicator creation and LCSA weighting as two main challenges of the assessment.

## S-LCA CHALLENGES

The biggest challenges about S-LCA are the ones that arise from its own nature. S-LCA deals with large numbers of qualitative data, since numeric information will be less capable of addressing the issues at hand. Some quantitative data on the other hand, may need to be supported with verbal interpretations. For example, minimum wages of workers in a company can be calculated and compared with others in the sector but they may need to be evaluated in the domain of living standards as well (UNEP/SETAC LCI, 2009).

On the other hand, there is not enough experience with use and implementation of S-LCA for international standardization as there is in E-LCA with ISO 14040 and 14044 (Reitinger et al., 2011). Also, definition of international social targets is required to compare results to place them on a scale. Considering E-LCA methodology has reached to a maturity in almost 50 years after it was first conducted in 1960s and S-LCA methodology goes back not earlier than late 2000s, S-LCA is still under development (Paragahawewa et al., 2009). These are some of the challenges of current S-LCA studies as well as one of the motivations since each research puts a building block to future S-LCA methodology (Martinez-Blanco et al., 2014).

Another challenge that S-LCA method faces is its compatibility. S-LCA can be carried out as a free-standing analysis tool or in combination with LCA and LCC. In this case, care must be taken to coordinate the key parameters with LCA and LCC (Grießhammer et al., 2007). Coordination requirements are suggested in Product Sustainability Assessment Guideline (PROSA) as a checklist:

- Feedback of the initial results from one tool to the input data and assessments for the other tools. Changes required?
- Functional unit defined equivalently? Different depending on target group?
- System boundary and geographical scope defined uniformly or equivalently? Patterns of use defined uniformly?
- Dealing with different “cost bearers” in Life-Cycle Costing, but uniform “impact bearer” in Life-Cycle Assessment (namely, the environment)?
- Dealing with especially relevant qualitative results in Social LCA and less relevant but hard figures in Life-Cycle Costing?
- Are the LCA, Life-Cycle Costing and Social LCA based on significantly different data?
- Normalization to the same reference (e.g. number of products, branch of industry, whole national economy)? Fair and symmetrical overall evaluation? Fair and symmetrical communication of findings?

UNEP/SETAC LCI (2011), lists research and development areas for further development of S-LCA method in its Life Cycle Sustainability Assessment (LCSA) report as such:

- the relationship between the function and the product utility;
- methodological sheets for the stakeholder subcategories to support the inventory analysis needs;
- methods for the assessment of impacts and cause-and-effect relationships for social and socioeconomic aspects;

- areas of protection;
- scoring systems;
- review process guidance;
- communication formats and the relationship between LCC and S-LCA,

On the other hand, S-LCA results can vary according to the companies involved. This is one of the differences between S-LCA and LCA since LCA results can be standardized according to standard process data and data aggregation is possible for this reason (Dreyer et al., 2006).

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# Developing a Social Life Cycle Assessment Methodology for Holistic Sustainability Assessment of Building Materials

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**Keywords:** building materials, social life cycle assessment, sustainability

## ABSTRACT

*The study aims to develop social life cycle assessment categories for building materials according to databases in the literature for a holistic sustainability assessment methodology. Each decision that is taken to improve energy efficiency of buildings reveals new impacts on society, environment and economy and eventually on sustainable development of the country. Monitoring all these impacts of buildings on sustainable development is a challenging subject. In environmental sustainability domain, life cycle assessment (LCA) method is being performed on buildings as a benchmarking and decision-making tool to measure environmental impacts of a product, service or activity primarily. Although recent LCA studies mostly define sustainability as a holistic approach, they only focus on environmental impacts. Nonetheless, sustainability assessment framework is not complete unless other aspects are included in the assessment as well.*

*"Three pillars of sustainability" approach has been designated to form a foundation to Life Cycle Sustainability Assessment (LCSA) method that covers environmental impacts that are defined in Life Cycle Assessment (LCA) method, cost implications that are defined in life cycle costing (LCC) method and social consequences that are defined in social life cycle assessment (S-LCA) method. Among them, S-LCA methodology has the greatest need for development and adaptation. For this reason, the study aims to build a S-LCA method based on the guidelines and define assessment parameters based on the databases in the literature. S-LCA method has been adapted from LCA to allow performing it within the framework of LCSA.*

## INTRODUCTION

Social lifecycle assessment covers all the steps in the lifecycle of a product within the given scope according to the defined workflow. Within these steps, all impact categories including health and safety of different parties, human rights, social security, contribution to national economy and technology and fair trade were assessed in relation with the definition of involved stakeholders on previous section. Afterwards, impact categories were further divided into indicators for evaluation. Most of the indicators were composed of qualitative data that needed to be converted into quantitative.

There are two main aggregation (data collection) phase in S-LCA. First one was conducted in life cycle inventory phase where all elements of the assessment are collected from the specific indicators to larger categories with respect to unit process locations as well (UNEP & SETAC, 2009). The other aggregation process was conducted in impact assessment phase. Literature was the main source of aggregation for this study. Literature database that have been used to define stakeholders were further analyzed to harvest information about the research structure of each study. It was realized that more recent studies that are published from 2013 up to today does not follow UNEP & SETAC (2009) hierarchy order of stakeholder, category, sub category, indicator. Sub-categories are generally taken as main impact categories and they were not categorized once more. This approach is also applied in this study. Thus, all these impact categories were collected under selected stakeholder categories and divided into indicators that were defined in some of the examined sources. Each item in all levels of the assessment system was gathered from literature

## **IMPACT CATEGORY DEFINITIONS**

Considering these specific points about these reference studies, a table for each selected stakeholder group was created including impact categories, their definitions and their weighting values. Similar to stakeholder evaluation in previous section, impact categories were evaluated according to their occurrence rate in different studies and normalized scores were used to set a limit to the impact category list. To do that, same normalization formula (Equation 3.9) and weighting formula (Equation 3.10) were applied to total impact category occurrence rates. Again, values equal to or greater than 0,5 were selected to ensure that category occurs in most of the mentioned studies. So that, case specific impact category elements were filtered out. Lower limit can be increased or decreased to redefine the scope for another study. In such a case, weight values must be recalculated.

### **Workers (Employees)**

In every given social sustainability assessment study reference, either "workers" or "employees" was included as a stakeholder party. However, its definition is considerably flexible since worker/employee refers to different parties depending on the location of the assessment (office, factory, construction site, etc.). Selected impact categories for workers are given on Table 1. According to the filtering rule, first 7 impact categories were selected for the study and they were interpreted to determine evaluation criteria.

Apart from factory data, these impact categories require data from worker surveys and executive interviews.

Table 1: Inclusion of “worker” impact categories in selected sources

	Griegshammer et al, 2007	UNEP/SETAC, 2009	UNCTAD, 2008	Paragahawewa et al, 2009	Reitinger et al, 2011	GRI, 2016	ISO, 2010	Hoseinijou et al, 2014	Dasmohapatra, 2012	Muller & Saling, 2011	Ciroth & Franziska, 2015	Hutchins & Sutherland 2008	Saranella et al, 2015	Brent & Labuschagne 2006	Manik et al, 2013	Azapagic, 2002	TOTAL	Normalized	weight
<b>1. Employees-Workers</b>																			
Health and Safety in work	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	16	1	0,2
Equality of opportunity and treatment & fair interaction / No discrimination	●	●	●	●	●	○	●	●	●	●	●	●	●	●	●	●	14	0,875	0,175
Adequate remuneration	●	●	●	○	○	○	●	●	●	●	●	●	●	●	●	●	12	0,75	0,15
Abolition of forced labour	●	●	●	●	○	○	●	●	●	●	●	●	●	●	●	●	10	0,625	0,125
Social Security	●	●	●	○	○	○	●	●	●	●	●	●	●	●	●	●	10	0,625	0,125
Abolition of child labour	●	●	○	○	○	○	●	●	●	●	●	●	●	●	●	●	9	0,563	0,113
Freedom of association, collective bargaining & workers’ participation	●	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	9	0,563	0,113
Adequate working time	●	●	○	○	○	○	●	●	○	○	○	○	○	○	○	○	7	0,438	
Training and Education	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,313	
Human rights	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	4	0,25	
Job satisfaction	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	3	0,188	
Employee social benefits	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	2	0,125	
Labour Practices / Company Communication	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,063	
Employee Influence on company	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,063	

## Local Community

Local community contains people who live or work in any areas (close or distant but affected) that are socially impacted by the organization's operations. Local community scope was defined with respect to lifecycle flowchart of each product. Production locations are taken as the local area of assessment. Local community assessment measures if organization's activities restrict basic indigenous rights or freedoms of the local community (access to resources, delocalization, safety, health) or introduce a social value to it (community engagement, employment, investment) (Ciroth & Eisfeldt, 2015). Also; according to ISO 26000 (2010) directive, a company should contribute in development of innovative technologies to help social and environmental issues of the community.

Impact categories that may affect local community are given on Table 2. After filtering, 5 impact categories were selected among them. Data was mostly obtained in the form of facility information and executive interviews. Then, they may be supported via desktop screening.

Table 2: Inclusion of “local community” impact categories in selected sources

	Griegshammer et al, 2007	UNEP/SETAC, 2009	UNCTAD, 2008	Paragahawewa et al, 2009	Reitinger et al, 2011	GRI, 2016	ISO, 2010	Hoseinijou et al, 2014	Dasmohapatra, 2012	Muller & Saling, 2011	Ciroth & Franziska, 2015	Hutchins & Sutherland 2008	Saranella et al, 2015	Brent & Labuschagne 2006	Manik et al, 2013	Azapagic, 2002	TOTAL	Normalized	weight
<b>2. Local Community</b>																			
Local Employment	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	11	1	0,256
Safe & healthy living conditions in community	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	10	0,909	0,233
Respect of Human Rights	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	10	0,909	0,233
Community engagement	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	6	0,545	0,14
Delocalization and Migration	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	6	0,545	0,14
Maintaining & improving social and economic opportunities	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,455	
Respect to cultural heritage	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,455	
Access to Material Resources	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	4	0,364	
Access to Immaterial Resources	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	2	0,182	
Family Support	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	2	0,182	
Community education & training	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,091	
Technology development and access	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,091	
Integration of disabled/disadvantaged citizens	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,091	



## Consumer (User)

Consumers are individuals who purchase or use property, products or services for private purposes (ISO, 2010). Apart from being one of the stakeholder categories, consumers are also the main group of people that assessment focuses on. All other impact categories were originated from complex decision-making process of modern consumers that take environmental and socio-economic impacts into consideration when choosing a product (UNEP & SETAC, 2009). One of the main goal definitions; "product utility" was defined according to consumer needs and demands (Grießhammer *et al.*, 2007).

According to filtering procedure, only three impact categories were selected. Although the study was conducted on a real building, it simulates the results of four different scenarios where different insulation materials are applied on the building. Thus; data required for consumer related indicators are mainly created by verifying executive interviews with desktop screening.

Table 3: Inclusion of “end-user” impact categories in selected sources

	Grießhammer et al, 2007	UNEP/SETAC, 2009	UNCTAD, 2008	Paragahawewa et al, 2009	Reitinger et al, 2011	GRI, 2016	ISO, 2010	Hosseinjou et al, 2014	Dasmohapatra, 2012	Muller & Salting, 2011	Ciroth & Franziska, 2015	Hutchins & Sutherland 2008	Saranella et al, 2015	Brent & Labuschagne 2006	Manik et al, 2013	Azapagic, 2002	TOTAL	Normalized	weight
<b>3. Consumer-User</b>																			
Protection of the user's / consumer's health and safety	●	●	○	●	●	●	○	●	○	○	○	○	○	○	○	○	10	1	0,5
Complete & understandable product information	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,5	0,25
Transparency	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,5	0,25
Protection of user's / consumer's privacy	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	4	0,4	
Fair competition & marketing practices	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	3	0,3	
Feedback accessibility	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	3	0,3	
Quality of product or service	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	3	0,3	
End of life responsibility	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	2	0,2	
Customer accessibility to services	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	2	0,2	
Enhancing the user's / consumer's social and economic possibilities	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,1	
Fair contractual practices	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,1	
Education & Awareness	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,1	
Feedback influence	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,1	

## Society

Social responsibility of an organization is related with its ability to monitor and adapt the instantaneous demands and expectations of the society (ISO, 2010). One of the expectations of the society is that the organization should contribute to sustainable development of its society by developing innovative technologies or contributing to national economy (UNEP & SETAC, 2009). Society is defined in national level.

Selected five impact categories about society and their weight scores are given in Table 4. Society in question is Turkey. Thus, company information, executive interview and desktop screening data was evaluated with respect to national data.

