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Unique Factors of Best Value Procurement From the Perspective of Nigerian Construction Professionals

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ABSTRACT

The construction industry is vital to the economic development of any country. It has a major role in providing built infrastructures in an innovative and cost-effective way using an effective procurement approach. In contrast, the most widely used procurement method in Nigeria is the traditional procurement approach which is known for plaguing the industry with the poor working condition and poor performances thus, reducing the sustainability and quality of products and services. For this reason, there is a need for a procurement approach which utilises expertise to minimise the risk of non-performance and create a win-win environment for both client and contractors, while increasing transparency and add value to the project such like, the Best Value Procurement. Against the background, this paper aims to establish the perception of the Nigerian construction professionals on the unique factors of the Best Value Procurement. The paper outlines the following objectives: To identify the unique factors of the Best Value Procurement and, to establish the perception of the Nigerian construction professionals on the Best Value Procurement unique factors. Using a questionnaire survey, data was collected form 314 construction professionals involving Quantity Surveyors, Architects, Builders and Civil Engineers. Kruskal Wallis Test and mean score ranking was used for data analysis. The findings show that the professionals generally agree that the Best Value Procurement unique factors can bring about transparency, accountability, increase project performance and the contractor is the best to control risk and adds value to the project. This paper derives its significance from the need to stabilise the procurement system in Nigeria by transferring the risk and control to contractors who must act in the best interest of the client.

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1. Introduction

Procurement is a series of activities and procedures that are necessary to acquire essential products or services from the best contractors at the best price (Fournier j, 2015). Lim (2014), opined that procurement involves the process of selecting contractors, creating payment terms, strategic vetting, selection and the negotiation of contracts and actual construction (Idiake et. al, 2015). The construction industry is so important to the economic development of any country that it cannot be ignored. A modern and efficient infrastructure is the key driver of productivity, and the construction industry has a major role in providing the built infrastructure in an innovative and cost-effective way (Walesbusiness.org, 2013).

Kashiwagi et. al. (2004) stated that a lot of changes has befallen the construction industry which has brought about several project delivery systems such as Lowest-bid, Design-bid-build, construction management at risk and others. This has been a major feature of the construction industry over the last three decades or so (Naoum and Egbu, 2015). Naoum and Egbu (2015), noted that despite the various project delivery systems in the construction industry there is, however, an absence of reporting on the association between procurement methods and matters such as innovation and technology, supply chain, lean construction, buildability, sustainability and value management. The association between the procurement method and these matters are supposed to help to improve the construction project delivery performances and provide insights on the best value to be delivered in the construction industry.

In Nigeria, the most widely used procurement method is the traditional procurement method also known as Design-Bid-Build (Idiake et. al, 2015). Baloi & Price (2003), highlighted that the traditional procurement method has plagued the construction industry with poor working condition, poor wages and a degraded environmental ideal, therefore, reducing the sustainability and quality of both products and services. Also, many users of the method have documented poor performance and poor quality of contractors procured using the traditional procurement method (Hampton et. al., 2012; Idoro, 2012; Smallwood, 2000). Mshelbwala (2005), stated that the role contractors play in the construction industry was key, as the services they rendered are critical to the quality of the end product as well as meeting cost and time targets. For that reason, selecting a suitable contractor increases the odds of a successful construction project completion which fulfils the client's goals of keeping the schedule, cost, time and quality in balance (Jiya, 2012). Mshelbwala (2005) also added that a good contractor is expected to complete a project on time, within budgeted cost and to the desired level of quality because, the quality of a product to a large extent depends on the skills and experience as well as the competence of the producing agents.

In contrast, the traditional procurement method used in Nigeria is known by its peculiar used of the contract to control both parties especially the contractors. The contractor, who is supposed to be an expert in managing, directing and visionary expert is not given adequate opportunity to impart their experiences hence, creating additional works, variations and prolong dissatisfaction (Kashiwagi et. al., 2012). As a result of the control, the procurement method is seen adversarial in nature and result in high expectations, lack of performance information and other aspects from lack of measurement (Dorée, 2004). Also, according to Bos, Kashiwagi and Kashiwagi (2015), the non-involvement of contractors from the beginning of the project leads to non-utilisation of their expertise, hence, create non-transparent, lose-lose, reactive project environment which the larger contractors felt uncomfortable with.

Therefore, there is that need to employ an innovative procurement approach which utilises expertise to minimise the risk of non-performance and create a win-win environment for both client and contractors, while increasing transparency and add value to the project. This innovative procurement approach is called the "Best Value Procurement".

1.1 Research Problem

The construction industry in Nigeria accounts for almost 70% of the fixed capital formation of the Nation and contributes about 1.4% of the GDP (Odediren et. al., 2012) also, employs approximately 25% of Nigeria's workforce; the largest in Africa (Ibrahim & Musa-Haddary, 2010). Yet, the public construction projects in Nigeria has been faced with a lot of challenges before and after the Due Process Policy contract procurement process in Nigeria (Olatunji, 2007 and Familoye, 2015).

The Due Process Policy contract procurement process came about in order to entrench an effective contractor selection model that is based on world's best practice (Olatunji, 2008) so as to adopt the ethos of transparency, objectivity and accountability in a value-based public procurement system (Salama et. al., 2006; Wong and Holt 2003). Regrettably, Familoye et. al., (2015), noted that the public procurement act of Nigeria has not been able to achieve its primary objectives of transparency, accountability and value for money. These lead to the challenges of project non-performance in Nigeria. These challenges are: lateness in honouring payment certificate, too many variations, technical incompetence i.e use of non-expert contractor, design deficiencies, material shortage or late delivery, delays, inadequate project documentation, disputes, poor work condition, increase in project risk, cost overrun, time overrun and poor quality of work done (Ogunsanya et. al., 2016; Oladinrin et. al., 2013; Olatunji, 2007).

The gap in this research is that the Best Value Procurement (BVP) utilises a tool called 'Performance Information Procurement System (PIPS)' as the actual delivery structure for optimising the supply chain and the alignment of resources to minimise management, direction and control of the expert contractor and, increase accountability, transparency and value (Kashiwagi, 2017). These leads to the minimisation of the project cost by 98%, reduction of time overrun by 98%, increases contractor's profit by so doing creating a win-win environment, maximise technical competency, maximise client satisfaction and delivers an outstanding project quality while adding value (Kashiwagi, 2015). If incorporated into the project delivery system in Nigeria, it has a potential of stabilising the entire project delivery system in Nigeria as it is that, Nigeria intends to adopt the ethos of transparency, objectivity and accountability in a value-based public procurement system.Hence, improving project performances in Nigeria. Just as shown in Figure 1.

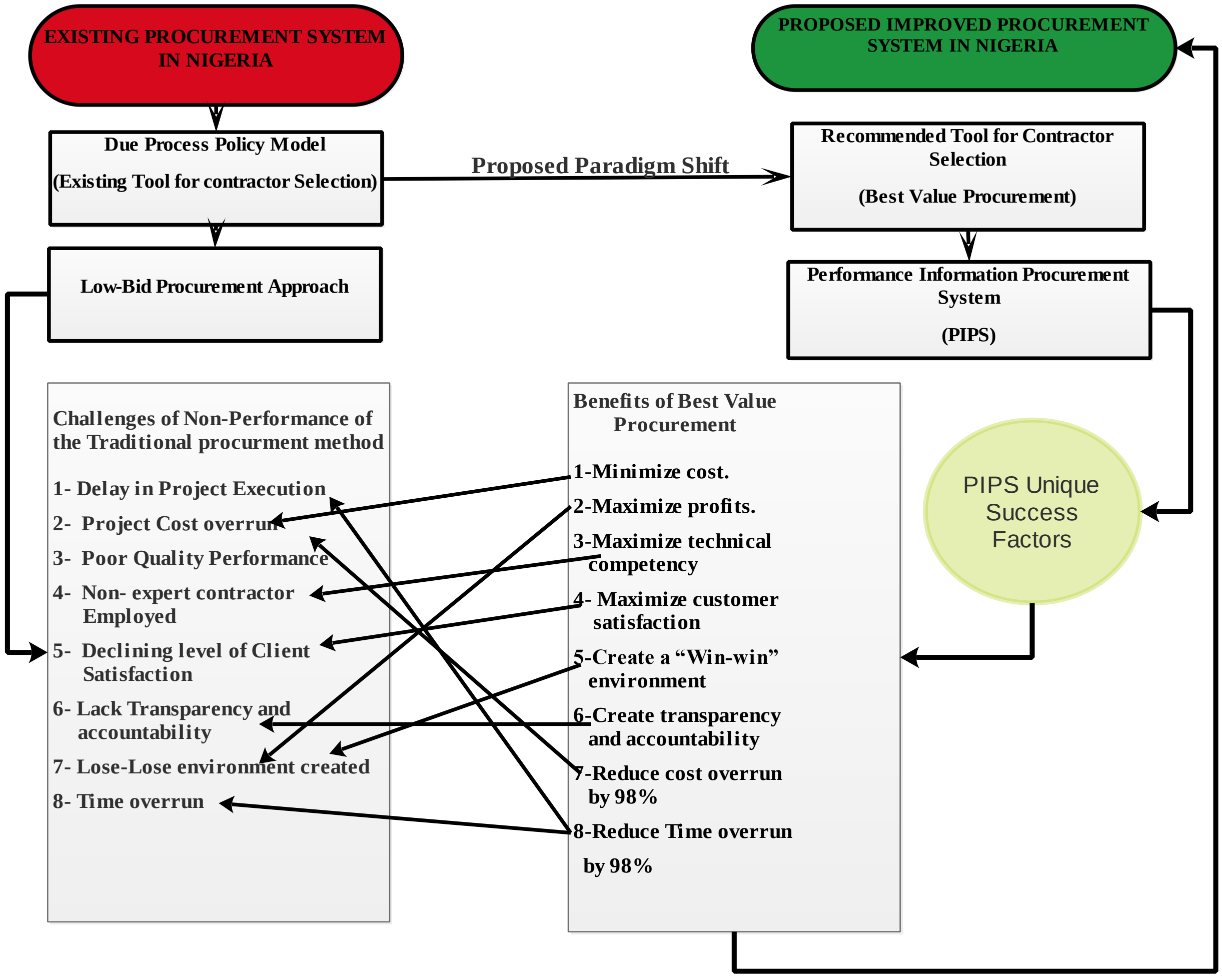

Figure 1 Conceptual Framework

1.2 Research Questions

1. What are those factors that make the Best Value Procurement unique?
2. How do the Nigerian construction professionals perceive these factors' ability to improve project delivery in Nigeria?

1.3 Aim and Objectives

This research aims at establishing the perception of Nigerian construction professionals on the unique factors of the Best Value Procurement. In accomplishing this aim the following objectives are to be achieved:

1. To identify those unique factors of the Best Value Procurement.
2. To establish the perception of the Nigerian construction professionals on the Best Value Procurement unique factors.

The best value Procurement (BVP) substitutes traditional project risk and, procurement management, as well as contract administration with the alignment of expertise and accountability (Kashiwagi, 2012). The Best Value Procurement (BVP) is a change in paradigm. As it focuses on replacing the traditional business model which involves making decisions, managing, directing and controlling the contractor with the utilisation of expertise, it is an approach of an intelligent person who utilises expertise to create a "win-win" environment for everyone. This approach is comprehensive in its application into business but is mainly used in the field of procurement (Kashiwagi solution Model Inc., 2016).

Kashiwagi et. al. (2012), Added that it is an efficient and potent method that reduces the detailed needless information and communications, and creates a win-win environment for both the parties, achieve superior possible value at the lowest price, high contractor profit, and minimal project deviations in cost and time. BVP emphasises efficiency, achieving worth for money, performance criteria and, it centres on instituting best practices for public sector organisations by putting into words incontestable standards and develops an adequate contractual procedure in delivering services to the public" (Akintoye et. al, 2003).

Therefore, the Best Value Procurement (BVP) selection method distinguishes the most qualified contractor from others based on provable past performance metrics instead of more traditional criteria (Abdelrahman et. al., 2008). As it is, the best value guarantees the selection of the most qualified contractor regardless of the price and, the understanding of the Best Value system will greatly benefit both clients and contractors (Hasnain and Thaheem, 2016). Below are the objectives of the best value procurement as well as the tool used in procuring an expert contractor in the BVP approach

1.4 Objectives of Best Value Procurement (University of Minnesota, 2016):

1. Reduce the risk of non-performance.
2. Optimise the supply chains.
3. Minimise life-cycle cost.
4. Increasing organizational efficiency
5. Improve the quality of construction work and vendor services (including on-time delivery and eliminating change orders).

1.5 Performance Information Procurement System (PIPS)

The delivery method of the Best Value Procurement uses the tool called "Performance Information Procurement System(PIPS)". PIPS was originally, strictly a selection process. The first test of the process was performed in 1994 according to Kashiwagi & Savicky cited in Kashiwagi (2013), was used in selecting roofing systems and contractors for private organizations such as Intel, IBM, and McDonald Douglas. The system was documented and performed so well, for the roofing industry, the system spread to other construction areas. It has been transformed into four models which are: (1) selection Model, (2) Measurement Model, (3) Risk model and, (4) Management model (Kashiwagi, 2012). Best value PIPS procurement is more than just a procurement system. It is a business model, cutting edge technology and a leadership model that looks at factors other than just prices, such as quality and expertise when selecting contractors. Hence, proving a visionary outlook to the construction project right at its onset (Nihas, 2017). Performance-Based Studies Research Group (2016), also concur that the PIPS process offers clients a tool to identify and choose the Best Value vendors or contractors for their projects, based on performance instead of just lowest price. Unlike other Best Value methods out there, PIPS also has mechanisms to measure the contractor's performance throughout the duration of the project.

1.6 The Concept of Performance Information Procurement System

The PIPS concept is based on outsourcing, quality control (rather than management and inspection), continuous improvement with minimal client control, and the process is based on leadership rather than management principles to improve the success rate (on time, on budget, no change orders) of construction delivery (Kashiwagi et. al., 2005). Deductive logic or common sense proposes, that since the construction industry non-performance problem has existed for such a long time, it may be a systems problem instead of individual participant's non-performance or lack of technical expertise or a problem that can be overcome simply by re-ordering or changing the grouping of participants (Sullivan et. al., 2009; Collins, 2001; Deming, 1982; Ford, 1922). Kashiwagi et. al. (2005), Also opined that the poor level of performance in construction is being stirred by the client's price-based environment. This will be best explained in the construction Industry Structure.

1.6.1 Construction Industry Structure (CIS) Analysis

Kashiwagi (2011), Uses Figure 2 The CIS explanation to show that PIPS has leading value and the reason the majority of project/risk management concepts are not precise or efficient.