Table 4: Inclusion of “society” impact categories in selected sources

	Grießhammer et al., 2007	UNEP/SETAC, 2009	UNCTAD, 2008	Paragahawewa et al., 2009	Reitinger et al., 2011	GRI, 2016	ISO, 2010	Hosseiniou et al., 2014	Dasmohapatra, 2012	Muller & Salting, 2011	Ciroth & Franziska, 2015	Hutchins & Sutherland 2008	Saranella et al., 2015	Brent & Labuschagne 2006	Manik et al., 2013	Azapagic, 2002	TOTAL	Normalized	weight
<b>4.Society</b>																			
Anti-corruption & no improper involvement in political activities	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	9	1	0,27
Contribution to the national economy and stable economic dev	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	7	0,78	0,21
Prevention of armed conflicts	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	6	0,67	0,18
Contribution to national technology / R&D	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	6	0,67	0,18
National commitments to sustainability issues	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,56	0,15
Compliance to social & economic laws	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	4	0,44	
National healthy and safety	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	3	0,33	
Protection of intellectual property rights	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	2	0,22	
Employment creation	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,11	
Transparent business information	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,11	
Education (illiteracy rate)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,11	
Foreign Direct Investment (FDI)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,11	
Imports from developing countries	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,11	

### Supply Chain Actors

Supply chain actors include each party that are involved in the product's lifecycle except users and workers (UNEP & SETAC, 2009). Supply chain is defined as a sequence of activities or parties that provides products or services to the organization (ISO, 2010). Thus, supply chain actors are defined for each process location on the lifecycle flowchart of a product. For each step, related process actors are supply chain actors. Selected impact categories are shown in Table 5.

Table 5: Inclusion of “supply chain actors” impact categories in selected sources

	Grießhammer et al., 2007	UNEP/SETAC, 2009	UNCTAD, 2008	Paragahawewa et al., 2009	Reitinger et al., 2011	GRI, 2016	ISO, 2010	Hosseiniou et al., 2014	Dasmohapatra, 2012	Muller & Salting, 2011	Ciroth & Franziska, 2015	Hutchins & Sutherland 2008	Saranella et al., 2015	Brent & Labuschagne 2006	Manik et al., 2013	Azapagic, 2002	TOTAL	Normalized	weight
<b>5.Supply Chain Actors</b>																			
Fair Competition	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	7	1	0,41
Promoting social responsibility among partners	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,71	0,29
Supplier relationships	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	5	0,71	0,29
Respect of intellectual property rights	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,14	
New suppliers are screened using social criteria	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,14	
Negative social impacts on supply chain: detection and corection	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,14	
Corruption	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	1	0,14	

### Indicator Definition

Inventory indicators are the parameters that provide the most direct evidence of the condition or result they are measuring. They have type and unit measurement characteristics (UNEP & SETAC, 2009). Unlike E-LCA, indicator definition is one of the essential steps of S-LCA since there are not definitive parameters yet (Grießhammer *et al.*, 2007). Since it is a social subject, a sheer number of indicators can be a subject of the assessment. Thus, it is important to select only relative ones. Indicators are generally defined via common dialogue between an expert group of people who are conducting the assessment and stakeholder parties (UNCTAD,2008).

In order to decrease subjectivity, indicators were extracted from examined sources and combined on an indicator table. Each indicator was rated according to their occurrence in selected sources. These ratings were utilized to determine indispensability of each indicator in another edition of the indicator table.

According to ISO 14044, (2006) a sensitivity analysis needs to be done during the modelling of the framework rather than at the end of the process to measure the effect of inclusion or exclusion of an indicator on the overall result. In quantitative analysis, 1% change in the overall result is often regarded as a significant change (UNEP & SETAC, 2009). Thus, a sensitivity analysis was conducted on the indicators to measure their overall weights.

Due to high number of indicators in the literature on worker/employee and society stakeholder categories, indicators in these categories lost their significance because of their overall weights decreasing below 1%. Similarly, consumer related indicators became outliers due to their high significance rates. To create a more balanced assessment structure, limit significance rates were defined. Maximum value was set to 3% (lowest integer to exclude outliers) and minimum value was set to 1% (lowest significance rate that is mentioned in UNEP & SETAC guideline). This redefinition process of system boundaries is called significance analysis and it is required to increase the reliability of indicator weighting values and determine the optimum number of indicators per category. (Wallbaum *et al.*, 2012; Jensen *et al.*, 1997; UNEP/SETAC LCI, 2009) According to the significance results following actions will be taken:

- Exclusion of indicators should be applied when the indicators of an impact category have lack of significance due to excessive number of indicators.
- Inclusion of new indicators should be applied when the indicators of an impact category have too much significance due to insufficient number of indicators.

A reduction task was done on the impact categories with lower overall weighing rates than 1%. While eliminating the indicators, ones with the lowest occurrence rates in all three indicator references and non-measurable indicators for this specific study were given priority. Indicators that were found too essential to exclude were kept in place. On the other hand, by introducing new indicators, outlying ones were normalized. This inclusion and exclusion phase of the study involved some subjective treatment with a consideration of specific goal and scope definition. The lowest significance limit was fixed to 0,9% and the highest significance rate was fixed to 3% (With a 0,0004 margin of error). Thus, optimum number of indicators were determined for each category while impact category weighting ratios remained the same.

According to UNEP/SETAC, (2009) there are three forms of Social LCA data; quantitative, semi-quantitative (i.e. likert scale rating responses) and qualitative (descriptive text).

Indicators which are related to facility and company information are mostly quantitative. Numeric data is directly collected for these indicators and minimum and maximum borders are determined for normalization. No data conversion from qualitative to quantitative is required for these items (Table 6).

Table 6: Indicator items depending on facility and company information

STAKEHOLDERS ID NO	ow	w	IMPACT CATEGORIES INDICATORS
WORKERS	0,258		
1.1	0,045	0,174	HEALTH AND SAFETY
1.1.1	0,009		Number of accidents at work
1.1.2	0,009		Number of recognized occupational diseases and reports on elevated health risks
1.1.3	0,009		Basic measures and arrangements to maintain and increase safety at work
1.1.4	0,009		Measures and arrangements to maintain and increase health at work
1.2	0,038	0,147	DISCRIMINATION
1.2.1	0,009		Reports on discriminatory practices of the company
1.2.2	0,009		Proportion of women in management positions
1.2.3	0,009		Ratio of salary of women wages to men
1.2.4	0,009		Proportion of disabled employees
1.3	0,036	0,138	REMUNERATION
1.3.2	0,012		Ratio of corporate minimum wages to local costs of living
1.5	0,028	0,11	SOCIAL SECURITY
1.5.3	0,009		# of workers with a contract
1.6	0,026	0,101	CHILD LABOUR
1.6.2	0,013		Reports on cases of young labour
1.7	0,028	0,11	FREEDOM OF ASSOCIATION
1.7.3	0,009		Rate of unionization
1.8	0,024	0,092	ADEQUATE WORKING TIME
1.8.1	0,024		Weekly working hours
LOCAL COMMUNITY	0,242		
2.1	0,055	0,228	LOCAL EMPLOYMENT
2.1.1	0,028		Percentage of spending on locally based suppliers
2.1.2	0,028		Work force hired locally
2.2	0,055	0,228	HEALTH AND SAFETY
2.2.1	0,018		Accidents connected to the company's activities
2.2.2	0,018		Negative and positive health impacts for the local population
SOCIETY	0,145		
4.2	0,032	0,222	CONTRIBUTION TO ECONOMY
4.2.1	0,011		Contribution to the national budget (taxes paid minus subsidies received)
4.2.2	0,011		Contribution to the foreign trade balance

Some data is provided via desktop screening. Each of them requires a specific evaluation system, conversion method and border values. Since data is mostly quantitative, they need specific interpretation processes to evaluate them within a quantitative scope (Table 7).

Table 7: Indicator items depending on desktop screening

STAKEHOLDERS ID NO	ow	w	IMPACT CATEGORIES INDICATORS
CONSUMER/USER	0,226		
3.1	0,104	0,462	HEALTH AND SAFETY
3.1.1	0,026		Health opportunities / risks related to product use
3.1.2	0,026		Accidents related to product use
3.1.3	0,026		Fatalities related to product use
3.1.4	0,026		Findings of product safety tests (incl. any awards, labels)
3.2	0,069	0,308	TRANSPARENCY
3.2.1	0,023		<u>Consumers' ability to reach full ingredient information</u>
3.2.2	0,023		<u>Publication of a sustainability report</u>
3.2.3	0,023		<u>Precise and readily understandable information about safe use and maintenance</u>
SOCIETY	0,145		
4.1	0,035	0,244	CORRUPTION
4.1.2	0,01		Reports on improper involvement in political activities
4.5	0,026	0,178	NATIONAL COMMITMENT TO SUSTAINABILITY
4.5.1	0,013		Awards for engagement in social and / or sustainability issues
4.5.2	0,013		Membership in alliances and programmes to support and promote sustainable business practices
SUPPLY CHAIN ACTORS	0,129		
5.2	0,035	0,273	SOCIAL RESPONSIBILITY
5.2.2	0,02		Membership in an initiative that promotes social responsibility along the supply chain

Finally, some indicator items depend on qualitative evaluation from surveys and interviews. To translate the qualitative data into quantitative format, likert scale is utilized. Each survey or interview question depends on a certain evaluation scale. The scale may be composed of simple answers like “yes” and “no” or more detailed choices that include “agree” and “disagree” options as well as “strongly agree”, “strongly disagree” and “not certain” options. Data is translated into quantitative format according to that scale and that scale also provides minimum and maximum values (Table 8).

Table 8: Indicator items depending on surveys and interviews

STAKEHOLDERS ID NO	ow	w	IMPACT CATEGORIES INDICATORS
<b>WORKERS</b>	0,258		
1.1	0,045	0,174	<b>HEALTH AND SAFETY</b>
1.1.5	0,009		Policies and programmes to combat HIV/AIDS and/or other locally important health issues (dengue, malaria, alcoholism etc.)
1.3	0,036	0,138	<b>REMUNERATION</b>
1.3.1	0,012		Average level of performance-related incentives
1.3.3	0,012		Payment of wages in due time
1.4	0,033	0,128	<b>FORCED LABOUR</b>
1.4.1	0,017		Voluntary commitments by the company on abolition of forced labour
1.4.2	0,017		Reports on cases of forced labour
1.5	0,028	0,11	<b>SOCIAL SECURITY</b>
1.5.1	0,009		Evidence of breaches of obligatory social contributions
1.5.2	0,009		Duration and level of wage continuation in the case of illness
1.6	0,026	0,101	<b>CHILD LABOUR</b>
1.6.1	0,013		Reports on cases of child labour
1.7	0,028	0,11	<b>FREEDOM OF ASSOCIATION</b>
1.7.1	0,009		Voluntary commitments by the company in the field of freedom of association & right to collective bargaining
1.7.2	0,009		Reports on hindering workers' organizations and their activities
<b>LOCAL COMMUNITY</b>	0,242		
2.2	0,055	0,228	<b>HEALTH AND SAFETY</b>
2.2.3	0,018		Measures and arrangements to maintain and improve safe and healthy living conditions
2.3	0,059	0,246	<b>HUMAN RIGHTS</b>
2.3.1	0,02		Voluntary commitments by the company in the field of human rights
2.3.2	0,02		Reports on human rights violations related to the company's activities
2.3.3	0,02		Human rights training for employees, particularly for security staff
2.4	0,038	0,158	<b>COMMUNITY ENGAGEMENT</b>
2.4.1	0,019		Information possibilities for residents
2.4.2	0,019		System to respond to community grievances
2.5	0,034	0,14	<b>DELOCALIZATION</b>
2.5.1	0,017		Delocalization or Migration resulted from company's activities.
2.5.2	0,017		Forced evictions / resettlements related to the company's activities
<b>CONSUMER/USER</b>	0,226		
3.3	0,052	0,231	<b>FEEDBACK ACCESSIBILITY</b>
3.3.1	0,026		Company's commitment to allow user feedbacks
3.3.2	0,026		System to respond user feedbacks
<b>SOCIETY</b>	0,145		
4.1	0,035	0,244	<b>CORRUPTION</b>
4.1.1	0,012		Evidence of corrupt and / or extortionate business practices
4.1.3	0,01		Corporate measures to combat corrupt business practices
4.2	0,032	0,222	<b>CONTRIBUTION TO ECONOMY</b>
4.2.3	0,011		Company's economic stability during market crisis
4.3	0,026	0,178	<b>CONFLICTS</b>
4.3.1	0,026		Link between economic activities and armed conflicts / Risk of conflict
4.4	0,026	0,178	<b>CONTRIBUTION TO NATIONAL TECHNOLOGY</b>
4.4.1	0,013		R&D Program participation
4.4.2	0,013		Development of innovative products and services
<b>SUPPLY CHAIN ACTORS</b>	0,129		
5.1	0,053	0,409	<b>FAIR COMPETITION</b>
5.1.1	0,026		Presence of anti-competitive behaviour or violation of anti-trust and monopoly legislation
5.1.2	0,026		Presence of policies to prevent anti-competitive behaviour Y/N
5.2	0,035	0,273	<b>SOCIAL RESPONSIBILITY</b>
5.2.1	0,018		Presence of codes of conduct that protect human rights of workers among suppliers
5.3	0,041	0,318	<b>SUPPLIER RELATIONSHIPS</b>
5.3.1	0,021		Interactions: payment on time
5.3.2	0,021		Interactions: sufficient lead time

## CONCLUSION

Indicator items are obtained, classified and weighted according to their occurrence in the literature. After the indicator items and their evaluation methods are determined one by

one, they are classified as “higher is better” (HIB) and “lower is better” (LIB). For LIB items, higher score means social impact and for LIB items, higher score means social benefit. After the scores are calculated for each item, they need to be normalized according to HIB and LIB classification and their related formulas. After normalization, overall weighting values on Table 6, 7 and 8 can be used to complete S-LCA study.

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# Production Of Biogas From Kitchen Waste

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**Keywords:** Kitchen waste, Biogas, Cow dung, Anaerobic digestion.

## ABSTRACT

*This work dealt with the production of biogas from different sets of kitchen wastes and various tests were run on it. The biogas was produced through anaerobic digestion. The plant that was adopted in this project was the fixed drum types and there were three sets of kitchen waste. The prototype biogas digester was constructed with a paint bucket of 20 litres and the experiments lasted for a combined time of 27 days. From the results obtained, the kitchen waste of set 2 which was mixed with cow dung and water in the ratio 2:5:7 (kitchen waste: cow dung: water) produced 250.69% more gas than set 1 kitchen waste with cow dung and water in the ratio 6:1:7 and 67.5% more gas than set 3 with only cow dung and water in the ratio 7:7. Kitchen waste is the best alternative for the production of biogas as it costs nothing because it help to recycle waste produced in the kitchen.*

## INTRODUCTION

On a global perspective, the prices and/or availability of fuels tends to be increasing without any form of immediate help in view. This has even a seemingly more negative impact on the economy of African. Even in Nigeria where this work is domiciled, when people are willing to pay the price, fuel is not available in required quantity or at times not available at all to the reach of the common man. The scarcity of fuel is worldwide but for under-developed or developing countries, it is turning out to be a major issue.

Nigeria with a population of over 140 million people is endowed with enormous energy resources, such as, petroleum, natural gas, coal, nuclear, tar sand. Others include solar, wind, biomass and hydro. However, development and exploitation of such energy sources have been skewed in favour of the hydro, petroleum and natural gas. At independence in 1960, agriculture was the dominant sector of the economy contributing about 70%. This trend changed with the discovery of oil in 1970's. The exploitation of the Nigerian energy resources began with coal in 1916 (Onakoya *et al*, 2013).

There are nearly three billion tonnes of indicated reserves in seventeen identified coalfields and over 600 million tonnes of proven reserves in Nigeria (Anaekwe, 2010).



Following the Nigerian civil war, many coal mines were abandoned, and coal production never completely recovered. The epileptic nature of electricity has led to scarcity of petrol and kerosene because the citizens have resorted to using generators and kerosene powered equipment to provide energy for use at homes. Also, import content of our domestic fuel usage has increased tremendously over the years. This has contributed to the use and over-reliance on wood as a fuel, which has increased the problem of deforestation and environmental desertification. In addition, the fossil fuel era seems to be coming to an end, and with this reality, Nigeria will be one of the countries having the highest energy crisis if alternate fuel sources aren't utilized. Thus, the crisis of energy and the price the people must pay for the energy will continue to increase if necessary steps for surviving the crisis are not implemented as soon as possible.

Kitchen wastes are organic materials, which are easily biodegradable. They are a potential raw material for biogas production. Generally, energy production from waste is becoming more popular these days. It has mainly two direct advantages, which are the disposal of waste and the fact that energy can be generated. Traditional biogas plants such as fixed dome or floating drum made of concrete or other materials are generally below the ground. The scarcity of land in urban areas like Lagos has made it nearly impossible for the local people to install the biogas plant. Further, cattle dung is not available in these areas. Use of biogas plants (above ground) using kitchen wastes seem to decrease the problem arising from scarcity of Liquefied Petroleum Gas (LPG).

The earliest record of biogas technology in Nigeria was in the 1980's when a simple biogas plant that could produce 425 litres of biogas per day was built at Usman Danfodiyo University, Sokoto (Dangogo & Fernando, 1986). Animal droppings from cow, pig, poultry and crop residues have been used in different countries. The degree of success of biogas technology varied for the different countries that employed biogas technology for rural energy supply (Ani, 2014).

Pilot biogas plant projects have been executed in some parts of Nigeria by ECN, UNDP, JICA, and some Tertiary Institution. There was a 10 m<sup>3</sup> biogas plant at Achara, Nsukka LGA, Enugu State which was executed by NCERD\UNN, for women cooperative garri processing. The plant fed on droppings of domestic animals, cassava peels and waste from the milling of cowpea, and bambara nut from the nearby food processing plant. There are so many other biogas plants in other parts of the country that are currently not working due to an increase in the number of poor quality constructions and it is damaging people's faith in the technology (Ani, 2014).

The Ifelodun farmer's cooperative at Ojokoro, Agege, had a piggery farm of about 3000 heads and within the farm they operate an abattoir which processes the swine to pork for sale to members. ECN – SERC/UDU in 1998 built 20 m<sup>3</sup> fixed dome bio-digester which was fed on pig waste and produces gas for cooking and natural manure which members use in their farm. At NAPRI, Zaria, a 20 m<sup>3</sup> biogas plant was constructed in 1996 by SERC and in 1998; the centre constructed 30 m<sup>3</sup> biogas digester for Zaria prison, which fed from human wastes. UNDP sponsored construction of 10 – 20 m<sup>3</sup> digesters in Kano, Yobe, Kebbi States, to mention a few. Unfortunately, most of the biogas plants in Nigeria are no longer functional due to lack of maintenance (Ani, 2014). About 21 pilot

demonstration plants with a capacity range of between 10 m<sup>3</sup>-20 m<sup>3</sup> have been sited in different parts of the country(Chima *et al*, 2012).

Over the years, several researchers have worked in this promising field. Hilkih *et al*, (2008) studied the effect of total solids concentration of municipal solid waste on the biogas produced in an anaerobic continuous digester. Their results showed that when the percentage total solids (PTS) of MSW in an anaerobic continuous digestion process increases, there is a corresponding geometric increase for biogas produced. A statistical analysis of the relationship between the volume of biogas produced and the percentage total solids concentration established that the former is a power function of the latter, indicating that at some point in the increase of the TS, no further rise in the volume of the biogas would be obtained.

Kumar *et al*, (2004) investigated the reactivity of methane. They concluded that it has more than 20 times the global warming potential of carbon dioxide and that the concentration of it in the atmosphere is increasing with one to two per cent per year. The article highlighted that about 3 to 19% of anthropogenic sources of methane originate from landfills. Shalini *et al*, (2000) studied increased biogas production using microbial stimulants. Their result showed that dual addition of aquasana to cattle dung on day 1 and day 15 increased the gas production by 55% over unamended cattle dung and addition of terasan to cattle dung: kitchen waste (1:1) mixed residue increased gas production.

Lissens *et al*, (2004) completed a study on a biogas operation to increase the total biogas yield from 50% available biogas to 90% using several treatments including: a mesophilic laboratory scale continuously stirred tank reactor, an up-flow biofilm reactor, a fibre liquefaction reactor releasing the bacteria *Fibrobacter succinogenes* and a system that adds water during the process. These methods were sufficient in bringing about large increases to the total yield; however, the study was under a very controlled method, which leaves room for error when used under varying conditions.

Jantsch and Mattiasson, (2004) discussed how anaerobic digestion is a suitable method for the treatment of wastewater and organic wastes, yielding biogas as a useful by-product.

However, due to instabilities in start-up and operation it is often not considered. A common way of preventing instability problems and avoiding acidification in anaerobic digesters is to keep the organic load of the digester far below its maximum capacity. There are many factors which affect biogas production efficiency including: environmental conditions such as pH, temperature, type and quality of substrate; mixing; high organic loading; formation of high volatile fatty acids; and inadequate alkalinity.

Kang *et al*, (2010) studied the on-site removal of H<sub>2</sub>S from biogas produced by food waste using an aerobic sludge bio-filter for Steam Reforming Processing. They showed that a bio-filter containing immobilized aerobic sludge was successfully adapted for the removal of H<sub>2</sub>S and CO<sub>2</sub> from the biogas produced using food waste. The bio-filter efficiently removed 99% of 1,058 ppm H<sub>2</sub>S from biogas produced by food waste treatment system at a retention time of 400 sec. The maximum observed removal rate was 359 g-H<sub>2</sub>S/m<sup>3</sup>/h with an average mass loading rate of 14.7 g-H<sub>2</sub>S/m<sup>3</sup>/h for the large-scale bio-filter. The large-scale bio-filter using a mixed culture system showed better H<sub>2</sub>S removal capability

than bio-filters using specific bacteria strains. In the kinetic analysis, the maximum H<sub>2</sub>S removal rate ( $V_m$ ) and half saturation constant ( $K_s$ ) were calculated to be 842.6 g-H<sub>2</sub>S/m<sup>3</sup>/h and 2.2 mg/L, respectively. Syngas was generated by the catalytic steam reforming of purified biogas, which indicates the possibility of high efficiency electricity generation by Solid Oxide Fuel Cells (SOFCs) and methanol manufacturing.

Recently, Xiao *et al.*, (2019) studied biogas production by two-stage thermophilic anaerobic digestion of food waste and paper waste, with special emphasis on the effect of paper waste ratio. They concluded that pH, total volatile fatty acids, total alkalinity, and total ammonium of the sludge in the second stage of anaerobic digestion decreased with the increase of paper waste ratio in the test. In addition to this continuously explored area of research, Yang *et al.*, (2019) presented a study on the estimate of restaurant food waste (RFW) and its biogas production potential in China. Their findings revealed that the annual biogas production potential from available RFW was estimated at 4209 million m<sup>3</sup> in total and varied from 20.8 million m<sup>3</sup> to 377.0 million m<sup>3</sup> across all the provinces. Availability of food waste has great potential for biogas production with the availability of information that will help policy makers and enterprise managers to understand the current state of RFW, and to optimize the utilization of RFW.

This present work is to generate and evaluate biogas from kitchen waste in “above ground fixed dome biogas plant” and to find the potential of biogas generation from major kitchen wastes. In achieving this, kitchen wastes using cow dung as an activator will be explored and various tests will be conducted on the biogas obtained from different feeds (kitchen wastes), to determine their energy production capabilities. On the overall, the target is to design a biogas plant which can be installed in the urban areas where there is very limited space which can address the problem of the shortage of cooking gas prevalent in the urban areas. This will in addition address the management of kitchen waste.

## **METHODOLOGY**

The design was carried out after different model, design and type of bio gas plant were studied. The most common type of design studied were the floating drum Type and the fixed dome type. After studying the two types, model and design, the fixed dome plant was chosen for the study to avoid moveable part and wear problems.

Materials required: Poly vinyl chloride (PVC) pipe (diameter 2 cm), Hacksaw (20x7), PVC Elbow joint, Soldering iron (220 volts, 60 watts), PVC Hose (diameter 1.2cm), Paint bucket (20 litres), Epoxy glue, Sand, Gas cylinder, Balloon and Mercury Laboratory Thermometer (0°

- 100° C), and portable pH meter. The schematic side view of the design is shown in Figure 1.

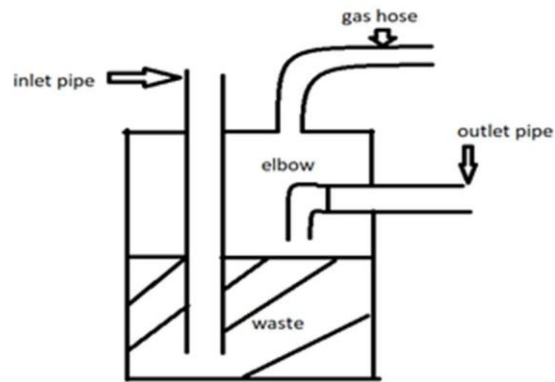


Figure 1: Schematic Side View of Biogas digester

Figure 2 shows the pictorial view of the fabricated biogas digester, while Figure 3 shows the schematic view of the biogas laboratory-scale plant.