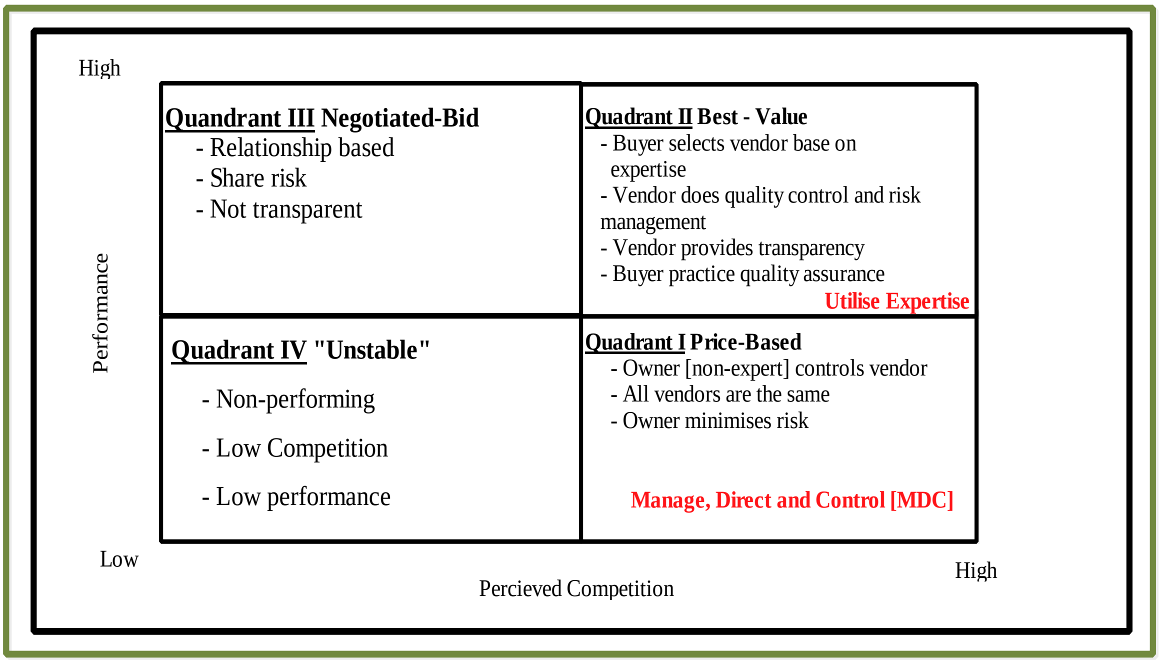

Figure 2 Construction Industry Structure. Source: (Kashiwagi, 2011)

1.6.2 Price based Quadrant I

"The BVP/PIPS was developed as a result of the fact that the service delivery system was identified as the problem and not the shortage or unavailability of qualified technical personnel (Meyer et. al, 2010; Kashiwagi, 2010). By means of an industry structure diagram (Figure 2), the following observations were deductively made:

a. In the price base environment, performance is low due to the fact that the client or client representative who has less technical experience is the one giving direction to the contractor that is supposed to be the expert.
b. Quality will constantly drop as a result of the usage of minimum requirement which is subjectively created and requires interpretation to apply. Hence, creating an adversarial relationship between the owner and the contractor. The owner hungers for a low price and superior value while the contractor wants a minimum performing systems.
c. The client tends to increase directing, controlling and management when the quality and prices decrease.
d. When the client increase directing, controlling and management, value and performance decrease thereby increasing the cost.

The lack of recognising and appreciating the differences in the contractor's quality, performance and value in the price based awards, tends to motivate contractors to be more adversarial, offer lower quality, not to pre-plan nor utilise expertise. No transparency in the price base system, it requires more of decision making that increases the risk of expectations and deviations. In order to shift from poor performance to high performance, there must be an increase in efficiency and minimising cost, directing, controlling and management from the owner. The contractor's expertise level must be increased also.

1.6.3 Quadrant II Best Value

When the contractor increases accountability, measurement of performance, pre-planning, quality and risk management then, will there be an increase in performance. The contractor is identified in the best value environment as an expert. Thus, assigned the role of quality control and risk management. While the client representative in the best value environment is given the role of non-technical quality assurance which ensures that the contractor has the needed systems used to minimise deviation. Therefore, in describing the best value quadrant, it is a deductive argument which is dominant and utilises common sense. The following deductive logic is the basis of the design of the BVP/PIPS structure:

a. An expert contractor can deliver at a lower price, a high quality and has less risk.
b. Controlling a contractor is impossible and, attempting to do so brings about decision making, additional transactions, increase in cost and risk also, a declining effect on quality and value.
c. The risk that expert contractors cannot control is their only risk, this is because an expert contractor has very little technical risk.
d. Expert contractors maximise their profits by attempting to manage and minimise the risk they have no control over.
e. Expert contractors pre-plan and do operate proactive systems of risk management that help manage their risk before it occurs.
f. The best value for the lowest price is the 'best value'.

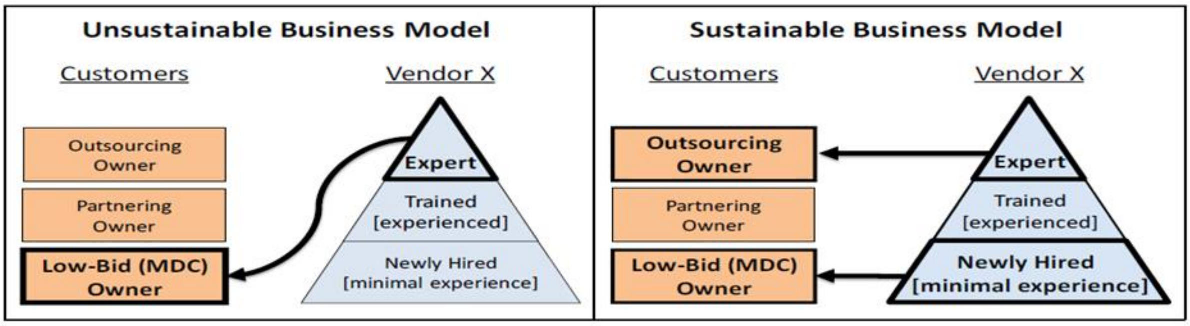

Figure 3 Industry Business Models. Source: (Kashiwagi, 2017)

Kashiwagi (2017), explained Figure 3 in his book titled "secrets of success how to know everything without knowing anything" which shows a vendor's employees as newly hired, trained and highly experienced. The owners are represented on the left side as outsourcing owner [utilize expert's expertise], partnering owner [collaboration and working together] and the low bid or price based owner who manages, directs and control [MDC].

If the vendor sends their most experienced and expert workers into the price based owner, who manages, directs and controls [MDC] the expert, the expert will resist the non-expert, the project duration will be extended, the cost will increase and the profit will decrease.

The vendors will quickly learn to send their new recruits to the MDC owner. They are cheaper and because they lack experience and expertise, they make the MDC owner comfortable by listening and following their instructions. The vendors have no risk if they carry out the instruction given to them diligently. Even if the results achieved are not satisfactory, as long as the vendor did as the owner directed, the owner's representatives become accountable for the results.

The only approach of successful vendors to utilize the expertise of the experts in their company is to send their experts to the outsourcing clients. The experts have a higher salary, but due to their planning, mitigation of risk, and expertise, they will lower the project cost. This is the only approach to maintain expertise in the industry.

The largest group of owners are the MDC owners. Due to their "blindness", they are driving the industry into the ground. There is no motivation for highly skilled project managers, skilled mechanical, piping and electricians (MEP) to increase in their level of expertise [change their paradigm, do more training and education and be proactive in leading projects].

1.7 Unique factors of the Best Value Procurement

Kashiwagi (2013), identified out of 44 clients'/contractors factors that Best Value Performance Information Procurement System (BVPIPS) has eight (8) unique factors that are different from the traditional procurement systems. These factors are:

1) No-influence, no-control, no management philosophy
2) Seamless contract
3) Supplier contract creation
4) Pre-planning
5) Problem Contracting
6) Communication Minimization
7) Expert Supplier Model
8) Dominant Information

No-Influence, No Control, No Management philosophy: PIPS gets the buyer to minimise direction and release control over the supplier since the supplier is the expert. This system also focuses on making the supplier accountable for the project, due to the owner minimizing direction and decision making on the project. According to Moteng (2016), it involves setting up a structure that makes each party responsible and accountable for knowing and doing the work they are hired to do which will be more efficient than the client having to manage, direct and control the project contractor.

Seamless Contract: Contract mitigates risk instead of being a legal/regulatory/control document. As established by Moteng (2016), If the project performance is measured on a weekly basis and published to all stakeholders, showing deviation created by each project stakeholder, then accountability will increase and project performance will improve.

Supplier Contract Creation: The supplier creates the contract and the scope of the project. Moteng (2016), asserted that contractors who are experts are more qualified than the client and its advisors to develop the best solution to the problem that the project is requested to solve.

Pre-planning: The PIPS/PIRMS places more importance on pre-planning before the contract is signed than after the contract is signed. The contract representing the start or implementation of the service, since usually the contract binds all parties to an identified project plan and set of activities. Therefore, Requiring the expert contractor to have a detailed project plan and to show what awaits each stakeholder over the entire course of the project before signing the contract will improve project performance (Moteng, 2016).

Problem Contracting: PIPS/PIRMS does not require the buyer to identify the scope of the project. Allowing the buyer to only relay their intent and expectations. This thus makes project requirement defined in terms of high-level objectives instead of minimum specifications which allows the expert contractor to be innovative and create greater value for all stakeholders (Moteng, 2016).

Communication Minimization: This system minimises buyer/supplier communication. Therefore, using simple terms that non-technical stakeholders can understand and reducing the circulation of highly technical information will improve communication and project performance (Moteng, 2016).

Expert Supplier Model: Supplier has no technical risk and focuses on mitigating risk the supplier does not control. Consequently, it Requires the expert contractor to identify and pro-actively track all the project risks that they do not control thus, making every stakeholder be more accountable (Moteng, 2016).

Dominant Information: Communication to be in simple, clear, and in non-technical terms. This creates a transparent system thereby; deters project parties from feeling like they are being cheated hence, benefits generated by the project becomes clearer (Moteng, 2016).

These factors were found to be unique because they could not be found in any other client/contractor systems. When compared to the traditional client/contractor factors, none of the factors could be matched up with a traditional factor.

2. Methodology

2.1 Area of Study

This study was conducted in Abuja, the Federal Capital Territory (FCT) of Nigeria and some significant states in Nigeria as well. These states are Kaduna State (Located in the north-western region of Nigeria, the capital of the former northern region of Nigeria), Jos, plateau state (located in the middle belt of Nigeria) and Minna, Niger State (located in west-central Nigeria). Being that Abuja is a hub of construction with professionals from different locations in Nigeria practising in different fields then, professionals from the north, Middle belt and west-central have captured a cross-sectional profile of the professionals in the country. See Figure 4

Figure 4 Map of Nigeria showing the state for data collection (Abuja, Kaduna, Jos and Minna)

2.2 Population and Sample size

The type of data collected is made up of primary data as Rubin & Babbie (2009), opined that the use of primary data collection method is effective to provide valid and reliable research data and it helps to develop relevant understanding about the topic by involving the research participants in the study. Therefore, a questionnaire was used for the collection of data being that questionnaires are effective means of measuring the behaviour, attitudes, preferences, opinions and intentions of relatively large numbers of subjects more cheaply and quickly than other methods" (McLeod, 2014). The questions in the questionnaire were close-ended and on an attitude scale called 'Likert Scales'. Hence, the target population of this study are Architect, Quantity Surveyors, Civil Engineers and Builders that are registered with their respective professional body. This is because, for any procurement approach to perform very well as to time, cost and quality which are the key performance indicators of any project, it has to depend on the expertise and experience of these professionals from the beginning to the end.

The target population of the construction professionals in Abuja, Kaduna, Jos and Minna put together as at 2017 when the data was collected was about 3,438 which comprise of Quantity Surveyors, Architects, Builders and Civil Engineers (Nigerian Institute of Quantity Surveyors 'NIQS'; Architects Registration Council of Nigeria 'ARCON'; Council of Registered Builders of Nigeria "CORBON" and Nigerian Society of Engineers 'NSE', 2016). Based on this, using Krejcie and Morgan (1970), table for determining Sample Size form a Given Population, the closest to this study's population is 3,500 of which the sample size for data collection is 341. Hence, a random sampling procedure was used in disseminating the questionnaires. This survey was carried out from February 2017 - September 2017. Out of 341 respondents 314 questionnaires were completed and returned for data analysis which is about 92% of the questionnaires completed and returned. According to Baruch (1999), cited in Nulty (2008 Pg. 306), he stated that the overall average acceptable response rate was 55.6%. Based on this, the response rate of this study can be said to be adequate.

2.3 Method of Data Analysis

The method of analysis used are Kruskal Wallis Test so as to, help access the differences among the professionals' perception on the unique factors of BVP (Najib and McKnight, 2010; Pallant, 2005) and mean score ranking to help determine the hierarchy of probability of the unique factors of BVP i.e., to quickly learn the true popularity ranking of the unique factors of BVP (unbiased by the made suggestions) and suggest true popular unique factors of BVP (Davino and Fabbris, 2014; Vojnovic' et. al., 2009)

2.4 Instrument (Questionnaire) Reliability

From Table 1, the professionals used for this pilot survey were 18 in number. Hence, the responses for the pilot survey was completely filled and returned. 5% of a total of 350 expected responses was used for the pilot survey. Viechtbauer et. al., (2015), asserted that, if a problem exists with 5% probability in a potential study participant, then the problem most likely for sure be identified with 95% confidence. Furthermore, Table 2 shows the reliability of the instrument used. According to Nunally (1994), Cronbach's alpha normally measures for scale reliability of 0.7 as a cut-off value. Anelli et. al. (2018), contributed that a value ≥ 0.7 indicates high reliability as well. Hence, form Table 2, the Cronbach's alpha coefficients for the instrument used is highly reliable at 0.901 value which is above the acceptable value of 0.7.

Table 1 Case Processing Summary

		N	%
Cases	Valid	18	100.0
	Excluded[a]	0	.0
	Total	18	100.0

a. Listwise deletion based on all variables in the procedure.

Table 2 Reliability Statistics

Cronbach's Alpha	N of Items
.901	59

2.5 Data Analysis.

2.5.1 Data Presentation and Discussion

Table 3 is a presentation of the number of registered construction professionals that were the respondents in this study. From the table the following where the number of each professional field: Architect (64), Quantity Surveyor (104), Builders (72) and Civil Engineers (74). These are the representation of the sample for the population of this study.

Table 3 Registered Professionals Involved in the Study

Professional Field	Professional Body				Total
	ARCON	NIQS	CORBON	NSE	
Architecture	64				64
Quantity Surveying		104			104
Building			72		72
Civil Engineering				74	74
					314

Table 4 Professional's Years of Experience in the Construction Industry

Professional Field	Years in the construction industry				Total
	6-10years	11-15years	16-20years	>20years	
Architecture	4	33	20	7	64
Quantity Surveying	13	44	33	14	104
Building	4	32	36	0	72
Civil Engineering	4	28	40	2	74
Total	25	137	129	23	314
	8%	44%	41%	7%	100%

Table 4 is a presentation of the years of experience of the respondent in this study. From the table, the following are the percentages of respondents' years of experience captured in this study: 6-10 years (8%), 11-15 years (44%), 16-20years (41%) and above 20 years (7%).

2.5.1.1 Perception of the Construction Professionals on Unique Factors of Best Value Procurement.

Table 5 shows the summary of the perception of all the professional fields as to their level of agreement to each best value statement of the BVP unique factors.