Figure2: Pictorial view of Biogas Digester

Precautions: Biogas plant is a digester and it involves the production of highly combustible methane gas while constructing a prototype. The container was airtight; it was a digester that digests the biological waste anaerobically. Transparent or translucent container was not used, because sunlight encourages algae growth which retards biogas production.

Standard gas fitting was used and places with high temperature were avoided.

Experimental Procedure: The PVC pipe was cut into 2 appropriate parts and the diameter of the pipe and hose were marked on the vessel. Soldering iron was used to make holes from the marked diameters. The pipes and hose were then inserted in the vessel. Sand and superglue were used to seal the vessel to make it airtight. The PVC elbow was inserted into the outlet pipe and the hose was connected to the balloon where the gas was stored.

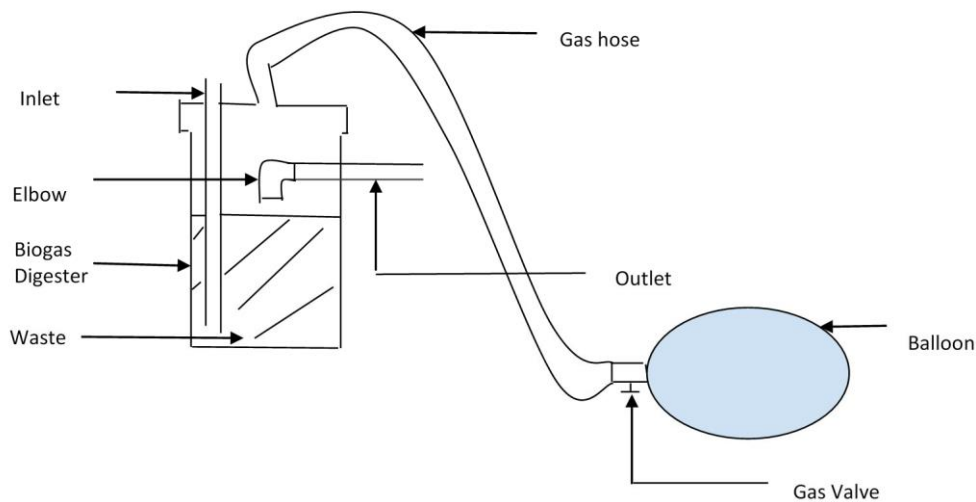


Figure 3: Schematic Diagram of Laboratory-Scale Biogas Plant

The first digester that was constructed was with a dispenser bottle but was scrapped because of the difficulty of inserting the pipes and sealing the hole. Also, the translucent nature of the bottle would have hindered the production of biogas and would have required to be painted with black paint. The selection of the plant site was difficult because of the dangers working with methane. Hose and balloon had to be changed a few times

In each set, certain amounts of kitchen waste as well as cow dung was mixed with water and were later added into the digester. The kitchen waste was blended with the cow dung before mixing and placement into the digester. The waste was allowed to stay for three days before readings were taken.

Set 1: Kitchen waste- 6 litres, Cow dung- 1 litres, Water- 7 litres

Set 2: Kitchen waste- 2 litres, Cow dung- 5 litres, Water- 7 litres

Set 3: Kitchen waste- 0 litre, Cow dung- 7 litres, Water- 7 litres

Throughout the weeks of experimentation, the mixture was poured in the digester with the aid of a funnel. Both the inlet and outlet pipes were properly sealed. On a daily basis, the volume of biogas was measured by a measuring cylinder mounted on a shelf along with the temperature and pH. The total percent solid was determined for the 3rd week alone.

The pH of the slurry at different stages and different states of reaction is an important parameter for the biogas production. The pH of the slurry was measured by making use of the pH meter.

The measurement of the volume was carried out by the downward displacement of water of pH 5. As the biogas is lighter than water; the volume of gas gets collected at the top of the water in the measuring cylinder. The trough was filled with water. The measuring cylinder after filling with water was mounted on the shelf inside the water. The gas outlet pipe from the digester was joined to the shelf. The valve of at the gas

outlet pipe was opened. The gas displaced the water downward and occupied the space at the top. The volume displaced was noted from the scale of the measuring cylinder. If the gas coming out was found to exceed the capacity of the measuring cylinder scale, the valve was closed at the appropriate position up to where the gas volume could be recorded. The gas collected inside measuring cylinder could escape. The cycle was repeated until the gas was evolved.

The temperature of the slurry was measured with a simple mercury thermometer of ranges 0 to 100°C. The temperature was always checked after gas was generated by dipping the thermometer through inlet pipe that is fixed in the cork. The Total Solids (TS %) which is the amount of solid present in the sample after the water present in it is evaporated was also determined. Exactly 10 gm was taken and poured in a foil plate and dried to a constant weight at about 105 °C in furnace.

## RESULTS AND DISCUSSION

Table 1 shows the proportion and ratio of each sample set used. Table 1: Proportion of Each Sample Set

Characters	set 1	set 2	set 3
Amount of kitchen waste (litres)	6 litres	2 litres	0 litres
Volume of water (litres)	7 litres	7 litres	7 litres
Volume of cow dung (litres)	1 litre	5 litres	7 litres
Ratio of volume of kitchen waste to cow dung to water (kitchen waste: cow dung: water)	6:1:7	2:5:7	0:7:7
Duration (days)	3-8	3-7	3-12

In all of the 3 sets, gas production occurred and gas burned with blue flame. The process continued and volatile fatty acids (VFA) were produced, which caused a decrease in the pH value of the mixture.

The quantity of biogas produced is given in Figure 4. The variation of temperature with duration is given in Figure 6 for the three sets. From the results obtained, it was seen that inset 2 which contained kitchen waste, cow dung mixed with water in the ratio 2:5:7 produced more gas, compared to other two sets. Set 2 produced an average of 250.69% more gas than set 1 (with kitchen waste and cow dung mixed with water in the ratio 6:1:7) and 67.5% more gas than set 3 (with cow dung and water in the ratio 7:7). Therefore, kitchen waste is a good alternative for biogas production as observed. The total biogas produced in Set 1, Set 2 and Set 3 after 5 days was 2.27 litres, 7.71 litres and 4.568 litres respectively.

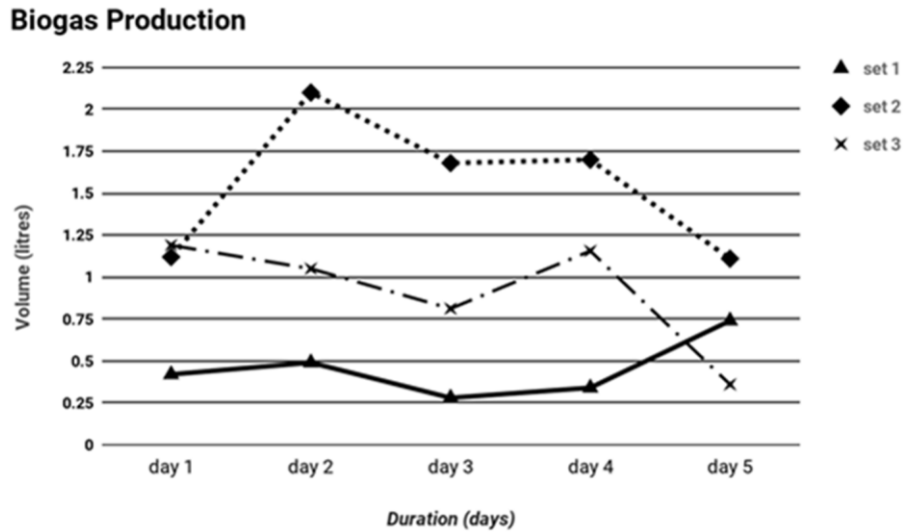


Figure 4: Biogas production per day. The variation of pH is given in Figure 5.

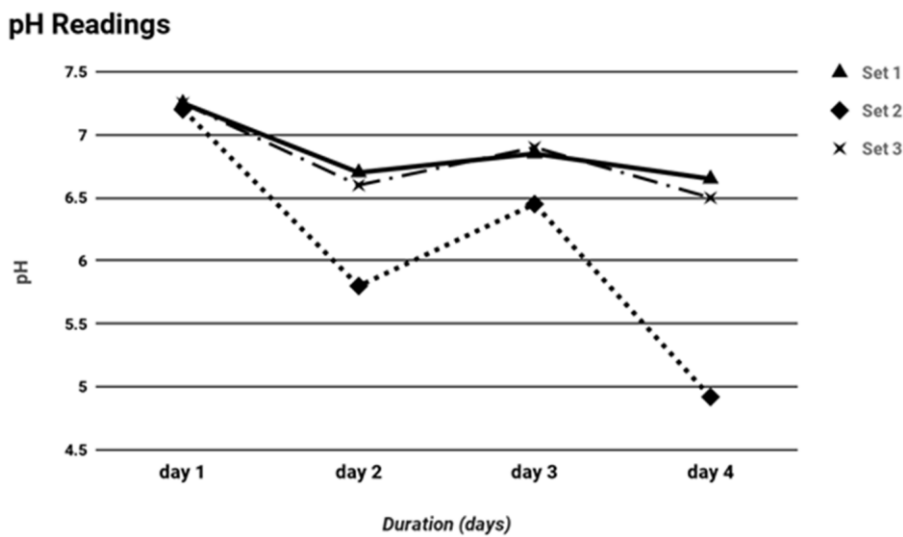


Figure 5: Variation of pH with duration for all the mixture sets.

In addition, it was seen that pH reduced as the process was going on due to the bacteria producing fatty acids. Here methanogens bacteria which utilizes the fatty acids, is slow in reaction compared to others, so it is the rate limiting step in this reaction. In set 2, which contained kitchen waste also, the pH decreased at a high rate, which means that the reaction was fast, meaning that hydrolysis and acidogenesis reactions were also very fast as the organisms utilizes the waste more speedily than dung. The total percent solids is presented in Table 2.

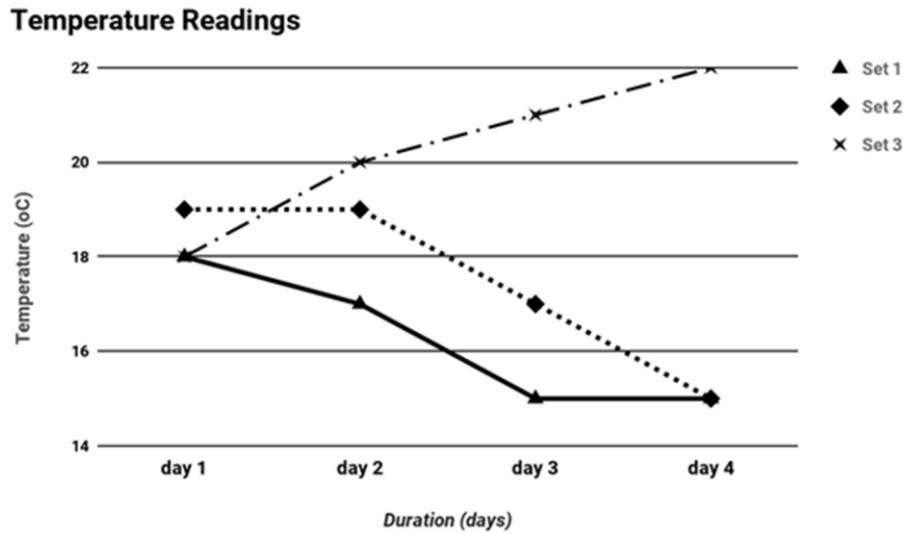


Figure 6: Variation of temperature with duration for all the mixture sets.

Table 2: Total solid percentage in Set 3

Total percent solid	8	7.7	7.5	7.2	7
Day	1	3	5	7	9

As observed in Figure 4 on day 2 production rate of biogas with Set 2, about 2 litres of kitchen waste in the mixture was able to produce above 2 litres of biogas. This result showed that the ability of this simple-designed biogas generator has capabilities similar or even better than similar digesters that utilized kitchen waste mixture to produce biogas as typically reported by Srinvasa *et al* (2017), where around 4500 ml of biogas was produced daily in a 8 litre reactor (digester).

## CONCLUSION

Kitchen waste is a very good source for the production of biogas, as it costs nothing because it helps to recycle waste produced in the kitchen. The 20 Litre bucket used for the study was suitable for biogas generation from kitchen wastes. The batch digestion used was suitable as well. The methane content by volume in the biogas produced seems appropriate, justified by the fluctuating temperature, low ratio of base diameter to depth of the jar, and absence of pre-fermentation. The pH initially was observed to be decreased and then increased after some days. Acetogenesis followed by methanogenesis could be accountable for this. The generation of biogas increased, reached maximum value and gradually decreased with time. This is due to decreasing availability of feed for the methanogens, as the feed was provided in a single batch mode. Gas produced burned freely and gently with blue flame, and can be concluded that the use of kitchen waste helped to increase the volume of biogas. Further study could be carried out by adjusting suitable parameters like C/N ratio, pH value and temperature by suitable means. Enough pre-fermentation time; preferably 15 to 20 days could lead to better yield. The use of



hydrolytic enzymes could be used to accelerate the biogas production.

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# Abstracts of full papers published by Springer

## The significance of social sustainability

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**Keywords:** Social sustainability, energy, population, development.

### Abstract

*Various societies that have achieved a sustainable mode of living are examined in the light of the global history of human development, which is reviewed first. These are societies that never made the transition from agriculture to mercantile capitalism, and one group that never adopted agriculture at all.*

*The objective of the paper is to identify how social sustainability played a part in these achievements. Some of the factors that drove the development of non-sustainability are also identified. The impact of western ideas and civilization on these societies is also identified and discussed. Societies that achieved social sustainability also achieved stable populations.*

# Urbanisation and the built environment: exploring how the built environment can enhance the health and wellbeing of the people living in urban slums

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**Keywords:** Urbanisation, urban slums, built environment, health and well-being.

## Abstract

*Recently, there is a phenomenal growth in the rate of the urbanisation of most countries of the world. As revealed by statistics, more than 50% of the world population already reside in cities, and this will rise to about 68% by 2050. This rapid growth represents a situation where most previously small cities are fast becoming megacities, and most previously megacities have continued to increase rapidly. Some of the immediate resultant effects of this unusual growth are both pressures on the already existing urban built environment, which consequently leads to its continuous expansion; and a remarkable increase in the population of people living in urban slums. The former and the latter effects that are the central focus of this study are worrisome situations that call for concern. The reason is that there is already a consensus among scholars that the built environment can have weighty negative impacts on the health and wellbeing of the people. The argument is that the level of these impacts hugely depends on the differences in the planning, structuring, and designing of the built environment in urban settings. With this, it may not be difficult to conclude that if living in urban centres where there are standard built environments that can affect people's health and wellbeing negatively, it may automatically mean that the impacts of living in urban slums/sub-standard built environment can be much more endangering. Accordingly, this study explored the built environment, health, and wellbeing of the people living in urban slums. As a literature-based study, it reviewed relevant literature that highlights essential issues on the urban built environment, the health and wellbeing of the people in slums. The review produced an analysis demonstrating the possible characteristics of the built environment, show how the environment can be structured and designed to enhance the health and wellbeing of the people living in urban slums. The recommendation emanating from the detailed analysis is that those who make decisions on the plan, design, and maintenance of urban built environments should start focusing on incorporating people's health and wellbeing in their subsequent plans and designs. In addition, they should pay particular attention to the planning, structuring, and designing of the urban slums built environment.*

# Future cities: the role of biomimicry architecture in improving livability in megacities and mitigating climate change risks

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**Keywords:** Biomimicry architecture, Climate change mitigation, Future and sustainable cities, Liveability.

## Abstract

*Since the early start of universe and creation, man and creatures were enclitic by nature and well organized in harmony. Biomimicry as a concept is the mimicry and imitation of systems and strategies seen in the living world as a foundation for different fields, science and applications such as architectural field. Biomimicry has been applied through three levels, an organism level, behaviour level, and an ecosystem level, in terms of its forms, materials, construction methods, processes, or functions. Biomimicry is source of innovation, particularly in creating more sustainable and potentially regenerative architecture. The problem is addressed according to the challenges that megacities face today, mainly high energy use, urban air pollution due to transport, large number of inhabitants' activities, CO2 level and natural resources consumption in all sectors. So, improving cities' infrastructure, mainly buildings is one of the major steps needed to enhance liveability in cities and mitigate climate change. The objective of this work is to assess the value of adopting biomimicry design concept, as a sustainable tool in architecture, due to its potential to create regenerative built environments. The research strategy is centred on a qualitative strategy and the method of data collection is a narrative and case studies' types. It is also depending on a deductive approach. In this paper, architectural examples are examined as a part of nature in order to explore the effect of nature on architecture. In addition, a comparative analysis of biomimicry approach depicting global applications of biomimicry in architecture is presented and discussed in terms of sustainability dimensions. Results of comparing the examined buildings show that the optimum building is CH2 Melbourne City Council House 2 in Australia which has the best sustainability features related to the biomimicry approach and linked to the climate change mitigation and adaptation.*

# Sustainable development and management of low volume road networks in Australia

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**Keywords:** Low volume roads, Development, Management, Social, Sustainability, Communities

## Abstract

*While low volume roads carry only limited volumes of traffic, they perform an essential social function through connecting communities, many of which are located in rural areas. These roads form a significant component of the Australian road network and should be constructed and maintained in a sustainable manner providing an ongoing effective, efficient, safe and reliable service. However, funding for them is often ranked at a lower priority than for roads with larger traffic volumes. Therefore, innovative and best practice network management strategies are required to ensure the productivity, safety, usability, social equity, sustainable environmental management, and resilience of these roads.*

*In order to further investigate current strategies for managing these roads, a survey was conducted of management practices for low volume roads and their networks in 38 local government areas, primarily located in the Australian state of New South Wales (NSW). The research found that enhancements to the current practices were possible and made several recommendations for improvement. The study was also successful in defining the term "low volume road" for both sealed and unsealed roads in NSW. It identified approaches to improve the level of service provided by these roads and their networks by improved planning, design, and construction practices, along with lifecycle management and renewal strategies. It was also found that additional information specifically relating to these roads is required to be collected, recorded, and made accessible to asset managers in a formal system that supports key renewal decisions backed by sound evidence. There was significant opportunity to increase the level of road safety reviews for these roads. Leveraging funding, ensuring that new low volume roads meet future traffic demands, and continuing to investigate best practices for life cycle based sustainable asset management; development and preservation were found to be the most successful strategies to meet these challenges.*

# A community-driven nature-based design framework for the regeneration of neglected urban public spaces

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**Keywords:** Community-driven design, Nature Based Solutions, Design framework, Urban public spaces.

## Abstract

*Nature based solutions are a popularising concept within current urban regeneration literature, exploring differing themes in the context of optimising public spaces. Focus on the adaptation of public space design, with the community at the forefront, has been documented to a limited degree, with few studies concentrating on possible design strategies. This literature review revealed that the majority of nature based design frameworks, since 2017, have suggested the benefits of nature in public spaces to human health and wellbeing: whether physically or psychologically, and either within the full framework or as part of the framework's scope. There are however variations in the number and clarity of steps needed to follow each framework, and it is evident that the importance of community driven designs are understated within built environment literature. Many frameworks favoured the use of academic studies as a secondary source for their creation, with few using primary analysis of community acceptance and co-creation. This paper explores the literature available on nature based solutions and their design frameworks. It maps out the existing studies, to date, and reports on the initial findings for this progressing PhD research. Public spaces are, in their very definition, a space for the public; despite this, development of these spaces, as well as the literature around the subject, are far more theoretical and professionally inclined, rather than community influenced. With an emphasis on sustainable development, this paper suggests that community views on nature based public spaces need to be the focal point of design frameworks for public urban spaces, which may then be used as a protocol for the production of optimal and effective nature-based public space regeneration.*

# Does the planning system in England deliver a sustainable and resilient built environment? A study of the experience of town planners.

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**Keywords:** Resilient Construction, Town Planners, Urban Planners, Professional Identity.

## Abstract

*The case has been made in the reports of the Intergovernmental Panel on Climate Changes for the crucial role of the built environment in mitigating the worst excesses of a warming global climate and in protecting people through adaptation. Town planners are essential actors in delivering sustainable and resilient urbanism. Given that legislation is implemented by people, the study aimed to examine how town planners experienced and thought about the changing legislation and how they understood the concepts of 'sustainability' and 'resilience' in the built environment. Semi-structured interviews were conducted with 19 planners working in England who had at least seven years' experience. In the analysis, we explored meanings of sustainability and of resilience, and how these concepts were seen as incorporated in legislation. Sustainability was seen by the participants as embedded in regulations, but its realisation varied substantially. Tensions were evident between the three pillars of environment, society and economy. 'Resilience' as a concept was poorly understood and legislative support was patchy at best: while flooding features extensively in local plans, wider issues of climate impact such as overheating are not comprehensively addressed. The conclusions are that planners are often frustrated in their attempts to develop a more sustainable built environment and that the current planning system is inadequate to deliver consistently sustainable and resilient outcomes. However, alignment between sustainability goals and professional identity were also noted, offering avenues to explore beyond the institutional constraints of legislation.*

# Ustainability assessments of urban railway systems: case study evaluations in Turkey

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Middle East Technical University, Department of Architecture, Turkey

**Keywords:** carbon emission, sustainability assessments, railway systems.

## Abstract

*With the increasing concerns on sustainability, there are ongoing efforts to control global warming potential (GWP) via reducing CO<sub>2</sub> emissions, which are mostly based on human activities. Due to the complexity of the process, a holistic sustainability approach is obligatory, ranging from the scale of cities to products. Life cycle assessment (LCA) is a versatile and flexible tool, which gives a wider perspective for spanning the project life cycle. Through carbon footprint (CFP) calculations, a clear picture of embodied CO<sub>2</sub> is provided. In general, developing countries mostly focus on reduction of operational carbon (OC), yet the impact of Embodied Carbon (EC) must be evaluated. In this study, the significance of EC estimation and reduction for infrastructure projects are interpreted and precautions are discussed. As a developing country, Turkey should adopt the principles of sustainability and constitute a frame in order to obtain a competitive advantage in the world. In this study, the main motivation is that, railway systems within infrastructure systems should have applicable sustainability strategies. In addition, it is aimed that these efforts would accelerate sustainable development in Turkey. Since there is no certification systems, range or database, these efforts would be reference for the future works. That is why, this paper arises many questions that would be answered in future works of this research. Research methodology is mixed as survey and case study, so it is not comparison based. Literature has been reviewed and real cases were analysed in order to have a better understanding of real projects. Three metro stations, which are located in Istanbul, were explored as case studies of urban railway systems - an important urban infrastructure. With the relevance of the study, it is anticipated that, Turkey will have further associated topics to investigate.*



# Perceptions of Teletubbyland: Public opinions of suds devices installed at eco-designed motorway service areas

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**Keywords:** BREEAM, Drainage, Runoff, and Natural landscapes.

## Abstract

*Sustainable buildings, sustainable businesses and sustainable behaviours are befitting of modern society. Combining these ideals has been realised in the UK's greenest motorway service areas (in Gloucestershire) where public perceptions towards the installation of sustainable drainage devices has been studied. Whilst the planning of sustainable drainage systems has gathered momentum (since the late 1990s), it is readily acknowledged that there is a deficit of community awareness and knowledge of the purpose, function and wider potential benefits derived from devices used to manage and minimise surface water. Until there is a comprehensive shift away from the traditional approach of underground piped drainage, bluegreen infrastructure will remain a relatively unknown entity for the populace and a concomitant shortfall in demand will be encountered. Therefore, public opinions of the motorway service area eco-designed amenity buildings (green roofs) and their surrounding landscapes (swales and ponds) were sought through questionnaire surveys (n = 86) completed by visitors to both the southbound and northbound M5 Gloucester motorway service areas. Results reveal the public share unanimous support for the eco-design sustainable buildings (designed to achieve BREEAM Excellent), and an overwhelming enthusiasm for the aesthetic landscaping of the sites. However, it was clearly evident that visitors were not forming a link between the appearance of the motorway service area features and their associated role in contributing to the sustainable surface water management of the sites, despite the architect's design intention for the landscape to be readily understood. It is concluded that a shift from 'grey infrastructure' will require the involvement of all stakeholders and changing public perceptions of 'blue-green infrastructure' will remain an obstacle until awareness of its value is far-reaching and celebrated beyond the confinements of architectural drawings and planning applications.*

# A decision support system for affordable and sustainable housing design and delivery in least developed countries (LDC's)

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**Keywords:** Design Management, Decision Making, Sustainability, Post Disaster.