Table 5 Summary of the Perception of all the Professional Fields

S/No.	BEST VALUE PROCUREMENT UNIQUE FACTOR	BVA STATEMENT	Professionals' Perception		
			Strongly Disagree / Disagree	Not Sure	Strongly Agree / Agree
1	No influence, no control, no management philosophy	Setting up a structure that makes each party responsible and accountable for knowing and doing the work they are hired to do will be more efficient than the client having to manage, direct and control the project contractor.	0%	4%	96%
2	Seamless contract	If the project performance is measured on a weekly basis and published to all stakeholders, showing deviation created by each project stakeholder, then accountability will increase and project performance will increase.	0%	0%	100%
3	Supplier contract creation	Contractors who are experts are more qualified than the client and its advisors to develop the best solution to the problem that the project is requested to solve.	0%	0%	100%
4	Pre-planning	Requiring the expert contractor to have a detailed project plan and to show what awaits each stakeholder over the entire course of the project before signing the contract will not improve project performance.	0%	0%	100%
5	Problem contracting	Having a project requirement defined in terms of high-level objectives instead of minimum specifications will allow the expert contractor to be innovative and create greater value for all stakeholders.	0%	1%	99%

6	Communications minimization	Using simple terms that non-technical stakeholders can understand and reducing the circulation of highly technical information will improve communication and project performance.	0%	0%	100%
7	Expert supplier model	Requiring the expert contractor to identify and pro-actively track all the project risks that they do not control will result in every stakeholder being more accountable.	0%	1%	99%
8	Dominant information	A transparent system prevents project parties from feeling like they are being cheated and helps them to see all the benefits generated by the project.	0%	0%	100%

From Table 5 it can be said that the Nigerian construction professionals do agree with the best value procurement unique factor's applicability to improve project delivery in the construction industry particularly the Nigerian construction industry. this agrees with Moteng (2016), in his research said that the majority of practitioners (80 %) believe that the BVP principles if implemented in can improve projects performance.

There is a need to confirm whether there are any differences in the professionals' level of agreement across the different professional groups to each of the Unique factors of BVP. Hence, a Kruskal-Wallis test was carried out to address the issue.

Table 6 Test Statistics [a,b]

Unique Factors of the Best Value Procurement	Chi-Square	df	Asymp. Sig.
No Influence, No Control, No Management Philosophy	15.385	4	.004
Seamless Contract	14.386	4	.006
Supplier Contract Creation	15.567	4	.004
Pre-Planning	.179	4	.996
Problem Contracting	13.807	4	.008
Communication Minimization	8.850	4	.065
Expert Supplier Model	10.452	4	.033
Dominant Information	7.163	4	.128

a. Kruskal Wallis Test
b. Grouping Variable: PROF FIELD
Note: Significance level, Value $< \alpha$ (0.05)

From the output in Table 6, of the Kruskal-Wallis test, it suggests that there is a significant difference in the professionals' level of agreement across the different professional groups to some unique factors of BVP and they are No Influence, No Control, No Management Philosophy, Seamless Contract, Supplier Contract Creation, Problem Contracting and, Expert Supplier Model all having significance levels value of < 0.05 each. While, to some, it suggests that there is no significant difference in the professionals' level of agreement across the different professional groups to the remaining unique factors of BVP and they are Pre-Planning, Communication Minimization and, Dominant Information all having significance levels value of $>$ 0.05 each. Consequently, meaning that, there is a difference in their perception on the following Unique factors: No Influence, No Control, No Management Philosophy, Seamless Contract, Supplier Contract Creation, Problem Contracting and, Expert Supplier. While, having an unwavering agreeing position on the following BVP unique factors: Pre-Planning, Communication Minimization and, Dominant Information.

For a better understanding of the professionals' rating of each of these unique factors of Best Value, a ranking of these unique factors was conducted by the use of mean score (MS) to ascertain the level of acceptability of each unique factors by the Professionals. The formula for the mean score used is:

$$MS = \frac{\sum n.p}{N} = \frac{P_1*n_1 + P_2*n_2\ldots n}{N}$$

Where, MS= Mean Score,
n = weighting number of the scale,
p = probability distribution of respondent,
N = total number of respondents.

The decision rule on Likert scale on the mean score from this entailed weightings of Strongly Disagree=1, Disagree=2, Not Sure=3, Agree=4, Strongly Agree=5. Therefore, and averaged on the scale is:

$$\frac{1+2+3+4+5}{5} = 3$$

Therefore, any score over the average score of 3 can be regarded as an agreement of some magnitude. As supported by Ameyaw (2015), Mean Score <1.50 = very low, 1.5 – 2.49 = low, 2.50-3.49 = moderate, 3.5-4.49 = high then > 4.50 = very high.

Table 7 Mean Score Ranking of the Unique Factors of Best Value Procurement from the Professionals' Viewpoint

S/NO.	PIPS SUCCESS FACTOR	ARCH	Q/S	BUILD-ING	CIVIL ENG	S ENG	AVE MS	RANK
		MS	MS	MS	MS	MS		
1	No influence, no control, no management philosophy	4.667	4.732	4.688	4.591	4.967	4.729	3
2	Seamless contract	4.772	4.598	4.672	4.652	4.933	4.725	4
3	Supplier contract creation	4.772	4.680	4.813	4.561	4.867	4.738	2
4	Pre-planning	4.596	4.577	4.609	4.591	4.600	4.595	6
5	Problem contracting	4.386	4.485	4.453	4.682	4.367	4.474	8
6	Communications minimization	4.561	4.649	4.547	4.682	4.400	4.568	7
7	Expert supplier model	4.737	4.701	4.766	4.561	4.667	4.686	5
8	Dominant information	4.825	4.794	4.703	4.682	4.867	4.774	1

Table 7 hereby, expresses how the Nigerian construction experts' rates the Best Value Procurement unique factors which bring about success in project delivery in the construction industry. From the average mean score of all the unique factors of Best Value Procurement in Table 7, using the decision rule by Ameyaw (2015) is shows that there is a very high level of acceptability of the Best Value Procurement unique factors in the Nigerian construction industry with an average mean score of each unique factors greater than 3.5 which indicate high acceptability. Also, from the ranking, the professionals agreed that Dominant information ranks no. 1 with an average mean score of (4.774), Supplier contract creation no. 2 with an average mean score of (4.738), No influence, no control, no management philosophy no. 3 with an average mean score of (4.729), Seamless contract no. 4 with an average mean score of (4.725), Expert supplier model no. 5 with an average mean score of (4.686), Pre-planning no. 6 with an average mean score of (4.595), Communications minimization no. 7 with an average mean score of (4.568) and finally, Problem contracting no. 8 with an average mean score of (4.474).

Table 7 expresses that the professionals in the NCI generally agree with all the BVP statements which elaborate its potential towards improving the project delivery in the NCI. Out of the eight (8) unique factors statements the highest is 'Dominant information' which states that "a transparent system prevents project parties from feeling like they are being cheated, and helps them to see all the benefits generated by the project. This suggests that with the inclusion of dominant information in the Nigerian project delivery a transparent system is perceived to be established. This is followed by 'Supplier contract' which shows that contractors who are experts are more qualified than the client and its advisors to develop the best solution to the problem that the project is requested to solve hence, the contractor should create the contract and the scope of the project from the client's brief.

The third highest is the inclusion of the 'No influence, no control, no management philosophy' which suggest that, when a structure that makes each party responsible and accountable for knowing and doing the work they are hired to do is Set up, it will be more efficient than the client having to manage, direct and control the project contractor who is an expert. That will reduce to higher degree disputes within the project delivery system. Next to this is 'Seamless contract' which likewise, suggest that contract should be designed to mitigate risk instead of being a legal/regulatory/control document. With this, the project performance will be measured on a weekly basis and published to all stakeholders, showing deviation created by each project stakeholder, then accountability will increase and project performance will increase. Then the 5th in ranking is the inclusion of the 'Expert supplier model' which shows that the Contractor being an expert has no technical risk and focuses on mitigating risk he does not control. Consequently, it Requires the expert contractor to identify and pro-actively track all the project risks that they do not control thus, making every stakeholder be more accountable. This is a model of accountability.

The 6th in ranking being the addition of the contractor's 'Pre-planning' in project delivery. This is because, the contract represents the start or implementation of the service and, since typically, the contract binds all parties to an identified project plan and set of activities. Thus, requiring the expert contractor to have a detailed project plan and to show what awaits each stakeholder over the entire course of the project before signing the contract by so doing, project performance will be improved. Then 'communication minimisation' in project delivery helps minimises client/contractor communication. And so, using simple terms that non-technical stakeholders can understand and reducing the circulation of highly technical information will improve communication and project performance hence, agreeing with dominant information. The last being, 'Problem contracting' Allows the client to only communicate their intent and expectations. This accordingly, makes project requirement defined in terms of high-level objectives instead of minimum specifications which allows the expert contractor to be innovative and create greater value for all stakeholders. These are the perceptions of the Nigerian Construction Professionals on the BVP unique factors.

3. Conclusion

Employing an innovative procurement approach such like, the Best Value Procurement approach that utilises expertise to minimise the risk of non-performance and create a win-win environment for both client and contractors while, increasing transparency and add value to the project will, make project delivery failures in the Nigerian construction industry a thing of the past. The unique factors of the Best Value procurement, are the driving force in most of the project delivery successes recorded of Best Value Procurement and, from the analysis of data collected from the Nigerian construction industry professionals, they agreed that the utilisation of these unique Success factors of the Best Value procurement in the Nigerian construction industry can help improve project delivery with a very high acceptability rate from these construction professionals in Nigeria. Therefore, the Nigerian construction professionals perceive that the quest for an improved and stabilised project delivery in the Nigerian construction industry can be achieved by the usage of the unique factors of the Best Value Procurement.

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Cultural Practices Generated by Structural Biodiversity of Two Urban Forests in Johor Bahru, Malaysia

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ABSTRACT

The use of urban green space is a determinant for urban inhabitant's well-being. However, increasing urbanisation lessened the opportunity for urban inhabitants to engage with green space. This situation requires landscape planners to design an urban green space with maximum benefits that fulfil inhabitants' needs for their well-being. Structural biodiversity is an essential element in generating the benefits and values interpreted through the activities at the urban green space. This paper aims to identify the cultural practices that influenced by structural biodiversity of two urban forests in Johor Bahru, Malaysia. Multiple Response Analysis was used to analyse the data from on-site questionnaire surveys completed by 253 visitors of both urban forests. The result shows that a high-density urban forest offers an opportunity for visitors to get attached to nature and attract visitors to involve in sedentary and moderate activities. In contrast, a moderate density urban forest offers a less natural value that attracts visitors to take part in moderate and vigorous activities with less engagement with nature. This study would contribute to a better understanding of the structural biodiversity that influenced visitors' cultural practices, where the present condition of the two urban forests has illustrated the current benefits that visitors obtained from the ecosystem.

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1. Introduction

Maintaining the well-being of urban inhabitant is a critical aspect of ensuring the quality of life. Currently, most of the developed countries, including Malaysia, are having rapid development because of the increasing population that lives in the urban area. Malaysia Department of Statistics (2019) stated that there are 32.4 million populations in Malaysia until the year 2018, and 75.45% from the populations lived in the urban area. Increasing the rate of urbanisation have a significant impact on green spaces (Aida *et al.*, 2016; Kabisch *et al.*, 2015) where the number decreases while the demands for green spaces increase in line with the increasing number of population. Availability of green spaces in an urban area is the platform for inhabitants to improve their physical and mental well-being (Karuppannan *et al.*, 2014; Schipperijn *et al.*, 2013; Schipperijn *et al.*, 2010). Besides supplying spaces for physical activity, urban green space plays a vital role in providing habitat for wildlife (Haaland & van den Bosch, 2015) which provides an opportunity for inhabitants to engage with nature (O'Brien et al., 2017). In a rapid development area, the spatial pattern of green space is influencing the way inhabitants perceived and used the place. Whether inhabitants using the green space with maximum benefits or they using it because they have no other places for their physical activity.

The central element that shapes the way inhabitants perceived and used green space is structural biodiversity which defined as the composition and configuration of biotic entities (Lausch et al., 2016). Voigt *et al*. (2014) have included the diversity of biotic features, abiotic site conditions and infrastructure of urban parks in measuring inhabitants' evaluation and activities. Biotic features are the only dimensions considered in this study because of the dominant factors that affect the ecosystem components and functions of green space (Giergiczny *et al*., 2015; Harrison *et al*., 2014; Van Renterghem, 2018). The composition and configuration of biotic features have shaped the spaces for inhabitants (Foo, 2016; Gunnarsson *et al*., 2017) and habitat for wildlife in green space (Jasmani *et al*., 2016; Mexia *et al*., 2018). These factors are related to spatial elements and spatial patterns that are affecting the functions of the green space and influencing inhabitants' movement and activities. A beneficial green space does not depend only on the size of the place but needs to consider benefits that inhabitants get from their visits (de la Barrera *et al*., 2016; Xu *et al*., 2016). It is how landscape planners play their roles in planning and designing the structural biodiversity of green space.

This study adapted from the cascade model (Haines-Young & Potschin, 2010; Potschin-Young *et al*., 2016; Small *et al*., 2017; Spangenberg *et al*., 2014). Cascade model is a framework that links the process in an ecosystem which starts from the organisation of elements in the ecosystem until the benefits that people get from the ecosystem. There are two main components in the model; supply and demand (Wei et al., 2017). The component of supply factors is a biophysical type that includes the structure and functions of an ecosystem which influences green spaces to provides ecosystem services to users. The component of demand factors is a beneficiary type which correlated to the supply factors. The organisation of ecosystem elements is crucial steps in the model that reflects the function of green spaces. It is about measuring the performance of green space in providing services that fulfil inhabitants demand while using the place. The model shows the capacity of a green space ecosystem in providing benefits to the inhabitants, and also to the wildlife of the greenery that becomes one of the main contributors to deliver the benefits.

Ecosystem services is a transition process in the cascade model that specifies whether a green space supplies the services that match the needs that inhabitants' demands. It connects the structural biodiversity of an ecosystem with the functions that give benefits to inhabitants (Andersson-Sköld et al., 2018; Potschin-Young et al., 2016). Millennium Ecosystem Assessment, MEA (2005) define ES as benefits that people obtain from ecosystems. Four types of ES commonly involved in this field: provisioning services, regulating services, supporting services and cultural services (MEA, 2005). Currently, ES research trend focused on cultural ecosystem services (CES) due to the lack of study on the services, especially in the urban area (La Rosa *et al*., 2016). CES describes as an intangible or non-material ES (Xiao *et al*., 2017) that challenging to measure because of the direct benefits offered to inhabitants that engage with green space which is subjective and influenced by inhabitants' onsite experience (Ko & Son, 2018; Stålhammar & Pedersen, 2017). It is a people-place and human-ecosystem relationship that directly affects inhabitants' well-being includes stress relief and health promotion, especially for urban inhabitants that have limited choice for green space (Ko & Son, 2018). As urbanisation continuously increased, the quality of urban green space is a vital role in ensuring CES to meet the increasing demand from urban inhabitants due to decreasing in the quantity of green space.

In the model, it shows that the balance achieved between supply and demand factors have enabled the use of CES. However, Fish et al. (2016) highlighted that various CES emerged from a series of cultural practices. In line with this, various frequent activities at urban green spaces shape the categories of cultural practices based on the engagement between people with each other and the natural world. Table 1 shows the operational definition of all categories of cultural practices. The cultural practices that visitor undertakes which in relation to the structural biodiversity of urban green spaces is a determinant for the benefits and values that they obtained from the place (O'Brien *et al*., 2017). Fish *et al*. (2016) have relate the formation of cultural practices with the places, localities and landscape of an ecosystem, which shaped the identities, experiences and capabilities of the green spaces that allow the cultural practices to happen. The consideration of the structural biodiversity and cultural practices are mutually reinforcing the formation of CES to fulfil inhabitants' demand for urban green spaces (refer Figure 1).