## Abstract

*Housing shortages in least developed countries (LDC's) continue to escalate beyond previous records and based on current projections this trend is set to increase. The resulting homelessness and poverty affect large populations in many LDC's. The main contributing factors are recognised as global population growth and natural disasters, which disproportionately affect LDC's when compared with developed countries. The challenge of how best to address these shortages in a sustainable manner while simultaneously building resilience against future disasters into the communities has been a central debate in many LDC's. Many different actors, such as governments, non-governmental organisations (NGOs) and communities undertake housing provision projects in these contexts. However, the outcomes are often of poor quality, which can be attributed to a lack of a coherent and holistic design and delivery process with the community served and lack of a sustainable design ethos.*

*The aim of this research is to explore the complex area of the design and delivery of sustainable and affordable housing in LDC's and post disaster contexts. The research focuses on the design decision-making and delivery process for selected international housing organisations, which operate in the field of sustainable housing in LDC's. The research bridges the domains of architecture and project and design management and in particular, the aspect of decision support. A multi case study approach with nine leading international housing organisations operating in LDC's is undertaken. The study identifies key barriers and challenges faced in the design and delivery of sustainable housing in LDC's as well as key drivers for improvement. Key themes and considerations in the designer's decision making and delivery process are identified. A decision support system (DSS) tool for the design and delivery of sustainable housing in LDC contexts is developed directly from these results, which can then be applied in practice.*

# Are construction professionals equipped with the knowledge and tools to address the sustainability dilemma?

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**Keywords:** BREEAM, Green building certification, Sustainable buildings.

## Abstract

*This study attempts to explore the depth of knowledge and understanding of sustainability issues across a range of construction professions and utilise this evidence to reveal if Building Research Establishment Environmental Assessment Method (BREEAM) is being delivered with due diligence across the industry. A range of construction professionals, key actors in achieving sustainability across the built environment through their advisory roles in design and specification were interviewed (n = 7). It became apparent that knowledge and understanding of sustainability was certainly below an expected level of competence suitable to deliver solutions across the multifaceted sustainability crisis, with many professionals failing to see beyond energy efficiency and carbon reduction. Furthermore, it revealed that planning policy changes incorporating BREEAM as a condition has had negative effects, leading clients and professionals to engage only when required. It was also evident that BREEAM schemes are being used with the goal to obtain development consents and cost was determining actions taken rather than best sustainability outcomes. This results in both BREEAM and Sustainability being perceived as an add-ons rather than core elements or drivers of a project and, in doing so, reduces the effectiveness of the design. Based on this evidence, it is proposed that there is a timely need to change construction professionals' perceptions to achieve a truly sustainable built environment. With BREEAM being one of many similar certification schemes it is worrying that these findings may be the same elsewhere around the world.*

# Sustainability in construction management education: a case study of the students' attitudes and beliefs at two cm programmes of study in Ireland and the United States

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**Keywords:** Construction Management, Education, Students' Attitudes and Sustainability

## Abstract

*This study investigated the level of construction students' familiarity and interest concerning sustainability in the built environment, their ability to identify recognisable sustainable principles, the important areas of sustainable knowledge for students' employment, and factors affecting students' outlook toward sustainability. To accomplish its main objectives, this study employed a survey research method as a main method of data collection. The survey instrument was developed by the authors through in-depth literature review in the areas of sustainability, sustainable construction, sustainable education, and transformation of people's attitude and behaviour. The survey instrument was distributed to Construction Management students in all stages of the programmes of study at the Milwaukee School of Engineering and the Technological University Dublin. The results of descriptive statistics and Analysis of Variance (ANOVA) using SPSS version xx present some interesting findings. CM students perceived that they had a relatively high level of familiarity with sustainable construction and sustainability. They identified that knowledge and understanding of the principles of sustainability were important however, a greater emphasis was placed on the knowledge of environmental rating tools. CM students also believed that general knowledge of sustainability would enhance their chances of securing a career in construction. Finally, several factors of the approaches to teaching and research in sustainability were addressed by the respondents where both US and Irish students indicated that a programme approach to embedding sustainability would be a more favoured approach. They also acknowledged that 'practical experience related to sustainability would be very beneficial', and that 'workshops and seminars associated with sustainable development should be offered' that would contribute towards better students' attitude toward sustainability. Interestingly, there was a very close alignment of attitudes and responses to the survey questions between the two groups.*

# Delivering energy savings for the supply chain through building information modelling as a result of the Horizon2020 energy BIMCERT project

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**Keywords:** building information modelling, Sustainability, Education, Horizon 2020

## Abstract

*The global buildings sector is now responsible for 40% of final energy consumption as well as accounting for 33% of energy-related carbon dioxide emissions. This has resulted in a growing urgency to address energy and emissions from buildings and construction, to meet restrictive 2020 targets as specified by the European Union (EU). To achieve these targets a number of funding initiatives have been put in place through Horizon 2020 with a focus on BIM, due to it having the potential to rapidly produce energy outputs that enable design teams to analyse and compare the most cost-effective, energy-efficient options. However, despite the recorded benefits that BIM can bring to the design, there is still a lack of understanding of how it can be used on site by the supply chain to impact energy savings directly. In order to address this industry-wide concern a Multi-International consortium, bid, won and then launched the Horizon 2020 Energy BIMcert project in March 2018 with the goal to educate all areas of the supply chain in the use of BIM, so as to achieve better energy efficiency during the design, construction and ongoing maintenance of an asset. An online platform will be launched in September 2019, which will deliver blended training that combines theory, practice, and eLearning that will enable workers to train more effectively. This paper will explore the initial stages of this project and will focus on how the findings from a survey and series of workshops conducted within the member states of the Energy BIMcert consortium has helped establish the training needs of the industry. These findings were cross-referenced with a state-of-the-art literature review on BIM pedagogy, which has resulted in the formation of the curriculum and learning outcomes for a number of BIM focused training units. Further to this, the paper will discuss how the delivery of the blended training and associated materials will affect current energy saving targets.*

# The application of virtual reality to recreate an interactive WW1 camp

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**Keywords:** Cultural heritage, Virtual Worlds, Local history

## Abstract

*It is now one hundred years since the end of the First World War. There has been much interest shown in visiting the battlefields and commonwealth war graves during this anniversary. We must never forget this terrible period of our country's history. However, our own local history seems to be rapidly forgotten. Many areas where the "Pals" units had training camps, or where German prisoners of war were interned are now forgotten, mainly due to housing development and expansion of towns and cities since then.*

*The application of Virtual Reality (VR) to enable the immersion and recreation of archaeological sites is well known. From ancient Mayan temples to the virtual immersion within a cave in order to interact with cave art by Native American Indians. More recently our museums are digitising fossil collections to put online, so that they can be viewed in VR, or 3D printed, from anywhere in the world, thus sharing knowledge.*

*This paper illustrates how, VR can be used to recreate an immersive experience of the WW1 camp at Raikeswood in Skipton. This started as an initial archaeological dig by local school children as part of the curriculum for local history. Subsequent funding received by Skipton council, enabled the production of online web and VR artefacts. The images and information used came from, camp plans and sketches, mainly produced by the prisoners themselves. This information has shown the layout of the camp, prison life, the characters involved and events that took place there.*

*The funding has resulted in a detailed web site, which shows a timeline of WW1 and the events within the camp. There are numerous images and extracts from diaries, including sketches by the prisoners. The VR model of the camp illustrates exactly where the camp was located geographically, the construction and function of each of the buildings and what took place within each major building.*

*This paper will show how our local history can be conserved and preserved through the application of VR to create a virtual world of the camp.*

# The need for the inclusion of construction health and safety (H&S) in architectural education

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**Keywords:** architectural, construction, design, education, health and safety

## Abstract

*A disproportionate number of accidents occur in construction relative to other industries, the direct and indirect cost of which, contributes to the cost of construction. Construction is a multi-stakeholder process and consequently all stakeholders, architectural designers included, influence the construction process.*

*Design influences and impacts on construction H&S directly and indirectly. Directly through concept design, selection of structural frame, detailed design, selection of cladding, and specification of materials. Indirectly through the selection of procurement system, related interventions such as prequalification, decision regarding project duration, and selection of contractor.*

*Therefore, architectural designers should be empowered to contribute to construction H&S. However, the need for such empowerment is amplified by legislation in certain countries, such as the OH&S Act and Construction Regulations in South Africa. Despite the influence and impact of architectural design on construction H&S and the evolution of legislation, traditionally South African architectural designers have perceived construction H&S to be the responsibility of the contractor.*

*This paper reports on two descriptive surveys conducted among architectural academics, and a range of built environment practitioners to evolve a framework for firstly, tertiary architectural, and then secondly, tertiary built environment construction H&S education at Universities and Universities of Technology in South Africa.*

*The findings of the literature and descriptive surveys amplify the need for the inclusion of construction H&S as a module, and the addressing of a range of construction H&S aspects, as opposed to merely legislation, relative to architectural programmes.*

# Who are the 'middle actors' in sustainable construction and what do they need to know?

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**Keywords:** Sustainable construction, Middle actors, Project networks, Skills, Knowledge.

## Abstract

*This paper explores what knowledge and skills are needed, and how those skills and knowledge might be gained, in order to deliver more sustainable outcomes from construction, using the concept of “middle actors”. “Middle actors” are the individuals who occupy the space between ‘top down’ policy and instruction, and ‘bottom up’ norms. In construction, ‘middle actors’ with influence on building performance include clerks of works, project managers, tradespeople and technical advisers.*

*There is a relentless drive for more sustainable buildings that use less energy, generate less waste during construction and use, and provide healthy environments for people to live and work in. This direction of travel can no longer be considered “new” and yet it remains far from the mainstream. To create buildings which are sustainable, we need to consider not only technology and design changes, but how to alter the wider system of construction. We use middle actors as the lens through which to examine these non-technical changes, and the skills and knowledge required to achieve them.*

*A review of the concept of middle actors as it has been applied to construction and an overview of skills and knowledge needs for sustainable construction is followed by identifying middle actors in new build and retrofit, commercial and domestic projects currently under way with one developer in Leeds, UK. The skills and knowledge needed by ‘middle actors’ to deliver more sustainable outcomes from their projects are described, based on empirical data gathered from project teams, and further structured by considering when in the project cycle they are needed, and what routes to gaining the required skills and knowledge might be most effective. This analysis reinforces that there is no single route to achieving more sustainable buildings and instead the activities, responsibilities and networks of individuals need to be carefully considered in developing training programmes for construction teams.*



# Developing a best practice framework for degree apprenticeships in civil engineering: A review of chosen methodology

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**Keywords:** Civil Engineering, Degree Apprenticeships, Industry-Academic Collaboration and Methodology.

## Abstract

*A research project is being undertaken to identify a delivery framework for managing, and successfully completing a degree apprenticeship in civil engineering. The research will investigate challenges, barriers and best practice experienced by the Employer, the Apprenticeship Training Provider (ATP) and the Apprentice: the tripartite stakeholders. Patterns of challenges, barriers and best practice will illustrate promising points of intervention to develop evidence to inform a supporting framework. As the Civil Engineering and Civil Engineering (Site Management) degree apprenticeship standards were approved for delivery in 2017, the first candidates for the End Point Assessment (EPA) are expected to be presented around January 2020. This means that research based specifically on successful degree apprenticeships in civil engineering is in its infancy so current performance data and insights are scarce.*

*This paper reviews the types of methodology that can be used to retrieve appropriate, accurate and valid data for the research, and presents findings of initial interviews using phenomenological methods that have been carried out with Small-Medium Enterprises (SMEs) about their initial experiences with the scheme. The discussion of the approach identifies time-bound considerations in relation to the main body of research and future investigations. Thus, the research parameters of the next phase of the research are identified and discussed.*

# User satisfaction of a green star-rated literary museum in South Africa

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**Keywords:** Post-occupancy evaluation, Green building

## Abstract

*The main aim of this study is to determine a Green Star-rated literary museum's post-occupancy user satisfaction. This research employed a case study survey research design in which a BUS (building use studies) questionnaire was administered to a case to determine the satisfaction of users with the performance of the green building. The data analysis involved the calculation of means for factors of satisfaction, parameters of comfort, determination of tolerance of users with the green building and a comparative analysis with similar buildings from the BUS database. The benchmarking determined whether the study building was better, the same as or worse than similar buildings. Findings of the study indicate the perceptions of occupants regarding the building design rated highest in terms of satisfaction, attributable to the integrative design process of the Green Building Council South Africa (GBCSA) and elements of social design, whereas perceived health rated the lowest. In terms of the factors of comfort, the perceptions of occupants regarding the overall comfort of the building contributed positively, whereas noise was a concern. Findings of the study further indicate that the study building performed better than the benchmark in terms of factors of satisfaction and those of comfort. The occupants of the study building demonstrated tolerance with the building's environment, which may be attributable to pro-environmental behaviours. This information is beneficial to the facilities managers to enable occupants to exercise more control over the thermal conditions of the building. In terms of future designs and heating, ventilation and air conditioning (HVAC) control strategies, it would be beneficial to install systems that mimic the desired conditions of the occupants. Building owners and managers should consider introducing noise reduction strategies in traffic areas such as floor padding for noise attenuation. Benefits could arise from a noise awareness campaign and the installation of a visible or audible decibel warning system as additional strategies.*

# Addressing accreditation criteria related to sustainable construction in the united states: A case study

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**Keywords:** Accreditation; Curriculum; Sustainability; Student Learning; Assessment

## Abstract

*The requirement to incorporate sustainability into the curriculum of construction management programs in the United States has only been required since July 2015. At this time the American Council for Construction Education (ACCE) introduced the revised Document 103: Standards and Criteria for Accreditation of Construction Education Bachelor's degree Programs. The curriculum requirements of the standards in previous versions had been prescriptive in nature, requiring construction programs to demonstrate the inclusion of a required number of credit hours of prescribed subject matter and topical content. The previous standard had no requirement to teach sustainability. A series of workshops was conducted with construction industry participants to gather data in order to develop a set of learning outcomes that would define the capabilities of students graduating from a 4-year ACCE accredited program. The new standard requires programs to demonstrate graduates of their program have achieved 20 Student Learning Outcomes, one of which is that upon graduation students should be able to "understand the basic principles of sustainable construction". The approach for delivering sustainable construction subject matter across the curriculum at an ACCE accredited university is presented, together with method of academic assessment of students during their senior year. Course learning outcomes addressing the principles of sustainable construction were developed and subject matter taught across several courses from freshman through senior level students. Academic assessment is achieved by senior students conducting an individual assessment of a project building to demonstrate understanding of how the design and construction of the building reflects the basic principles of sustainable construction. Students are set six specific tasks that address: LEED Certification; Erosion & Sedimentation Control; Building Commissioning; Environmentally Preferred Products; Construction Waste & Indoor Air Quality. Students are graded using five criteria grading rubric. Results from academic assessment conducted since the Fall of 2015 suggest students are consistently meeting performance criteria.*

# Stakeholder management: Proposal for research - Do successful project managers employ 'interest-based negotiation' to create successful project outcomes?

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**Keywords:** Project Management; Stakeholder Management; Stakeholder Engagement; Interest Based Negotiation.

## **Abstract**

*Increasingly the management of stakeholders is reported, by research on the management of projects, as being critical to the successful development of projects. Current research into the management of stakeholders charts a move from: classifying who stakeholders might be; to one of determining whether and how to manage them; to one of recommending 'engagement'. Stakeholders are seemingly important players in the project's environment because they are able to both: significantly influence the project's delivery and because they may well be the arbiters of whether the project can be considered successful or not. This latter point indicates the role that stakeholders and those stakeholders that are beneficiaries of the project can have in determining how 'value' is interpreted. This research proposal identifies a gap in existing literature; that gap is in the final process of stakeholder management. Aligned to a risk management process, stakeholder management ends with the idea that the stakeholder will be managed. As writers show that 'engagement' might be beneficial, then 'interest-based negotiation' (IBN) allows for a project manager to engage with these groups through IBN. Anecdotal evidence shows that elements of IBN might be unconscious components of successful project managers interactions with stakeholders. This paper proposes a study design that will allow for the hypothesis H1 "Successful stakeholder engagement can be correlated with project managers employing elements of interest-based negotiation" to be tested.*

# Effective management of hazardous asbestos waste within a confined watermain pipeline construction project: Multiple case study review

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**Keywords:** Asbestos, confined site construction, critical space analysis, Irish construction industry, space scheduling, water main.

## Abstract

*As urban sprawl continues to put pressure on cities across the globe, so too is the need to service those who live and work within these regions. The need to provide fresh, clean drinking water to each person is becoming increasingly difficult and somewhat unsustainable. In the context of Ireland, this is no different, particularly with ageing and leaking services. To counteract such issues, there is a need to replace old and often hazardous asbestos watermain pipelines with more durable solutions. However, in doing so, the process unearths particularly hazardous material to those who have the task of replacing it. There is an ever-growing need for advanced methods of materials management and space scheduling on confined construction sites with a considerable gap in literature accounting for the management and removal of hazardous waste. Therefore, the aim of this study is to investigate the effective management of such hazardous waste, within what is invariably a confined construction site environment. To achieve this aim, three case studies are identified, all of which involve the removal of old asbestos watermain, in a confined city centre environment. Three individuals on each case study are interviewed, using a semi-structured approach, to investigate how they effectively manage and mitigate the risks associated with the decommissioning, packaging and removal of hazardous asbestos waste from each of their respective projects. The findings indicate that, in order of importance, Space Scheduling, Critical Space Analysis, and Supply Chain Management, are critical in the safe identification, decommissioning, excavation, extraction, packaging and ultimate removal and disposal of hazardous asbestos waste watermain. This research is conducted with the ultimate viewpoint of increasing the efficiency of pipeline construction where hazardous waste is present, reducing costs on-site and, ultimately, improving the health and safety, both of those working onsite, but also those in the vicinity of the removal of this hazardous waste.*

# Construction programme failure and the impact on waste, resource efficiency, and natural capital in construction project environments

Neil Pickavance, Andrew Ross and Damian Fearon

**Keywords:** planning, programme, sustainability, waste, resources.

## Abstract

*Delayed and disrupted construction projects contribute poor sustainability in construction project environments. UK construction documents an extensive history of project delay and disruption, with contracting organisations operating in environments with a prevalence of excessive sub-letting, fragmentation, poor integration of sub-contractors, build strategy dislocation, contractual-adversarial relationships, and poor adoption of project planning frameworks.*

*This investigation reviews the extent and impact of individual and team behaviours and cultures within a contracting organisation project and the influences on the success of Critical Path Method (CPM) project planning and scheduling. CPM remains the standard method of project planning and scheduling in the construction industry, despite newer systems such as Lean Construction, Last Planner® System, Agile Project Management, and PRINCE2.*

*Exploratory qualitative data was collected through a purposive sample of six semi-structured interviews with UK construction management personnel on a sample case study project. Experienced project managers and project planning staff from contracting and sub-contracting organisations were consulted on project planning, scheduling and programme development, co-ordination, integration, procedures, methods, techniques, training and development.*

*Results identify CPM planning operating in unstructured environments characterised by poor operating and application protocols, and poor understanding and ad-hoc engagement by project teams. Poor leadership and facilitation of programme development by senior project management could be associated with later project failure. It is concluded that fundamental problems with basic project planning and scheduling undermine sustainability in construction due to late completions.*

# An investigation into the gap between programme management theory and practice

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**Keywords:** Programme Management Theory; Strategic Alignment; Value and Benefits; Governance.

## Abstract

*The programme management approach was intended as a way of delivering organisational strategy and achieving beneficial outcomes through the coordination, prioritisation, and precise resources allocation of projects based on their relative 'value' contribution. Such coordination of projects would offer greater sustainable valued outcomes, and has been widely adopted in the U.K. Despite the intentions of the theory of programme management, and the fact that literature largely concurring on the themes and facets of 'programme management theory', as much as 53 % of programmes underperform in delivering their strategies and 34% of projects were found to offer no beneficial outcomes (NAO, 2016), suggesting that issues and flaws exist within this theory and that perhaps there is a gap in terms of the attention being given to the experience of managing programmes in practice. This study aimed to illustrate the challenges faced when exercising the theory of 'programme management' in practice and utilised a qualitative in-depth focus group discussion amongst programme and project experts to do so. The primary data findings concluded that there is indeed a gap between the two that especially manifests in regard to issues with: the lack of strategic focus leading misalignment of projects thus the distortion of strategic vision, the subjectivity of 'value' leading to conflict in the selection and prioritisation of projects and the rigid governance structures that prevent strategic decision making and hinder innovation. Several attributions were made as to the root causes of these issues as well as possible solutions based on interpretations of expert opinions and the overall data analysis. Following a critical discussion and comparison between the primary and the literature findings, this study hypothesises that programme management theory and practice are still at an embryonic stage and yet to meet one another and that governance might be the missing link between strategy formulation and execution. This study further recommends more empirical and qualitative research be conducted in order to bridge the gap between theory and practice and suggests that elements a hierarchically flatter governance structure, a bottom-up approach to strategy, visualisation to aid prioritisation, and human behavioural errors are important aspects to be taken into consideration when doing so.*

# Obstacles of sustainable construction project management in South Africa construction industry

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**Keywords:** Construction industry, Sustainable construction, sustainable construction project management, Mpumalanga Province.

## Abstract

*Green building is mostly adopted by the private sector or the private property development companies who are enjoying the benefits of it. Hence the study will explore the obstacles impeding the implementation of sustainable project management in the public sector in South Africa. Structured questionnaires were distributed to different construction companies and construction professionals involved in the public projects. From 80 questionnaires distributed, 65 were brought back and they were all valid and usable. Findings from the survey results obtained from the chosen respondents revealed that there is resistance to change from conventional to green practices by organization employees, Lack of awareness of green building methods and technologies, absence of dependable exact cost data/ information, limited government involvement, the complexity of codes and regulations on green building and sustainable construction, high cost of green building material and also attracts a higher risk of delays in construction. From the findings the government of South Africa needs to play a huge role implementing sustainable construction project management in public buildings, which will benefit the government, and the end users and reducing the nation's carbon emission emanating from construction sector.*



# Long-term durability of solar photovoltaic modules

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**Keywords:** Durability, Solar, Photovoltaic, Ultraviolet Radiation

## Abstract

*Solar photovoltaic (PV) panels experience long-term performance degradation resulting in lower like-per-like efficiencies and performance ratios when compared with their initial performance. Manufacturers of solar photovoltaic modules usually guarantee the life span for more than 20 years. It is therefore necessary to track and mitigate degradation of PV modules over this period to satisfy such guarantees and beyond this period to identify maintenance and repair requirements. Degradation of solar PV modules makes them less efficient, less reliable and, ultimately, inoperative. This paper reviews relevant literature to discuss:*

- *causes of efficiency reductions in photovoltaic cells;*
- *ways to achieve long-term durability of solar photovoltaic modules;*
- *how viability of solar photovoltaic modules is affected by degradation;*
- *the remedies to solar photovoltaic (PV) degradation.*

# Impact of public charging infrastructure on the adoption of electric vehicles in London

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**Keywords:** Behaviour Change, Public Charging Infrastructure, Electric Vehicles.

## Abstract

*The discussion on the importance of public charging infrastructure is usually framed around the 'chicken-egg' challenge of consumers feeling reluctant to purchase without the necessary infrastructure and policy makers reluctant to invest in the infrastructure without the demand. However, public charging infrastructure may be more crucial to EV adoption than previously thought.*

*Historically, access to residential charging was thought to be a major factor in potential for growth in the EV market as it offered a guaranteed place for a vehicle to be charged. However, these conclusions were reached through studies conducted in regions with a high percentage of homes that have access to residential parking.*

*The purpose of this study is to understand how the built environment may encourage uptake of EVs by seeking a correlation between EV ownership and public charging points in an urban and densely populated city such as London.*

*Using a statistical approach with data from the Department for Transport and Zap Map, a statistically significant correlation was found between the total (slow, fast and rapid) number of public charging points and number of EV registrations per borough – with the strongest correlation found between EV registrations and rapid chargers.*

*This research does not explicitly prove that there is a cause and effect relationship between public charging points EVs but challenges some of the previous literature which indicates that public charging infrastructure is not as important as home charging. The study also supports the notion that the built environment can influence human behaviour.*

# Performance evaluation-based claims process for insuring energy performance of new dwellings

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**Keywords:** housing, energy performance, energy efficiency gap, insurance, energy performance gap.

## Abstract

*This paper describes the development and testing of a building performance evaluation-based claims process that underpins a new insurance-backed energy performance warranty for guaranteeing the in-use performance of new homes in the UK. The insurance backed warranty is based on the principle that if there are deficiencies in the building fabric or energy systems (physical factors) of an insured dwelling which causes excessive energy consumption, the insurance will make good those deficiencies. However, excess energy consumption resulting from occupancy factors is not insured. To be able to accurately identify the cause (physical or occupancy factors) of excessive energy use, a socio-technical building performance evaluation based claims process is developed and tested for four low energy new-build flats located in a development in Southeast England. Data on energy use, environment (temperature, relative humidity, CO2 levels) and occupant behaviour (opening-closing of windows, appliances' use) were collected using high frequency energy and environmental data loggers, questionnaires, interviews and activity logging diaries over a full heating season (October 2017 – April 2018). The influence of physical (form, location) and occupant factors (occupancy patterns, heating schedules, hot water requirement, use of electrical appliances) on in-use energy consumption was investigated for three end uses: space heating, water heating and electrical appliances. Results suggest that in the four low energy flats, occupant behaviour does not significantly affect actual space heating demand (which is mainly determined by physical factors), as much as hot water and use of electrical appliances, indicating that in low energy gas heated dwellings, excessive gas use is more likely to be eligible for an insurance claim than high electricity use. In future research the claims process could be less invasive using smart meter data to identify the influence of physical or occupant factors.*

# **A multi-dimensional analysis of smart energy systems: Towards developing a common framework for assessing the sustainability of small-scale renewables in selected societal sectors**

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**Keywords:** Smart energy systems, sustainability, assessment framework, stakeholders.