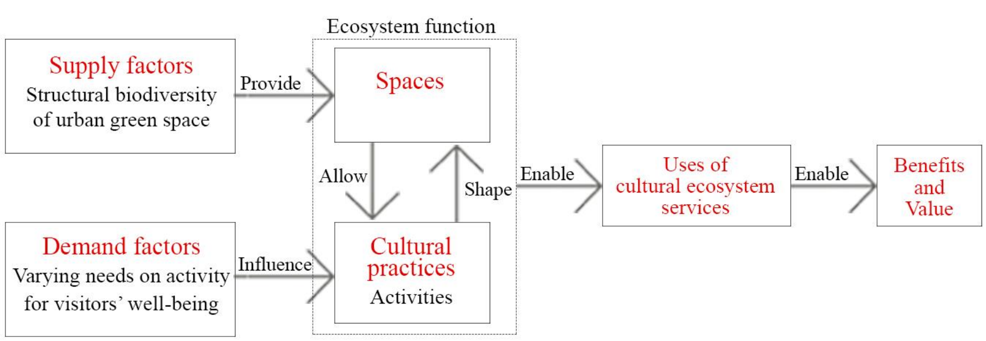

Figure 1 Key aspects include cultural practices, in cascade model of a green space

Table 1 The operational definition of categories of cultural practices according to Church *et al.* (2014) framework

Cultural practices:
Activities that relate people to each other and the natural world.

Categories of cultural practices	Definition	Examples
Playing and exercising	Activities of non-work leisure time involving informal and physical interactions between people and the natural environment	Walking, jogging, cycling, sitting, viewing, listening, picnicking and paddling
Creating and expressing	Activities of non-work leisure time defined by the conscious construction of symbolic artefacts and processes	Drawing, painting, photography, writing, and poetry
Producing and caring	Activities that blur the distinction between labour and non-labour engagements with the natural environment	Cultivating land for food production, fishing, gardening environmental volunteering, and citizen science
Gathering and consuming	Activities spanning passive and active engagements with the natural world and which occur in both work and non-work contexts	Consuming food and drink of local provenance, collecting wild food, fibre and ornaments and consuming non-conversational media and genre about a place (e.g. local art/artefacts/popular media/performances)

Although the study on the field of cultural ecosystem services increases, yet there is still a lack of study on the structural biodiversity of the accessed green space that influences cultural practices derived from the place. Since the cultural practices are a new component in the model (Church et al., 2014), current studies on cultural ecosystem services that related to physical elements of green space are mostly not considered cultural practices. Some examples of the current studies are visitors' perception (eg. Riechers et al., 2018; Bertram and Rehdanz, 2015), mapping cultural ecosystem services (eg. Clemente et al., 2019; Brown et al., 2018; Soy et al., 2018) and green spaces components that influence the services (eg. Ridding et al., 2018; Belmeziti et al., 2018; Palliwoda et al., 2017). Therefore, this paper aims to identify the cultural practices of urban inhabitants that influenced by structural biodiversity of urban green space. Which cultural practices are the most happening in the urban green space? How the structural biodiversity of urban green space affect the cultural practices of the place? The aim will support the cascade model in discovering cultural ecosystem services of green space which shaped through inhabitants' various frequent activities.

2. Methods

2.1 Study Area

The unit of analysis for this study is urban inhabitants that use urban green space for their well-being. Urban forest was selected as a study area because it offers a variety of spaces that provides all type of structural biodiversity. This study was conducted at two urban forests located at the second-largest city in Malaysia, which is Johor Bahru. The city is a rapidly urbanised area that increasingly populated until this period. The increasing rate of development in Johor Bahru every year leads to the current number of population which is above 1.5 million inhabitants (Pelan Pertumbuhan Strategik Johor, 2019) and 0.8 from the numbers are live in the city (World Population Review, 2019). This scenario shows the high percentage of urbanisation occurs, which requires a more substantial area for development that causes decreasing in the greenery of the city area. The two urban forests are Majlis Bandaraya Johor Bahru Urban Forest (MBJBUF) and Majlis Bandaraya Iskandar Puteri (MBIPUF). Both vary significantly in the surrounding landscape and therefore provide different structural biodiversity. These two urban forests are open to the public, attached to heavy vehicle road and have differences in terms of site context, stand age and the density of vegetation. Table 2 shows the criteria of each urban forest. The differences between urban forest give different impact to visitors because the different criteria and percentage of vegetation cover might influence the impact that inhabitants get when access to the place (Mexia et al., 2018). Figure 2 shows the situatedness of the urban forest located in the south of Malaysia and near to Singapore, which is one of the reasons why the rate of urbanisation of the district is rapidly increasing.

2.2 Data Collection

2.2.1 Site Survey on Structural Biodiversity

The independent variables for this study consist of biotic features that contribute to forming an ecosystem and providing cultural ecosystem services to visitors. In the context of this study, the data collected consist of the land cover of the urban forest that was parallel to the function offered to the urban inhabitants. A site survey was conducted through an observation using unmanned aerial vehicles, UAVs (Park & Ewing, 2017). The data gathered from UAV observation were able to identify the current configuration of vegetation at the urban forest, as shown in Figure 3. The data includes the spatial aspect of a landscape such as spaces, vegetation density, canopy cover and site context. The step was followed by the on-the-ground observation that able to identify in detail the presence of each element. The percentage of the land cover was analysed and quantified using i-Tree Canopy application from i-Tree Eco v5 modeling tool (www.itreetools.org). A 1000 sampling point was plotted in the application that involved with five elements, which were tree canopy cover, field, lake, facilities and other surfaces. The elements of other surfaces include pedestrian walkway and jogging track. Figure 4 and Figure 5 demonstrates the percentage of the land cover for both urban forests.

Table 2 The criteria of MBJBUF and MBIPUF

Criteria	Urban Forest	
	MBJB	**MBIP**
Location	Located approximately 1.5 km from the city centre, Johor Bahru	Situated at Mutiara Rini, a township in Skudai, one of well-developed Johor Bahru district.
Site context	Government centre, educational centre, residential area and graveyard	Residential area, and commercial centre
Stand age	31 years	10 years
Vegetation density	High density because it was covered by 76.86% vegetation of the used area	Medium density because it was covered by 57.9% vegetation of the used area

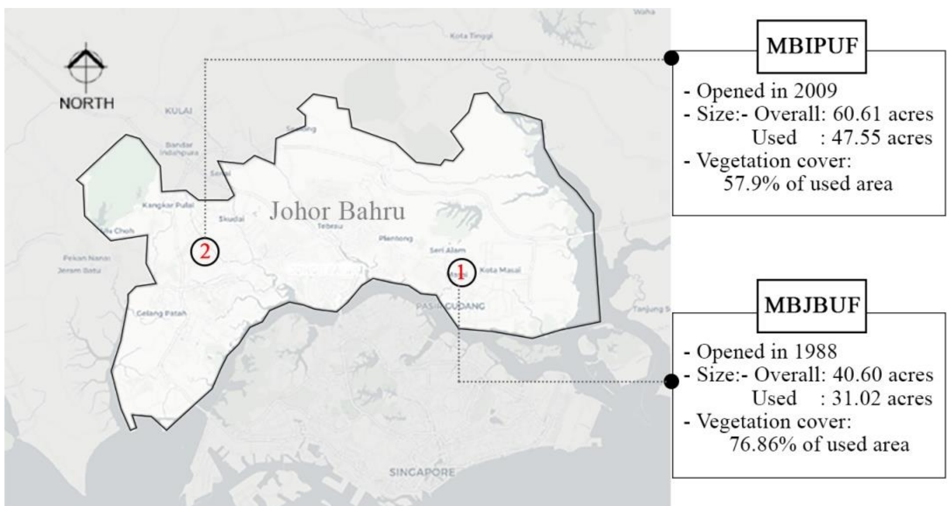

Figure 2 Location of the two study areas in Johor Bahru; (1) MBJBUF and (2) MBIPUF

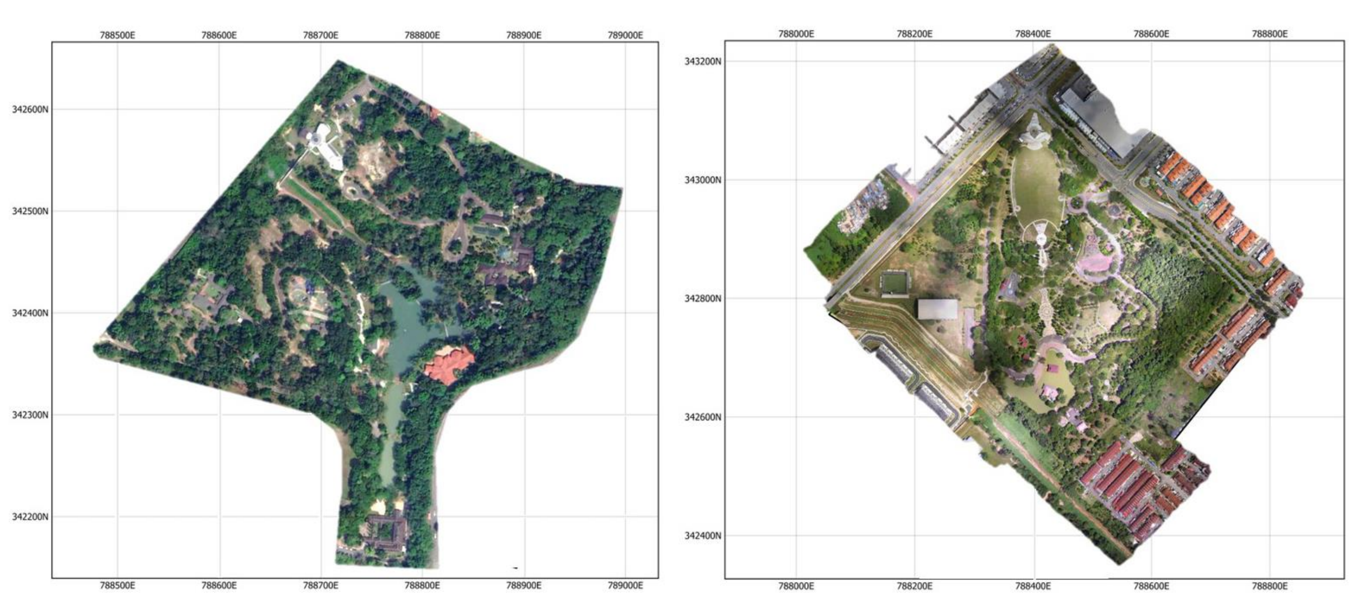

Figure 3 Aerial photos of MBJBUF (left) and MBIPUF (right)

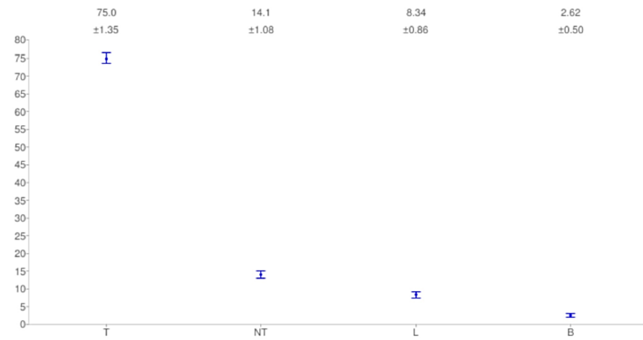

Figure 4 The percentage (+/- SE) of land cover at MBJBUF [T: Tree canopy cover; NT: All other surfaces; L: Lake and B: All facilities provided]

The data in Figure 2 and Figure 3 illustrates that MBJBUF is a natural-like area that provides mature trees with diverse tree species and dense canopy cover (50-70% canopy closure). This is corresponding to Figure 4 that shows 75% of MBJBUF consists of tree canopy cover. Besides the children's play area, the primary area of the urban forest that highly utilised by visitors was the spaces around the lake. The area has a high percentage of tree species diversity, a group of big trees and diverse water edge. The least used was the area that not well maintained, although it has a high percentage of vegetation cover. The percentage of the land cover indicates that MBJBUF has a high complexity of tree canopy density which gives continuous shade to the visitors.

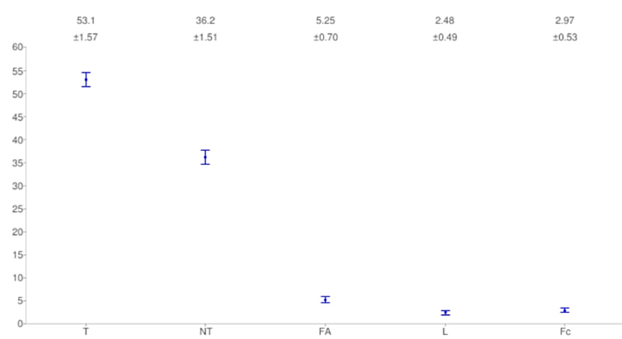

Figure 5 The percentage (+/- SE) of land cover at MBIPUF [T: Tree canopy cover; NT: All other surfaces; FA: Field area; L: Lake and F: All facilities provided]

In contrast, Figure 3 shows that MBIPUF provides medium vegetation density with medium canopy cover (30-50% canopy closure) that offers less shade to the urban forest. In sum, MBIPUF has a high density of large woody vegetation area, playground area, field, a group of small tree, open spaces, tree-lined path and lake area. As shown in Figure 5, the most dominant is tree canopy cover (53.1%), followed by all other surfaces (36.2%), field area (5.25%), facilities (2.97%) and lake (2.48%). The most utilised area was open canopy spaces around the lake and field, followed by the walking or jogging route that lined with a row of trees. All of the areas in MBIPUF were used, but not all visitors attracted to access to the dense-wooded area at the east side of the urban forest.

Data in Figure 4 and Figure 5 reveals significant differences of the land cover between MBJBUF and MBIPUF. Almost all spaces of MBJBUF were covered by dense tree canopy, whereas only half of MBIPUF stands with dense canopy cover. The difference of the land cover is the main contribution of the structural biodiversity in an ecosystem in shaping cultural practices for visitors' well-being. In line with Irvine and Herrett (2018), difference structure of an ecosystem may provide difference opportunity and need for socio-ecological interaction that highlight the delivery of multiple cultural ecosystem services to the visitor.

2.2.2 On-site Survey Questionnaire

The first phase of this stage is a semi-structured face-to-face interview to identify the dependent variable of this study which is the frequent activity of visitors when visiting the urban forest. This phase was also created to identify the most common words used in describing the activities. Based on the gathered results, the authors have revised back the questionnaire that was designed for the actual data collection.

It was a multiple-choice question that allowed visitors to choose more than one activity in the answer list because this study was to investigate the most frequent activity at the urban forest. The actual data collection was involved with the distribution of survey questionnaires. It was conducted within two months during the weekend and weekdays. Two hundred and fifty-three questionnaires were completed by the visitors which were randomly approached at different areas of the two urban forests. The respondents included all of the visitors in the age between 15 years and above, with the diversity of ethnicities, occupations and levels of education. One hundred and thirty-six respondents completed the questionnaires at MBJBUF and the rest by visitors at MBIPUF. The numbers of respondent were adequate to represent the total population of urban inhabitants that use the urban forest in two months. The minimum sample size was identified using the equation by L.Grande (2016) as shown below, with 95% of confidence level and 0.045 margin of error.

$$\text{Sample size} = \frac{\frac{Z^2 \cdot p(1-p)}{e^2}}{1 + \left(\frac{Z^2 \cdot p(1-p)}{e^2 N}\right)}$$

2.3 Data Analysis

IBM SPSS Statistics 24 was the data editor used to compute all of the data from the survey questionnaires. The question involved in this study was designed to investigate the frequency of activities done in both urban forests. Multiple Response Analysis was used to analyses the differences of cultural practices at MBJBUF and MBIPUF based on the frequency of visitors' activities.