## **Abstract**

*The UK power sector is migrating from an old centralized network of large, mainly fossil-fuel based generating stations toward a more dynamic energy ecosystem with new entrants generating and actively managing their consumption. This is occurring at a time when electricity system participants are searching for solutions to tackle three criticalities known as the “energy trilemma”; de-carbonising, securing long-term supply resilience and affordability. The wider context is that energy is a fundamental part of UK society. The inability to access clean, reliable sources of affordable energy is a barrier to securing development which is sustainable. However, there is limited published research which takes a comprehensive approach to assessing whether the impact of changes to the UK power system are contributing to sustainable development. This research is therefore focused on an evaluation of sustainability through the investment decisions of stakeholders in respect of solar photovoltaics (solar PV), in the UK context. This research considers the “sustainability impact” within three sectors: the public, private and third sectors. Relevant metrics and benchmarks will be considered against the UN Sustainable Development Goals (UNSDGs) whilst also exploring the ‘real’ value to society.*

# Evaluating Solar Prediction Methods to Improve PV Micro-grid Effectiveness Using Nonlinear Autoregressive Exogenous Neural Network (NARX NN)

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**Keywords:** Nonlinear autoregressive, NARX NN and NAR NN Models, Prediction, Performance comparison.

## Abstract

In recent years, insufficient access to energy and environmental challenges caused the push for clean and sustainable means of power generation. The integration of renewable energy resources into the electricity grid is known to reduce Greenhouse Gas (GHG) emissions and environmental pollution. Solar power has the enormous benefit of availability and can often be accessed cost effectively. However, there is a recurring problem of intermittency and variability in most solar power generation systems. The variability and intermittent nature of solar power sources introduce significant challenges in the planning and scheduling of smart grids. Solar power prediction can mitigate this variability and improve the integration of solar power resources into smart grids. This paper presents an Artificial Neural Network (ANN) model for solar power prediction, and assesses how several weather input variables from Leeds, UK, affect the prediction accuracy. Following this, the Nonlinear Autoregressive Exogenous Neural Network (NARX NN) model performance is compared with Nonlinear Autoregressive Neural Network (NAR NN) model using a time series modelling approach. The result shows that NARX NN model outperformed NAR NN model for the studied geographical location.

# Responsible retrofit measures for traditional listed dwellings: An energy simulation validation strategy

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**Keywords:** Building Energy Simulation, Calibration, Cultural Heritage dwellings, Energy retrofit.

## Abstract

*Energy and carbon retrofitting of traditional listed dwellings (TLDs) in the South-East England is much required but faces a multi-faceted and complex suite of issues and problems. A research project has been designed to specifically address those problems. It utilises a mixed methods approach centred around multi-staged dynamic Building Energy Simulations (BES) for selected case studies of TLDs in Brighton and Hove. The cases have been surveyed, modelled and simulated to assess their current energy performance and thermal behaviour as well as potential benefits of responsive and effective retrofit interventions. The use of simulation implies the need for a thorough validation strategy to ensure that the data generation and analysis tool is reliable, valid and replicable in similar or identical contexts. Case studies research allows for an empirical validation, based on the calibration of simulated models with monitored data. For this on-going research project, a calibration strategy has been devised, based on the findings of a critical review of literature. It utilizes energy consumption data as well as temperature and relative humidity data for each case study.*

*Providing a brief overview of the methodological framework of the research, the paper describes in detail the approach utilised to ensure that the datasets, collected and generated using different sources, corroborate each other. Such validation process aims to generate virtual models capable of accurately representing the real case studies in their status-quo energy performance and thermal behaviour. The calibrated models can therefore be reliably used during the following stages of analysis when the impacts of selected retrofit interventions are to be evaluated.*

# Understanding factors influencing overheating: The UK's first large-scale domestic Passivhaus retrofit

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**Keywords:** Climate change, Overheating, Passivhaus, Occupant Behaviour.

## Abstract

*Overheating in dwellings is a major consideration affecting buildings in both temperate climates like the UK, as well as in warmer climates. At the same time, it is recognised that the impacts of global warming and climate change are affecting weather patterns in the UK resulting in many changes, including long periods of hot weather in the summer and warmer wetter winters (Lowe et al., 2018). In order to reduce global CO2 emissions, fabric improvements are being made to buildings to make them more energy efficient. To achieve these improvements the thermal insulation and airtightness of the building is often improved. The combination of these factors not only serves to retain heat energy during winter heating periods, but it can also result in excessive rises in internal temperatures during the summer, resulting in overheating. This can result in the building occupants' experiencing discomfort and they may even be exposed to temperatures that pose serious health risks for the most vulnerable in society. In order to provide a safe and healthy environment for occupants, we must provide energy efficient dwellings that consider not only current but future climate scenarios. The paper presents the initial findings of a study investigating the risk of overheating in the UK's first large-scale Passivhaus retrofit.*

# A South African experience of building energy retrofit project challenges and solutions

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**Keywords:** Building, Challenges, Energy and Retrofit.

## Abstract

*Delivering building energy retrofit project will bring about economic gains, while enhancing social wellbeing and engendering sustainable development. However, building energy retrofit projects encompass additional considerations and requirements in terms of process, material, expertise, and technology. All these factors constitute complexities in the delivery of the project. In addressing this problem, the paper presents how stakeholders understand implementation challenges in the delivering of projects amongst South African service providers. The case-based study highlighted the challenges, and solution concerning the methodologies that are appropriate in ameliorating the situations.*



# Serious games for the built environment: Eco material trumps

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**Keywords:** sustainable construction materials, environmental impact, game-based learning, experiential learning, teaching and learning resource.

## Abstract

*This paper describes the research, development, design, production and analysis of a prototype teaching and learning resource entitled 'Eco-Material Trumps'. A card game intended to be used within an educational setting and as a source of reference for built environment professionals. The set of cards contain data on the sustainability credentials of common building materials and the aim is for the game to be used to stimulate debate on how, in practice, decision-makers need to balance the differing criteria that are used to establish the environmental impact of construction materials. This research has revealed that there is a disparate body of existing knowledge from a wide variety of industry and academic sources related to the subject matter which until now has not been collated into a single resource. One of the main barriers to the development and uptake of games in a learning context is the lack of empirical data to support the hypothesis for its effectiveness, as well as a lack of understanding about how these games might be used most appropriately in practice. This study used a questionnaire to investigate participants' perceptions of the value and importance of the active learning and cooperative activities they undertook during interactive and experiential workshops and the results and analysis are presented within this paper. Findings from the feedback elicited from workshops shows that this resource enables the processing of complex sets of data, brings together data from disparate sources, encourages interaction and discussion, promotes learning through visual and tangible presentation of data and encourages sustainable thinking about and beyond the subject matter.*

# Sustainable development of mankind through ecological services: A literature review

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SARChi in Sustainable Construction Management and Leadership in the Built Environment, University of Johannesburg, Auckland Park, 2006, South Africa

**Keywords:** Ecological Services; Mankind, Remuneration, Sustainability

## Abstract

*A working ecosystem is a cornerstone to human prosperity. When ecological concerns are associated with the economic aspects, the challenge lies in addressing human issues without corrupting the environment. The presence of mankind and society relies upon the life support framework of the physical environment. Thus, the purpose of the study is to appraise the sustainable development of mankind through ecological services in developed and developing countries. The research relied on the use of credible past and present literature from the theoretical and conceptual analysis undertaken to form the fundamental concept which this study is formed upon. The literature revealed that the economic significance of ecological services to the sustainable development of mankind legitimizes the need to comprehend their value. Similarly, to understand the association between ecological services and the development of mankind as a component that supports policy decisions, different approaches can be implemented towards the remuneration of ecological services. These approaches are mainly through the market and governmental approach. Moreover, the study contributes to the body of knowledge on how ecological services could bring about radical sustainable development in developing countries.*

# Waste management: The case of construction and demolition waste in Port Elizabeth

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**Keywords:** Construction, Demolition, Environment, Materials, Waste.

## Abstract

*The construction industry has both positive and negative repercussions on the environment. One of the main negative impacts is waste generation. The huge amount of construction and demolition waste (CDW) entering landfills in Port Elizabeth, South Africa, has stressed the local environment. To alleviate its adverse impacts, the municipality and construction industry have adopted a set of measures. A study was conducted to provide insight into CDW management practices in Port Elizabeth, to develop a response to the CDW problem. The objectives were to determine whether: CDW is indiscriminately disposed of; certain CDW is hazardous; there is a disproportionate amount of CDW, and generated CDW is often re-wasted. The sample included construction managers, site agents, and municipal officials in the employ of the Nelson Mandela Bay Municipality, constituted the sample strata of the study. The study revealed that the number of CDW disposal sites is inadequate, which contributes to illegal dumping of CDW, and a culture of lawlessness engenders and leads to illegal dumping of CDW. Furthermore, illegal dumping of hazardous waste is a threat to human and environmental health. Lastly, the research determined that contractors manage their schedule of materials ordered, packaging of material, and recycle damaged or incomplete material, which mitigates CDW. The challenges encountered during this research are beneficial to both researcher and industry practitioners, since they could develop further research and CDW management plans accordingly.*

# Performance evaluation of five sediment barriers using a full-scale testing apparatus

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**Keywords:** construction, sediment barrier, sediment control, and water quality.

## Abstract

*Erosion and sediment controls on construction sites minimize environmental impacts from sediment-laden stormwater runoff. Sediment is contained on project sites by installing sediment barriers. However, there is little performance-based testing data for the various designs, configurations, and materials for sediment barriers. To better understand sediment barrier performance, researchers at the Auburn University-Erosion and Sediment Control Testing Facility (AU-ESCTF) developed a full-scale testing apparatus to conduct performance testing on sediment barriers. Using this apparatus, researchers have evaluated five sediment barrier options to compare performance and identify possible shortcomings using standardized full-scale testing methods. This performance testing subjected sediment barrier practices to simulated field conditions typically experienced on-site without the variability of testing in nonstandard field locations or the limitations imposed by small-scale testing. Through testing, the researchers measured sediment barrier performance in the following areas: improvement in water quality by measuring turbidity, sediment retention, and structural integrity. The sediment barriers were installed using the same tools and techniques used for construction site installation. The full-scale testing apparatus exposed the evaluated sediment barriers to water and sediment loads expected to be encountered as the result of a two-year, 24-hour storm from central Alabama. Two nonwoven, wire-backed silt fence installations were evaluated with which the standard trenched method proved to capture a greater amount of sediment compared to the sliced-method of installation, which experienced significant undermining. The best performing practice was the ALDOT Sediment Retention Barrier that captured over 90% of sediment introduced without undermining. The worst performing practice was a wheat straw wattle that undermined so significantly, it was deemed to be a failing practice, resulting in the premature stoppage of each test.*

# Contractor's readiness for LEED requirements in Ireland: factors for consideration

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**Keywords:** Contractor Readiness, Irish Construction Industry, LEED, Sustainability.

## Abstract

*LEED (Leadership in Energy & Environmental Design) certification is becoming increasingly prevalent, not only globally, but also in the Irish construction industry. This paper investigates the current readiness of contractors in Ireland for achieving LEED certified construction projects, while identifying factors for consideration going forward. Objectives include evaluating the current readiness of Irish contractors respective to LEED and subsequently, highlighting factors for consideration, to better enable those working towards securing and delivering LEED certified construction projects. In achieving this aim, a qualitative methodology is undertaken, using three case studies as a basis for the study. Within each case study, three semi-structured interviews are carried out, with the results analysed, coded, with themes emerging for subsequent discussion. The key findings from the study indicate that Irish contractors are not adequately prepared to achieve LEED certification. In overcoming this, the study concludes that further education is essential, both at third level graduate level, but also for further/return to education prospects. Those interviewed unanimously agreed that further education and training is essential to bridge the divide to achieve higher Irish contractor conformance to the requirements set out when achieving LEED Certification. The findings represent value to Irish contractors as it shows a clear dearth in both knowledge and ability in achieving LEED certification, while providing proposed solutions, to better enable Irish contractors in attaining LEED certification through further education and training.*



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