3. Result and Discussion

3.1 Structural Biodiversity and Cultural Practice of a Mature High Density Urban Forest

Figure 6 reveals the frequent activities that visitors do when visiting the two urban forests. The frequent activities in MBJBUF were walking (14.3%), enjoying nature and greenery (13.8%), sitting (12.6%), spending time with family (11.5%), and jogging (11.2%). The result shows that the mature and high density urban forest has provided natural-like surrounding that attracted visitors to enjoy nature and leisure activities of the setting. MBJBUF with high biodiversity purposes has given variety ambience of dense greenery that increased the attractiveness of the urban forest (Giergiczny et al., 2015). According to Wang *et al.* (2019), an increasing number of trees was enhancing visitors' aesthetic preferences. This is corresponding to the structural biodiversity of MBJBUF, which provided complex and rich greenery that increased the aesthetic value of the study site. In line with the study by Wang *et al*. (2017), the structural biodiversity of MBJBUF has motivated visitors through the high level of vegetation where sedentary and moderate activities were preferred over the vigorous activities.

Additionally, in conjunction with the study by Guo *et al*. (2017), the urban forest with a high density of vegetation was able to attract wildlife because of the light penetration, multiple resources of food and sufficient open spaces to forage. This type of structural biodiversity has widened the ecological corridors for wildlife and birds to move without interference from the visitors. The dense vegetation cover of MBJBUF as shown in Figure 3 has also provided enough shades for visitors and shelter for the wildlife and birds. The interrelationship of the natural value offered by the urban forest has brought relaxation and serenity to the visitors that they rarely get from a densely built-up urban area (Sandifer, Sutton-Grier, & Ward, 2015). This situation was parallel to the four activities at MBJBUF that have a higher frequency than MBIPUF, which were enjoying nature and greenery, wildlife and birds viewing, picnicking and spent time alone. The result highlighted that the structural biodiversity of MBJBUF has shaped the cultural practices of the urban forest, which promoted the opportunity for urban inhabitants to be close to nature. Furthermore, the dense vegetation cover has influenced visitors' activities to be dependent on shaded spaces, seating possibilities, as well as the feeling of solitude.

However, some activities were less frequently happened at MBJBUF such as picnicking (5.2%), playing sports (4.3%) and cycling (1.8%). The data in Figure 4 illustrates that the urban forest only has 14.1% of spaces that accessible for activities. Although the larger space of tree canopy cover has provided better engagement between visitors and nature, this kind of environment has lessened the spaces for the activities that involved with the specific social group. This reflects the low frequency of social activities due to the limited space, which decreased the opportunity for interaction between visitors. Identical to Moulay *et al.* (2017), the relationship between the size and function of spaces in a large urban green space need to associate with each other in order to fulfil visitors' needs on the activities that require specific space. The configuration of dense tree canopy cover also plays a vital role as it offered various environments that influenced visitors' satisfaction towards services that they get from MBJBUF. Instead of the size and function of the space, the dense structural biodiversity has reduced the spaces allocated for all activities. This situation has minimised the privacy and comfort for the activities of the specific social group. The result demonstrated that MBJBUF has no specific functional spaces for picnicking, playing sports and cycling, which weakened visitors' dependency on MBJBUF for that purposes.

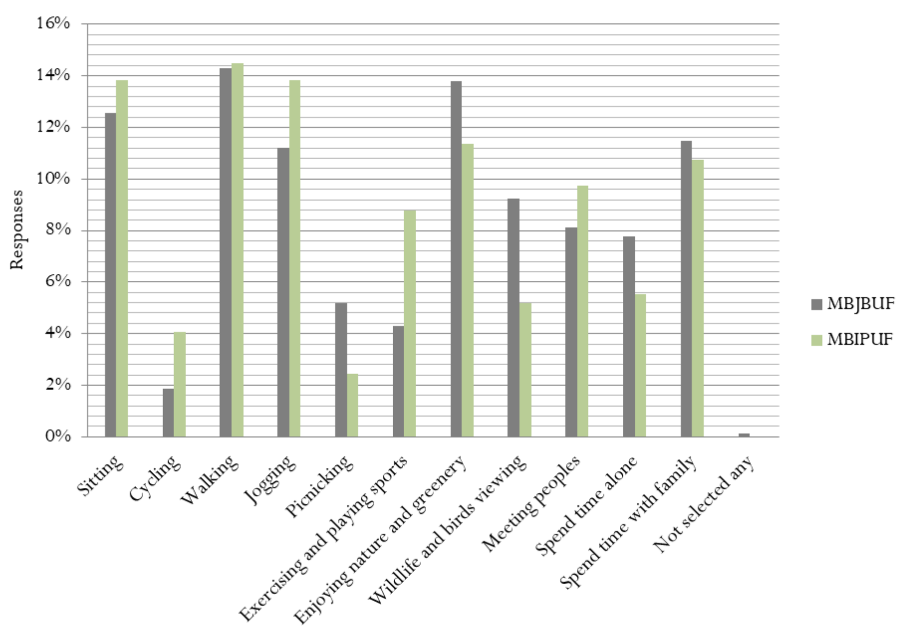

Figure 6 Result from Multiple Response Analysis on the frequent activities at the two urban forests

3.2 Structural Biodiversity and Cultural Practice of a Moderate Age with Medium Density Urban Forest

In contrast, the most frequent activities at MBIPUF were walking (14.6%), jogging (14.0%), sitting (14.0%), enjoying nature and greenery (11.5%), and spending time with family (10.8%). The result shows that the medium density urban forest with medium canopy covers (30-50% canopy closure) has provided a surrounding that encouraged visitors to enjoy the moderate, vigorous and sedentary activities more than they enjoyed the nature. The most frequent activities at MBIPUF were slightly different from MBJBUF, where jogging was among the highly ranked activity. Although MBIPUF has a space of the dense-wooded area, it was not commonly used by the visitors because of poorly maintained. The wild and messy surrounding of the area has given a negative valuation on the services offered by the dense-wooded area (Muratet, Pellegrini, Dufour, Arrif, & Chiron, 2015). The structural biodiversity of MBIPUF was spatially spreads and forms a medium level of biodiversity that consists of more open spaces and medium canopy stands with various heights of vegetation. The visitors' engagements with the nature of MBIPUF were lower because most of the visitors' activities were concentrated at a well-managed area that has medium canopy covers. This was in line with the studies by Gunnarsson *et al*. (2017), where the area that offered less density of structural biodiversity has decreased the natural value of the urban forest which also impacted the attractions of the greenery among visitors.

Equally important, the open and semi-open spatial design of the structural biodiversity of MBIPUF has provided the opportunity for visitors to involve in vigorous activities. As illustrated in Figure 6, there are three significant differences of activities at MBIPUF that have a higher frequency than MBJBUF. The activities were playing sports, jogging and cycling. The result was in consistent with Rey Gozalo *et al.* (2019), where a larger size of the urban forest was matters in influencing visitors' vigorous activities. The size of MBIPUF, 60.61 acres, was reasonable to provide a greater length of route and adequate spaces for that type of activities. The tree-lined paths along the provided route were connecting the open spaces with the spaces of medium canopy covers. The continuous structural biodiversity of MBIPUF was provided greenery that maintained the biological diversity of the medium density urban forest that contributed to the well-being of visitors. This situation shows that despite having vast open spaces for vigorous activities, the medium density vegetation cover was still provided a comfortable environment for visitors, such as shade effect and aesthetic attraction from the medium greenery (Adinolfi, Suárez-Cáceres, & Cariñanos, 2014).

Besides, the least frequent activities at MBIPUF were wildlife and birds watching (5.3%), cycling (4.1%) and picnicking (2.5%). The result was corresponding to the structural biodiversity of the area that used to be accessed most by the visitors. Identical to Palliwoda *et al.* (2017), the structural biodiversity of MBIPUF was reflected the lower activity of wildlife and birds watching as the environment has minimised the key factors needed by the creatures. In fact, in spite of having continuous canopy covers for wildlife and birds' travel routes and diverse height of vegetation for their sources of food, the medium canopy covers was surrounded by open spaces that lessen the size, protection and microclimate of wildlife and birds' habitat which reduced their biodiversity level at the urban forest (Bahari, Said, & Rusli, 2018). The result also demonstrated that the urban forest was not preferred by visitors for the activities of cycling and picnicking. The main reason was because of the wide-open spaces provided by MBIPUF were exposed to the hot and humid weather of Malaysia that lowered the relaxation and serenity environment for the activities (Sreetheran, 2017). In the same vein of MBJBUF, the less frequent activity of picnicking and cycling at the urban forest shows that these two activities were not the primary intention for visitors in Johor Bahru to visit an urban forest.

4. Conclusion

This study reveals the primary category of cultural practice shaped by both urban forests in Johor Bahru, which is 'playing and exercising'. The existing structural biodiversity is influencing the activities that visitors undertake based on the condition of spaces that they engage in the urban forest. Specifically, the size and functions of a space have a significant relationship with the structural biodiversity that build aesthetic appeal, privacy and comfort of the space. Urban forest with a dense canopy cover is providing a better opportunity for urban inhabitants to get closer to nature, while medium canopy cover that has wide open spaces is supplying convenience spaces for vigorous activity. However, some specific limitations must be taken into consideration. This study only focuses on how the existing structural biodiversity of urban forest was influencing the cultural practices of urban inhabitants. These aspects are essential for landscape planners in enhancing or maintaining the existing urban green space to optimise the quality of spaces in order to offer maximum benefits for urban inhabitants' well-being. It is crucial to consider on the correlation between different elements of structural biodiversity and urban inhabitants' demand for urban green space for future research. In this respect, despite the opportunity provided for playing and exercising, the identification of the impacts of specific structural biodiversity elements on urban inhabitants' demand may result in investigating other categories of cultural practices needed by the inhabitants.

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3D Topological Validation of Compact Abstract Cell Complexes (CACC) Data Structure for Buildings in CityGML

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ABSTRACT

3D models without the preservation of 3D topological information hinders the ability of 3D models to serve its full potential in terms of 3D analyses. The support of 3D topology is crucial for analyses that requires information regarding adjacencies and connectivity. One of the ways to maintain topological information is by implementing a topological data structure such as the Compact Abstract Cell Complexes (CACC) topological data structure. This paper demonstrates the topological validation for the implementation of the CACC topological data structure for buildings in LoD2 CityGML. Directed graphs and adjacency matrices were constructed for the test datasets of buildings in CityGML. The in-degree and out-degree for all vertices were calculated based on the adjacency matrices. Based on the "Hand-shaking" theorem, the number of α_0-cycles of the CACC topological data structure which connects points to form 1D topological links was compared to the number of directed edges of the constructed directed graphs. Therefore, the implementation of the CACC topological data structure for buildings in LoD2 CityGML was found to be topologically sound.

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1. Introduction

One of the objectives of conveying information is to ensure the users' understanding regardless of the users' different backgrounds of knowledge. In the field of geoinformation, the manner in which the real world is represented is important to provide information that meets the requirements of the user or applications. A city is also known as an urban system of urban structures which is modelled or represented as a city model. A city model is defined as a representation of the urban structures and spatial properties that depicts the actual city (Billen et al., 2014). A city can be represented as a 3D city model or 2D representation. Generally, a representation of the real world (city) in 2D refers to a representation that is bounded by x and y coordinates. A few examples of 2D representations are maps, plans and computer-aided drawings (CAD). On the other hand, 3D city model or also known as virtual reality urban modelling represents cities with x, y and z coordinates. A 3D city model can also be defined as a model which represents a city with the usage of 3D spatial information as well as semantic information within a single framework (Chen, 2011). This allows the representation of a city as a 3D city model which is a mirrored image of the actual city but in a virtual environment. Therefore, a 3D city model is able to provide realistic simulations and accurate information for various applications such as cadastre, urban planning and navigation.
Given the many applications that may benefit from the use of a 3D city model, an international standard and open data model

for 3D city modelling was introduced. CityGML is an international standard and open data model for 3D city modelling which was established by the Open Geospatial Consortium (OGC) (Gröger & Plümer, 2012). The development of CityGML was targeted to be a shared definition of entities, attributes and relationships within a 3D city model (Kolbe, 2009). CityGML encompasses five main aspects of a complete 3D city model which are 3D geometry, semantics, scale or level-of-detail (LoD), appearance and topology. The first aspect which is 3D geometry refers to the geometric properties of the features which is based on the Geographic Markup Language (GML) standard. Next, the semantics aspect deals with the semantic information or attributes of the features. The third aspect allows multiresolution modelling which represents the scale as LoDs where the coarsest LoD is LoD0 and the finest LoD is LoD4. The fourth aspect which is appearance handles how CityGML displays the 3D city model in terms of textures which differentiates between surfaces or facades. The final aspect is topology which refers to the mechanism used within CityGML to store topological properties of the 3D city model.

The real world is considered as a space or topological space whereby an object resides in the space. Kumar (2014) defined a natural geographic situation as a set {G, F, R} where G and F are two features and R is the relation between G and F. Topology can be defined as the adjacencies between objects residing in a space (McDonnell & Kemp, 1995). This means that topological properties of an object are properties that remain unchanged despite transformations of the space and define the qualitative properties of the object in terms of relationships to other objects. The way objects are related can also be described at a geometric level which describes the topology, projective geometry and Euclidean geometry (Clementini, 2019). Hence, a topological model can be defined as a schema which specifically represents the topological properties and relationships of spatial features (Ghawana et al., 2012; Lee & Kwan, 2005). In terms of city modelling, a city can be topologically represented as the adjacencies of objects. As a single building, the relations between building elements are able to describe the connectivity of building elements and the function of the building (Krämer & Huhnt, 2009; Xie et al., 2013). In order to maintain consistency and connectivity of elements in an object, a comprehensive 3D topology is required (Ellul, 2007). Furthermore, analyses involving exploration of building elements also requires a comprehensive preservation of topological properties (Isikdag et al., 2013; Hyeyoung et al., 2009). 3D topology is also required to support analysis which yields results in 3D as a 2D topology is will ultimately deliver results in 2D (Ellul & Hakley, 2006). Topological properties are able to support analyses such as adjacencies, intersections, connectivity, containment and disjointedness (Li et al., 2016). These analyses may appear simple yet supports more complex applications such as navigation and simulations (Salleh et al., 2018). The topological component of CityGML as the international standard for city modelling does not employ the topological model by GML3. This is due to the complexities of the topological model which will complicate the data model and physical entities within the CityGML model (Gröger & Plümer, 2012; Kolbe, 2009).

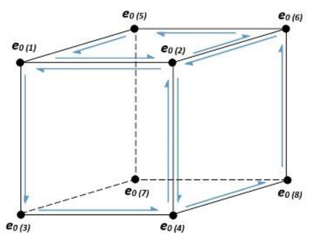
Generally, topology for city modelling can be divided into two subdivisions which are 2D topology and 3D topology. The type of topology currently used in CityGML is a 2D topology which is the topology-incidence (Li et al., 2016a). This topology is based on the relationships of surfaces whereby if an incidence occurred between two surfaces; the surfaces will be referenced to each other. The topological primitives approach is a 3D topology which maintains topological properties of features using the basic topological primitives similar to geometric primitives. This is different for the cell-based approach and boundary representation approach where the topological properties of features can be maintained based on the boundary of the features. However, none of these approaches were utilised in the maintenance of topology within CityGML.

The topological component of CityGML provides information regarding to related building elements in the form of simple relations such as doors belonging to rooms or building parts that make up a building. However, the topological component of CityGML does not support direct retrieval of topological relationships (Rook et al., 2016). This simple topological information is insufficient for topological analysis regarding 3D adjacencies and nearest neighbour (Ujang et al., 2019). The method of establishing topology by incidence can only be done with the explicit representation of the common surface as an individual geometry (Li et al., 2016). This is due to the inability of CityGML to support topological primitives and effectively build 3D topology (Boguslawski et al., 2011; Li et al., 2016). Moreover, this disadvantage also hinders the preservation of relationships between topological primitives in different dimensions (Ghawana et al., 2012).

This paper attempts to topologically validate a CACC topological structure implemented for buildings in CityGML. The CACC topological data structure is briefly explained in Section 2. The methods used for the topological validation is elaborated in Section 3. Subsequently, the results are presented in Section 4 which includes the topological validation results and a brief comparison of connectivity capabilities between the CACC topological data structure and existing CityGML topological mechanism. Finally, the paper is concluded in Section 5.

2. Compact Abstract Cell Complexes (CACC) Topological Data Structure

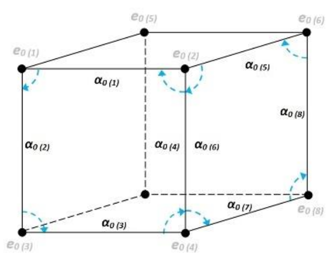
The topological data structure implemented in this study is the Compact Abstract Cell Complexes (CACC) data structure. This structure employs a compact yet abstract method of storing topology in which the topology is not limited to the bounds of a geometric space (Ujang et al., 2014). Moreover, CACC was found to be the most compact method of storing topological information in comparison to other topological data structures such as dual half-edge (DHE), cell tuple, G-Maps and others (Ujang et al., 2014). The concept of the CACC data structure which stores topology as atomic cycles made up of deconstructed parts of cycles allows navigation through the cycles. Each dimension is represented by a different cycle such as 0D points are connected to 1D edges in α_0-cycles, 1D edges are connected to form 2D faces in α_1-cycles, 2D faces are connected to form 3D volumes in α_2-cycles, and connectivity between volumes are represented as α_3-cycles (Ujang et al., 2014). Figure 1 depicts α_0-cycles as the blue markers which details the paths of 1D edges via 0D vertices.



α_0-cycles	Paths
$\alpha_{0(1)}$	$e_{0(2)}$ -> $e_{0(1)}$
$\alpha_{0(2)}$	$e_{0(1)}$ -> $e_{0(3)}$
$\alpha_{0(3)}$	$e_{0(3)}$ -> $e_{0(4)}$
$\alpha_{0(4)}$	$e_{0(4)}$ -> $e_{0(2)}$
$\alpha_{0(5)}$	$e_{0(6)}$ -> $e_{0(2)}$
…	…
$\alpha_{0(24)}$	$e_{0(8)}$ -> $e_{0(7)}$

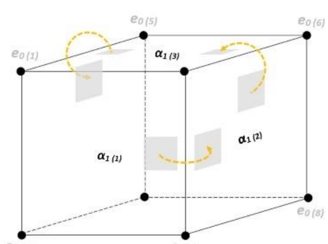
Figure 1 α_0-cycles and its paths (Ujang et al., 2014)

Figure 2 shows α_1-cycles that represents paths of connected 1D edges previously stored as α_0-cycles to form 2D faces. Meanwhile, the α_2-cycles are depicted in Figure 3 as paths between connected 2D faces previously stored as α_1-cycles to form 3D volumes.



α_1-cycles	Paths
$\alpha_{1(1)}$	$\alpha_{0(1)}$ -> $\alpha_{0(2)}$ -> $\alpha_{0(3)}$ -> $\alpha_{0(4)}$
$\alpha_{1(2)}$	$\alpha_{0(5)}$ -> $\alpha_{0(6)}$ -> $\alpha_{0(7)}$ -> $\alpha_{0(8)}$
$\alpha_{1(3)}$	$\alpha_{0(1)}$ -> $\alpha_{0(5)}$ -> $\alpha_{0(9)}$ -> $\alpha_{0(10)}$
…	…
$\alpha_{1(6)}$	$\alpha_{0(3)}$ -> $\alpha_{0(7)}$ -> $\alpha_{0(24)}$ -> $\alpha_{0(23)}$

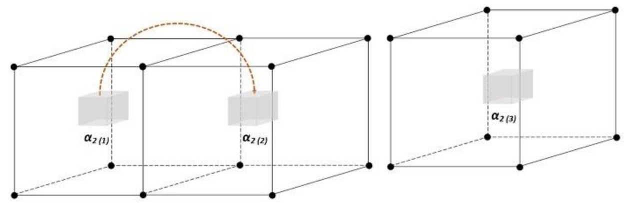
Figure 2 α_1-cycles and its paths (Ujang et al., 2014)



α_2-cycles	Paths
$\alpha_{2(1)}$	$\alpha_{1(1)}$ -> $\alpha_{1(2)}$ -> $\alpha_{1(3)}$ -> $\alpha_{1(4)}$ -> $\alpha_{1(5)}$ -> $\alpha_{1(6)}$

Figure 3 α_2-cycles and its paths (Ujang et al., 2014)

In addition, the adjacencies of 3D volumes are also represented by α_3-cycles as connectivity between 3D volumes as depicted in Figure 4.



α_3-cycles	Paths
$\alpha_{3(1)}$	$\alpha_{2(1)}$ -> $\alpha_{2(2)}$

Figure 4 α_3-cycles and its paths (Ujang et al., 2014)

The cycles of lower dimensions which act as the building blocks for higher dimension cycles ultimately provides support for connectivity across cycles and dimensions (Ujang et al., 2014). This also supports the traversing through connected elements in a 3D model which as a result also describes topological relationships between elements (Ujang et al., 2014). That being so, the retrieval and preservation of information regarding the connectivity of elements in a 3D model is also supported. Consequently, the preservation of topological information using the CACC data structure requires minimal storage which is practical for applications which deals with both geometrical and topological properties (Ujang et al., 2014)

3. Methodology

As this paper focuses on the topological validation of CACC topological data structure, the procedures carried out to implement the CACC topological data structure are not detailed. The general methodology of the CACC topological data structure implementation for buildings in CityGML are shown in Figure 5.

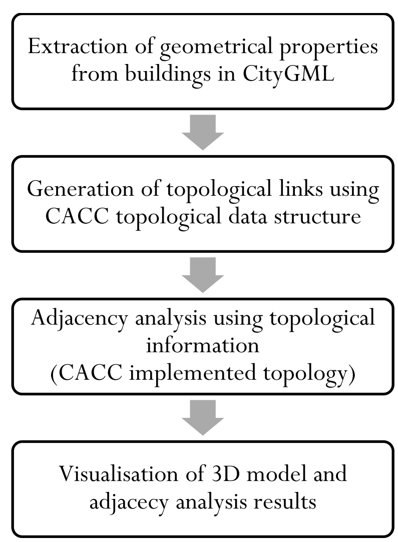


Figure 5 General methodology of CACC implementation for buildings in CityGML

In order to implement the CACC topological data structure for buildings in CityGML, the geometrical properties were extracted from the CityGML data. The geometrical properties included the points, lines and polygons which makes up the building in CityGML with the respective x, y and z-coordinates. The procedures executed to extract the geometrical properties are elaborated in Salleh and Ujang (2018). The geometrical properties act as a stand-in for the construction of CACC topological links explained in the previous section. The CACC topological data structure is implemented for buildings in CityGML by preserving comprehensive topological information in the form of CACC topological links. The construction of CACC topological links is detailed in Salleh et al. (2018). The topological information was used in the adjacency analysis which tested the connectivity of building elements using the CACC topological links and is elaborated further in Salleh, Ujang, Azri and Choon (2019).

The topological validation of the CACC topological links is pivotal in ensuring that the implementation of the CACC topological data structure for buildings in CityGML is topologically sound. The following section elaborates the methods carried out in validating the topology of the CACC topological data structure implemented.

3.1 Topological Validation of Implemented CACC Topological Data Structure for Buildings in CityGML

The topology of a structure can be represented as a directed graph or digraph which is homeomorphic to the structure. A digraph is defined as follows:

$$\vec{G} = (V, E, \eta) \tag{1}$$

where *v* is a vertex and *e* is an edge in the graph

$$v \in V$$
$$e \in E$$
$$\eta(e) = (v_i, v_j).$$

The equation above defines a digraph as a graph which consists of vertices, edges and edges with direction (η) which are ordered pairs of connected vertices. The ordered pairs can subsequently be used in an adjacency matrix which represents the connections of the digraph. Adjacency matrix is defined by Aldous and Wilson (2003) as follows:

Let *G* be a digraph with *N* vertices labelled 1,2,3,…*N*. The adjacency matrix A(*G*) of *G* is the *N* × *N* matrix in which the entry in row *i* and column *j* is the number of edges $N(\eta(e))$ joining the vertices (*v*) *i* and *j*.

The in-degree of a vertex can be defined as the number of directed edges where the specified vertex is the "head" of the edge. The in-degree of a vertex is denoted by the following equation:

$$d^-_{\vec{G}}(v_i) = N|\{e \in E : \eta(e) = (x, v_i) \text{ for some } x \in V\}| \tag{2}$$

As shown in the equation above, the in-degree of vertex *i* in a digraph is the number of edges such that the direction of the edge is going into the vertex *i* as the "head" of the edge. On the other hand, the number of directed edges of the direction that goes out of the specified vertex is defined as the out-degree of the vertex. The out-degree of a vertex is denoted by the following equation:

$$d^+_{\vec{G}}(v_i) = N|\{e \in E : \eta(e) = (x, v_i) \text{ for some } x \in V\}| \tag{3}$$

The equation above shows that the out-degree of vertex *i* in a digraph is the number of edges such that the direction of the edge goes out of the vertex *i* where vertex *i* is the "tail" of the directed edge. Based on the adjacency matrix, the total of in-degree and out-degree of a vertex can be calculated by:

$$\sum d^-_{\vec{G}} = \sum_{i=1}^{V} col_{v_i} \text{ and } \sum d^+_{\vec{G}} = \sum_{i=1}^{V} row_{v_i} \tag{4}$$

The total of in-degree of an adjacency matrix can be calculated by summing up the columns of the adjacency matrix while the total of out-degree of an adjacency matrix can be calculated by summing up the rows of the adjacency matrix.

4. Experiments and Results

The CACC topological data structure was implemented for buildings in CityGML, specifically buildings in LoD2. Two CityGML datasets were used where dataset A consists of two connected buildings and dataset B consists of two disjointed buildings as shown in Figure 6.

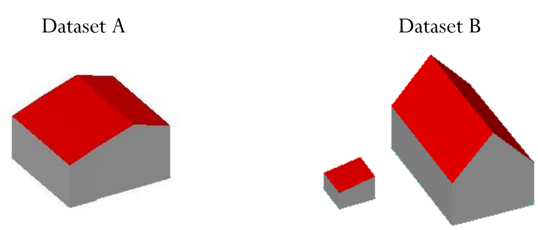


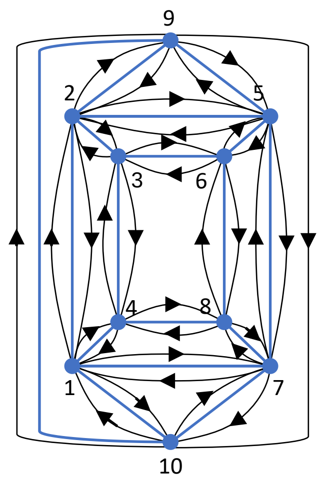
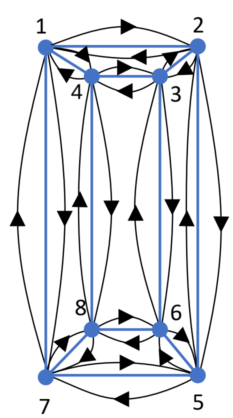
Figure 6 CityGML test datasets in LoD2

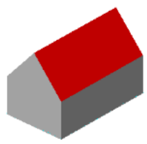
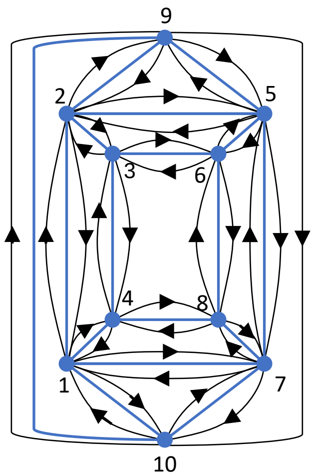
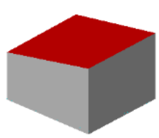
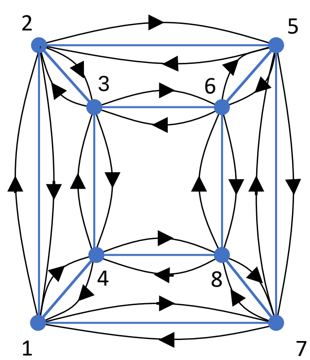
For the purpose of validating the topological information preserved for buildings in CityGML using CACC topological data structure, two simple cases of connected and disjointed buildings were used. This is parallel to the findings of Knoth, Atazadeh and Rajabifard (2020) whereby the key significant spatial relations of 3D buildings are 3D buildings can share boundaries (connected) and 3D buildings cannot penetrate each other (disjoint).

4.1 Topological Validation

Directed graphs and adjacency matrices were constructed for both datasets and are illustrated in Table 1. The arrows represent the topological connection between points of the buildings in CityGML which are based on the CACC topological links generated for the two datasets.

Table 1 Directed graph representation and adjacency matrix of buildings in LoD2 CityGML

Building	Building Visualisation	Digraph Representation	Adjacency Matrix
Dataset A: Connected Buildings			$\begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \\ v_7 \\ v_8 \\ v_9 \\ v_{10} \end{array}\begin{array}{c} v_1\ v_2\ v_3\ v_4\ v_5\ v_6\ v_7\ v_8\ v_9\ v_{10} \\ \begin{bmatrix} 0&1&0&1&0&0&1&0&0&1\\ 1&0&1&0&1&0&0&0&1&0\\ 0&1&0&1&0&1&0&0&0&0\\ 1&0&1&0&0&0&0&1&0&0\\ 0&1&0&0&0&1&1&0&1&0\\ 0&0&1&0&1&0&0&1&0&0\\ 1&0&0&0&1&0&0&1&0&1\\ 0&0&0&1&0&1&1&0&0&0\\ 0&1&0&0&1&0&0&0&0&1\\ 1&0&0&0&0&0&1&0&1&0 \end{bmatrix} \end{array}$ $\sum d^{-}_{\vec{G}} = \sum_{i=1}^{10} col_{v_i}$ $= 4+4+3+3+4+3+4+3+$ $3+3$ $= 34$ $\sum d^{+}_{\vec{G}} = \sum_{i=1}^{10} row_{v_i}$ $= 4+4+3+3+4+3+4+3+$ $3+3$ $= 34$
			$\begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \\ v_7 \\ v_8 \end{array}\begin{array}{c} v_1\ v_2\ v_3\ v_4\ v_5\ v_6\ v_7\ v_8 \\ \begin{bmatrix} 0&1&0&1&0&0&1&0\\ 1&0&1&0&1&0&0&0\\ 0&1&0&1&0&1&0&0\\ 1&0&1&0&0&0&0&1\\ 0&1&0&0&0&1&1&0\\ 0&0&1&0&1&0&0&1\\ 1&0&0&0&1&0&0&1\\ 0&0&0&1&0&1&1&0 \end{bmatrix} \end{array}$ $\sum d^{-}_{\vec{G}} = \sum_{i=1}^{8} col_{v_i}$ $= 3+3+3+3+3+3+3+3$ $= 24$ $\sum d^{+}_{\vec{G}} = \sum_{i=1}^{8} row_{v_i}$ $= 3+3+3+3+3+3+3+3$ $= 24$

Dataset B: Disjointed Buildings			$\begin{array}{c} \\ v_1\\ v_2\\ v_3\\ v_4\\ v_5\\ v_6\\ v_7\\ v_8\\ v_9\\ v_{10}\end{array}\begin{array}{c} v_1\ v_2\ v_3\ v_4\ v_5\ v_6\ v_7\ v_8\ v_9\ v_{10} \\ \begin{bmatrix} 0&1&0&1&0&0&1&0&0&1\\ 1&0&1&0&1&0&0&0&1&0\\ 0&1&0&1&0&1&0&0&0&0\\ 1&0&1&0&0&0&0&1&0&0\\ 0&1&0&0&0&1&1&0&1&0\\ 0&0&1&0&1&0&0&1&0&0\\ 1&0&0&0&1&0&0&1&0&1\\ 0&0&0&1&0&1&1&0&0&0\\ 0&1&0&0&1&0&0&0&0&1\\ 1&0&0&0&0&0&1&0&1&0 \end{bmatrix}\end{array}$ $\sum d_{\vec{G}}^{-} = \sum_{i=1}^{10} col_{v_i}$ $= 4 + 4 + 3 + 3 + 4 + 3 + 4 + 3 + 3 + 3$ $= 34$ $\sum d_{\vec{G}}^{+} = \sum_{i=1}^{10} row_{v_i}$ $= 4 + 4 + 3 + 3 + 4 + 3 + 4 + 3 + 3 + 3$ $= 34$
			$\begin{array}{c} \\ v_1\\ v_2\\ v_3\\ v_4\\ v_5\\ v_6\\ v_7\\ v_8\end{array}\begin{array}{c} v_1\ v_2\ v_3\ v_4\ v_5\ v_6\ v_7\ v_8 \\ \begin{bmatrix} 0&1&0&1&0&0&1&0\\ 1&0&1&0&1&0&0&0\\ 0&1&0&1&0&1&0&0\\ 1&0&1&0&0&0&0&1\\ 0&1&0&0&0&1&1&0\\ 0&0&1&0&1&0&0&1\\ 1&0&0&0&1&0&0&1\\ 0&0&0&1&0&1&1&0 \end{bmatrix}\end{array}$ $\sum d_{\vec{G}}^{-} = \sum_{i=1}^{8} col_{v_i}$ $= 3 + 3 + 3 + 3 + 3 + 3 + 3 + 3$ $= 24$ $\sum d_{\vec{G}}^{+} = \sum_{i=1}^{8} row_{v_i}$ $= 3 + 3 + 3 + 3 + 3 + 3 + 3 + 3$ $= 24$

The calculation of the total of in-degree and out-degree of vertices in the digraphs for all buildings using the adjacency matrix are shown in Table 1. The equation below denotes the "Hand-Shaking" theorem which proves that the amount of edges of a regular graph is equal to the total of vertex degrees for all vertices divided by two:

$$\sum_{v_i \in V(G)} d_G(v_i) = 2|E(G)| \quad (5)$$

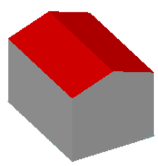
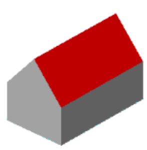
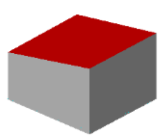
However, the graphs constructed to represent the topology of the buildings in LoD2 CityGML are directed graphs which represents the connectivity between points in the building. Hence, a theorem parallel to the "Hand-Shaking" theorem for digraphs is used as a means of topological validation of the CACC topological data structure implemented as defined below:

$$\sum_{v_i\in V(\vec{G})} d^-_{\vec{G}}(v_i) = \sum_{v_i\in V(\vec{G})} d^+_{\vec{G}}(v_i) = |E(\vec{G})| \qquad (6)$$

The previous equation (6) denotes that for a digraph; the sum of in-degree for all vertices is equal to the sum of out-degree for all vertices and is also equal to the number of directed edges of the digraph.

The results shown in Table 1 illustrates that the sum of in-degree and out-degree of all vertices for all digraphs are equal which results in the number of directed edges. Based on the CACC topological data structure, directed edges are represented as α_0-cycles which connects vertices to form edges. The number of α_0-cycles for each building are shown in Table 2.

Table 2 Number of α_0-cycles for each building

Building	Building Visualisation	Number of α_0-cycles
Dataset A: Connected Buildings		34
		24
Dataset B: Disjointed Buildings		34
		24

Based on Table 1 and Table 2, the number of directed edges of the digraphs are equal to the number of α_0-cycles for each building. This adheres to Equation (6) hence, proving that the CACC topological data structure implemented is topologically sound. According to Jahn et al. (2017), a topological representation of an object that is equal to its geometric properties is said to be topologically consistent and ensures the correctness of topological information retrieval as the topology of the model is bound to the Euclidean space.

5. Conclusion

One of the most important characteristics of an object is its location which describes its position within the space. The geometric components of the object also describe the form or shape of the object. This allows the determination of the spatial properties of the object and what the object looks like. Apart from the geometrical component of the object, the topological component is also important in the representation of the elements. 3D topology is required as a means of support for various 3D analyses for city modelling which produces 3D results. However, the topological component of CityGML as the international standard for city modelling remains in 2D with the utilisation of the simple topology-incidence mechanism. A comprehensive preservation of topological primitives is required to ensure the maintenance of connectivity information between buildings or building elements. 3D spatial queries and space segmentation are also important in the planning and management of building complexes for a sustainable development of cities. Individual units in a building complex can be represented as 3D blocks which are related. The use of topological relationships in 3D spatial queries allows the determination of common parts of an object. For example, a 3D query of other units that are related to a wall of a unit that is undergoing repairs can be retrieved and checked or given early warning.

This paper demonstrated a topological validation of the implementation of the CACC topological data structure for buildings in CityGML. Two CityGML datasets were used for testing which consisted of connected and disjointed buildings in LoD2. Directed graphs and adjacency matrices were constructed for each building to represent the topology of the building elements. The in-degree and out-degree of vertices were calculated. The "Hand-shaking" theorem which denotes that the sum of in-degree equals the sum of out-degree also equals the number of directed edges was used. The number of directed edges was found to be equal to the number of α_0-cycles of the CACC topological data structure generated for the building. Therefore, this verifies that the CACC topological data structure used to maintain topological information for buildings in CityGML is topologically sound. This study focused on the wall, roof and ground surfaces of a CityGML building in LoD2 and to other connected buildings. Future studies could attempt to implement the CACC topological model for buildings of higher LoD which could lead to the improvement of indoor navigation and other applications.

Acknowledgements

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Material Thermal Performance Comparison Between The Tomb Of Mohammad Ghaus Heritage Building And A Modern Style Dwelling In Madhya Pradesh

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ABSTRACT

Building envelope not only provides us the protection from outside environment but also provides the necessary thermal comfort required for anyone residing inside it. It is observed that the natural cooling arrangements provided in the ancient buildings have a great influence on the thermal comfort inside the buildings. This type of arrangement of thermal comfort is not considered while designing new structures. So, the energy consumption in modern structure is more for the same thermal comfort as in ancient structures. Inside humidity, room temperature, mean surface temperatures, air variation ratio and lighting are some factors affecting thermal comfort. The materials such as cement and steel used in modern constructions are highly durable but not energy efficient. Hence necessary balance must therefore be achieved between energy efficiency and durability of modern buildings. Against this background, the paper presents a comparison of the thermal comfort inside the Tomb of Mohammad Ghaus heritage building and a modern style dwelling estimated around 10 years old. The average inside temperature of modern and heritage building was 32.65°C and 26.96°C respectively while the average outside temperature during observation period is 29.96°C. The average inside relative humidity of modern and heritage building was 61.73% and 68.93% respectively. As the heritage building was found cooler than the modern building, the study suggests that the cooling arrangement provided in the ancient buildings is imitable and beneficial to be incorporated in modern buildings.

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1. Introduction

Nowa day, a role of an architect and engineers are increasing in the construction sector. While constructing a building, along with its design various factors need to be considered like its cost, environmental impact, aesthetic look etc. The building construction involves various steps from its preliminary designs to final construction. The various building systems put some restrictions on one another as they are inter-related. Each system has various sub-systems like designing building from environmental point of view includes consideration of thermal, audio and video sub-systems. The paper is about the thermal consideration while designing building from environmental point of view.

With increasing population, the energy reserves are depleting at a very faster rate. The buildings need to be designed in a way that it consumes lesser energy produced from various conventional energy resources. The effort is made toward utilization of natural resources as much as possible. As the ancient structures are designed in such a way that there is no need of AC or cooler or fan for creating thermally comfortable environment. They have inbuilt feature for providing thermal comfort. But in modern structure, due to lack of awareness the people are not considering about climatic design. The buildings can be made energy efficient by adopting solar passive arrangements as per the climatic condition of a particular location (Zinzi and Santamouris, 2019). Bano and Kamal (2016) presented the review showing the impact of building envelope on heating and cooling load of various office building in India under different climatic zones.

Sustainability is considering environmental, economic and social requirement all together while designing a building. All these aspects are already considered in ancient buildings but now in modern structures the building regulation mostly focuses on environmental impact of building especially reducing the usage of fossil fuel. The steps are taken towards the reduction of CO_2 generation from construction of building to its daily use. The ancient structures were already sustainable and net zero energy buildings. As for the transportation of ancient building material, mostly man or animals were used, emitting zero carbon. Even for lightning, building heating and cooking, the biomass is used which is in itself a sustainable source of energy. The wind and water (Hydro) energy were also used where available either for transportation purpose or for timber making. The heritage buildings can be preserved or can be reused by upgrading it thermally as per the principles of building conservation and its sustainability. In many cases it is observed that by proper adoption and reuse, the new structure formed is of high-quality architecture.

The paper compares the thermal comfort in modern and heritage building (Tomb of Mohammad Ghaus) in Gwalior, India and the techniques that can be adopted from ancient building for creating better thermal comfort in modern buildings with less energy consumption. The inside temperature and humidity inside the heritage building was compared with the inside temperature and humidity of modern style building. The difference between the two is shown by graphs plotted.

2. Literature Review

2.1 Researches on Traditional Buildings

Hatamipour and Abedi (2008) described the natural cooling arrangement in ancient Bushehr architecture in hot and humid region of Iran. These arrangements protect the people from hot summer climate for a long time without using any electric air conditioner. The arrangements made for natural cooling are: properly insulated roof sand walls, smaller windows and use of light color in walls for lesser heat gain, building orientation along direction of wind, using wooden sunshades and high thermal mass (heavy walls).

Traditional and modern architecture of Ghana is compared by Abdul Manah Dauda (2016). Maximum temperature inside the modern building was 37°C while in ancient building it was 35°C. In traditional building, the mean room temperature was found 4-5°C less than modern buildings. This is due to roof made of thatch providing proper ventilation and pores in them allow hot air to escape through it. While in modern structure, the metal sheet used creates thermal discomfort as it increases the room air temperature by absorbing the inside heat and transferring it to the air inside.

In Nepal, Susanne Bodach et al. (2014) studied about the climate responsive vernacular architecture, its designed construction strategies. After the study it was found that the thermal comfort in the vernacular architecture was due to higher thermal mass, overhanging roof preventing sunrays to enter directly inside the building, solar natural heating and cooling arrangement, medium sized windows etc. It was recommended to use this technique in modern structure also.

In Bhopal, Megha Jain and Singh SP (2013) reported the passive solar techniques used in the Gohar Mahal (Heritage Building). The building was constructed in 1820 having incorporated passive solar arrangements. The inside temperature, air velocity and humidity inside the Gohar Mahal were observed and compared with the outdoor condition. In summer season the inside temperature was below 26°C which is due to proper envelope design and high thermal mass that helps in providing better thermal comfort and stabilizes the inside temperature.

Manoj Kumar Singh et al. (2014) optimize the design of vernacular building in North-East India by using TRNSYS 17. The 3 types of construction and 8 possible orientations of 3D models were used for optimizing design. Various parameters like window to wall ratio, thermo-physical properties, ventilation, shading, heat load inside the building, its orientation and false ceiling types were considered for optimizing design. The energy consumption in vernacular structure has been found increasing in recent years. With the objective of reducing thermal discomfort, he suggested that use of ventilator and windows with large opening promotes cross ventilation. Double glazed windows and proper shading improves the inside thermal comfort. The vernacular structure was found more comfortable in pre-summer and pre-winter season.

Usha Bajpai and Sachin Gupta (2015) reported the solar passive arrangement provided in Avadh Architectural Buildings, Lucknow, India. Tomb of building had various feature aiding passive concept like curved and high roof, thick wall, proper openings and light-colored exterior preventing heat transfer inside the building. The building has a height of around 10 m which is suitable for proper natural convection. Due to large wall thickness, the U-value of wall was also high.

Manoj kumar singh et al. (2010) carried out the thermal performance evaluation vernacular buildings of North-Eastern part of India. For study, 50 vernacular houses with 100 residents were taken. The study was done in the months of January (winter), April (pre-summer), July (summer/monsoon) and

October (pre-winter). The doors, windows and ventilators cover about 50 % of area. Window to wall ratio was 0.216 and heat transfer lags by 5-6 hours which shows higher insulation. Inside house temperature swing by maximum of 10°C, that is noble for naturally ventilated buildings but the inside day lighting was found insufficient.

During retrofication of traditional building of Sugganahalli near Bangalore, Praseeda et al. (2014) studied the effect of material change on Embodied Energy (EE) and Operational Energy (OE). Comfort standards by ASHRAE and TSI model by Sharma and Ali were used. It was observed that the traditional buildings with passive arrangements consume lesser operational energy in extreme climatic change also. The change in material will increase the embodied energy of the building.

Kranti Kumar Mynani (2013) studied the effect of providing courtyards in traditional buildings in Athangudi village, Tamilnadu, India. It was observed that the courtyard in the houses provides the cool environment inside the house during daytime. He suggested making the courtyard a part of modern building so as to have a better living condition.

Some of the previous studies undergone in traditional buildings in various part of the world having different climatic condition are shown in Table 1.

Table 1 Observations from various Traditional buildings

S. No.	Buildings/Structures	Building features	Climate
1.	Bushehr architecture	• Properly insulated walls and roofs, light coloured surfaces reduces heat gain through walls. • Overhung shading, wooden sunshades and using trees for shading of buildings. • High roofed buildings with sufficient windows.	Hot and humid
2.	James town light house	The thatched roof having pores provides proper ventilation and allows hot air to escape through it.	Tropical
3.	Vernacular Houses	Courtyards and semi-shaded open spaces like verandas and balconies provide cool environment in summer.	Subtropical
4.	Gohar Mahal	Includes landscaping, water bodies, orientation, site features, open spaces and envelope design.	Subtropical
5.	Vernacular buildings	• Windows and ventilators with large openings will promote cross ventilation. • Double glazed window and proper shading elements improves indoor thermal conditions	Warm and humid climate
6.	Avadh Architectural buildings	• Due to very thick wall, U-Value of the wall was low. • Usage of water and landscaping created the micro climate inside and around the building.	Warm and humid climate
7.	Hangudi village Buildings	Courtyard provides the cool inside environment during daytime.	Agro climatic zone
8.	Sugganahalli Building	• Passive arrangements consume lesser operational energy in extreme climatic change. • Embodied energy increases due to change in material. • ASHRAE comfort standards and TSI model were used.	Tropical savanna climate
9.	Jack Arch (JA)	• Self-shading by arches reduces solar heat gain. • Brick roof reduces solar heat gain as bricks have low thermal conductivity than concrete.	

2.2 Researches on Modern Buildings

Some of the previous studies undergone in modern buildings in various part of the world having different climatic condition are shown in Table 2

Table 2 Observations from various modern buildings

S. No.	Buildings/Structures	Building features	Climate
1.	Western Cape (South Africa)	• Used self-shaded courts, higher ceiling, wall and roof with high thermal mass. • East-west orientation with North light roof, elongated north and south fronts for receiving day-light and natural ventilation.	Subtropical
2.	New Assist housing in Egypt	As per bioclimatic chart for summer season, data measured was found within the boundaries of natural ventilation and evaporative cooling.	Tropical
3.	Modern low-cost housing units at Kanyakumari, Thirunelveli and Madurai Districts	Study shows that houses at these three locations were thermally uncomfortable. Various solar passive arrangements have been recommended to increase thermal comfort.	Tropical

For residential buildings in Western Cape, South Africa, sustainable solutions are suggested by Fahimeh Foudazi and Mugendi M Rithaa (2013). Solar passive cooling arrangement will provide the better thermal comfort and reduces consumption of electricity. It was suggested to use self-shaded courts, higher ceiling, wall and roof with high thermal mass, East-west orientation, elongated north and south facades for daylight and natural ventilation, domed and light-colored roof with vents, landscaping and geothermal cooling.

The indoor environments and thermal comfort in newly assisted houses in Egypt was studied by AMR Sayed et al. (2013). For study during summer season, psychometric charts by ASHRAE standard 55 and Adaptive Comfort Standard (ACS) were used. The maximum and minimum outside temperature was 43°C and 27°C with corresponding relative humidity of 4% and 40% respectively. The inside temperature varies from 31°C to 40°C for different ventilation arrangements.

The effect of glazing tile, window to wall ratio, courtyard and atrium in the performance of building is analyzed by Tofigh Tabesh and Begum Sertyesilisik (2015 & 2016). It was observed that the courtyard and atrium in buildings results in energy saving in all three climatic conditions. In summer, courtyard with larger openings was found suitable while in winter atrium made is best.

Thermal performance of modern low-cost housing units was investigated by Vincent Jayaseelan V and Ganapathy C (2007) in three different locations of India (Kanyakumari, Thirunelveli and Madurai Districts). Tropical summer index (TSI) by Sharma and Ali 1986, was found out and compared with comfort temperature given by Nicol F et. al. 1994. Study shows that houses at these three locations were thermally uncomfortable. Various solar passive arrangements have been suggested to improve thermal comfort.

2.3 Comparison of Traditional and Modern Buildings

Comparison of modern and traditional architecture in North Sulawesi-Indonesia is done by Sangkertadi et al. (2008). For study, ten modern and ten traditional buildings with 60 residents has been taken as sample. The residents feel comfortable at temperature maximum upto 29°C and humidity upto 60 % with air flowing at slow speed.

Thermal performance of modern and traditional architecture in Thailand had been compared by Paruj Antarikananda et al. (2006) using ECOTECT simulation model. The modern structure consists of bricks walls, concrete floor and roof, plasterboard ceiling and tiles over roof while the traditional buildings in Thailand consist of high roof, adequate walls and windows and central terrace. The air conditioning in modern buildings is done using mechanical devices which results in more energy consumption and affecting the environment. It was observed that the traditional structures using passive cooling techniques are more responsive to extreme climate condition.
The modern low-income housing built at Sarawak; East Malaysia was found thermally uncomfortable as reported by Tinker JA et al. (2004). The traditional Malaysian houses were designed as per the climate condition and provide better thermal comfort inside the house. Parameters affecting thermal comfort are measured in both traditional as well as in modern building. Comfort level is investigated by using CFD and corrected effective temperature index method. They observed that traditional structures are more comfortable than modern ones. They suggested using ventilation with grills for proper air flow and better thermal comfort in modern buildings.

In Kerala, questionnaire survey had been done by Dilli AS et al. (2010 & 2011) from the peoples living in traditional and modern buildings. The survey result shows that 70% peoples feels comfortable in traditional buildings in all climatic conditions while only 20% feels comfortable in modern buildings in summer season.

Subramanian C.V. et al. (2017) observed that the natural cooling arrangement in ancient building provides more thermal comfort than modern building in all seasons. He suggested employing the passive techniques of ancient structure in modern style buildings. People feel more comfortable with a less electricity consumption and air conditioning, due to integrating with customized strategies as per local climatic conditions. This phenomenon is an attempt towards Energy efficient green buildings for future.

Priya Shanthi R et al. (2012) conclude that ancient building is thermally comfortable than Modern style buildings for the similar environment. The inside temperature is higher in modern style building in comparison to inside temperature of ancient buildings with the same outside temperature for both buildings. The evaporative cooling phenomena is the main causes for significant temperature variation between inside and outside temperatures of ancient building in summer take places in stone based ancient house management measures in shop-house enterprises. It will lead to identifying potential EMMs that can be applied to all stakeholders including shop-house entrepreneurs, residents, planners and district managers

3. Methodology

The research objective is to compare the thermal comfort in modern and heritage building (Tomb of Mohammad Ghaus) in Gwalior, India and to present the techniques that can be adopted from ancient building for creating better thermal comfort in modern buildings with less energy consumption. For case study, building is selected from a range of naturally cooled heritage buildings considering various factors such as shape, size, design plan, types of ventilation and the physical state of the building like construction and material property. The climate characteristics like temperature (WBT and DBT), and relative humidity is calculated in one heritage building (Tomb of Mohammad Ghaus) and one modern style building of sub-tropical region from morning 8:00 am to 5:00 pm evening for a time of two days in month of April.

The inside temperature and humidity inside the heritage building was compared with the inside temperature and humidity of modern style building. The difference between the two is shown by graphs plotted. The measured data is compared with ASHARE standards to evaluate the thermal comfort in ancient building. It is hope that research will not only increase the energy savings but also helps in achieving maximum sociocultural advantages.

3.1 Description of Selected Heritage Buildings (Tomb of Mohammad Ghaus)

The case-study is conducted out in a one of the heritage buildings (Tomb of Mohammad Ghaus) positioned in the region of Madhya Pradesh that is 500 years old (shown in Figure 1). This building was constructed on rectangular plot typically facing the East side. The building of a 16th century prince-turned-sufi is now situated in the town of Hazira, Madhya Pradesh, India. The beautiful tombstone and the stunning architecture of the mausoleum give this place a sense of serenity and peace. The building's walls are inlaid with exquisite pierced-stone jail screen.

To the East of the town stands the mausoleum of Mohammad Ghaus. It is built in the form of square with Hexagonal Towers at its corners surmounted by small dome. The body of Heritage Building is enclosed on all sides by carved stone lattices of elaborate and dedicated design the whole being crowned by a big dome which was once inlaid with blue glazed tiles. The angle of Latitude and Longitude of Buildings are 78.1774527°N and 26.2317800° E respectively.

It was constructed during the reign of Mughal Emperor Akbar in 16th century. A true example of Mughal architecture, the structure holds great importance in the history of the country. The wall of the Tomb of the building has been carved using pierced stone technique and a number of chattris in blue tiles covers the tomb. Figure 2 and Figure 3 shows the inside view and some other features of selected heritage building. The intricate carving and the latticework are also something to watch for in the edifice. Set in a lovely garden and backed by a cemetery of the saint's devotees, the tomb is also the site of annual Tansen Music Festival.

Figure 1 Selected Heritage building for case- study (Tomb of Mohammad Ghaus)

Figure 2 Inside View of Heritage buildings with large ventilations

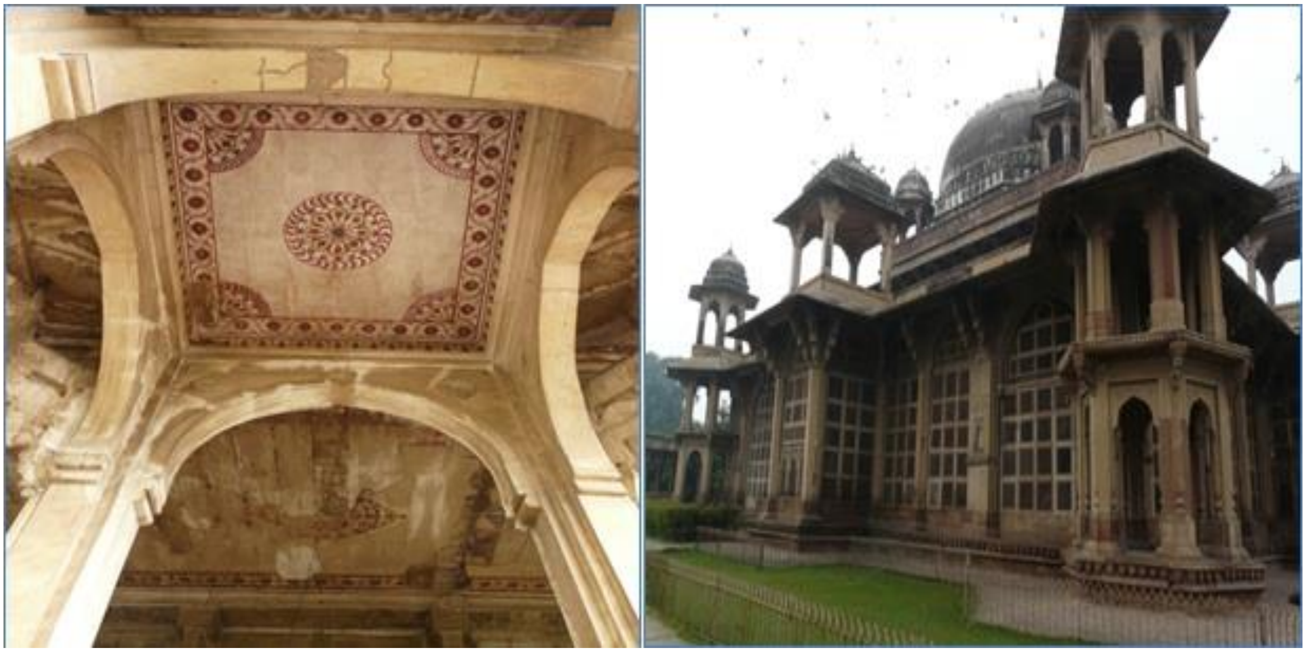

Figure 3 Salient Features of Heritage Buildings

4. Description of Selected Modern Style Building

The selected modern style building is approximately 10 years old and is located at a distance of 150m from heritage building in the same region of Madhya Pradesh. The Building is double story (ground and first floor) and has three bedrooms with other activity spaces such as veranda, study room, kitchen as shown in Figure 4. The modern style composed of bricks walls with plaster and reinforced cement concrete roof slab with use of iron rods without providing any types of insulation. Single glazed windows are provided. The width of brick walls is 10 inch that is covered with cement mortar. The maximum room height of the building is 3.5 m.

Figure 4 Selected Modern Style building for case- study

5. Thermal Comfort Index

According to ASHRAE Standards 55-2004, Thermal comfort is defined as "the situation of the mind that feels satisfaction with the thermal environment". The environment affecting the heat gained and lost by the human is termed as thermal environment. In order to evaluate the thermal comfort of any building, thermal comfort index is used. Some other indices are also available for evaluating thermal comfort like Predicted Mean Vote (PMV) method is used in air-conditioned structures; Adaptive neutral temperature model (ANTM) is used in buildings with natural ventilations etc. Therefore, ANTM is used in the study. Neutral temperature is the operative temperature at which the maximum number of people in a group feel neutral (neither cool nor warm). It is given by Eq. 1 (Fergus and Michael, 2010) as shown below,

$$T_n = 0.33T_{rm} + 18.8 \quad (1)$$

Some of the previous study on thermal comfort parameters (Temperature and Humidity) is shown by Table 3. As per the ASHRAE Standards, the thermal comfort temperature is upto 30 °C. In the study, the neutral temperature calculated using ANTM model for heritage and modern building are 27.69°C and 29.57°C respectively. Thus, in the heritage building better thermal comfort was noticed than modern structure. The maximum, minimum and average values of thermal comfort parameters are shown in Table 4 below for both modern and heritage building.

Table 3 Previous Studies on thermal comfort

S. No.	Author	Thermal Comfort Temperature Range (°C)	Relative Humidity (%)
1.	Vernon	18.94 in summer 16.72 in winter	35 to 70
2.	Bedford	18.16 in winter 13.22 - 23.16 comfort zone	30 to 68
3.	Markham	15.55 – 24.44 in ideal range	40 to 70
4.	Brooks	20.55 – 26.66 comfort zone	30 to 70
5.	ASHRAE Standards (55-2004)	24 – 30 comfort zone	

Table 4 Comparison of recorded thermal comfort parameters of modern and heritage building

	Outside Data		Inside Data Of Modern Building		Inside Data Of Heritage Building	
	Temperature (°C)	Rh (%)	Temperature (°C)	Rh (%)	Temperature (°C)	Rh (%)
Minimum	24	50	28	49	22.5	60.5
Maximum	40.2	85	37	78	33.1	73
Average	29.96	71.60	32.65	61.73	26.96	68.98
Neutral Temperature (T_n)			29.57 °C		27.69 °C	

5.1 Location of Sensors in Heritage and Modern Style Building

A number of sensors such as thermocouple, thermometer and hygrometer were fixed in traditional as well as in modern building for detecting ambient temperature and RH values outside the building as well as inside the building. The data measurements were carried out in both buildings during the same period (April 2018) of the hot summer season.

5.2 Uncertainty Analysis

Uncertainty is the key factor for determining the accuracy of the measured data. Uncertainty in the data is of two types, type A is due to random error and type B due to systematic error. The data is uniformly distributed, so here the type B uncertainty is calculated. The standard uncertainty of the instruments used for measurement is given by Eq. 2. The accuracy and standard uncertainty of the instruments used is shown by table 5.

$$\text{Standard Uncertainty} = \frac{\text{Accuracy of instrument}}{\sqrt{3}} \quad (2)$$

Table 5 The technical specification of the instruments used in the experiments

Instruments Used	Accuracy	Range	Standard Uncertainty
Thermocouples	±0.1°C	-20 to 400 °C	0.288
Digital hygrometer (model HT-315)	0.1 % RH	10 % to 95 % R.H.	0.068
Pyranometer (version WACO-206, least clarity ± 10 W/m2)	± 10 W/m^2	0-24 hours	0.00058

6. Result and Discussion

The data measurement had been conducted in summer season of Gwalior, Madhya Pradesh i.e. on 16th of April 2019 for duration of 24 hours. From the obtained data it was found that in ancient buildings ambient outside temperature has a temperature swing of 17.3°C, i.e. from 24°C to 41.3°C, while inside building temperature was altering from 23.2°C to 29.0°C showing everyday swing of the about 5.8 °C only (Figure 5). Inside ambient temperature at the time of night is maintained at around 23.2°C and outside ambient temperature at the same time is around 25.8°C. The relative humidity inside fluctuates from 56% to 100%. Then compared with ASHRAE standards it was come to know that inside temperature falls in the thermal comfort zone. This is because the ancient building has Maximum walls thickness, large area veranda,curved terracotta roof tiles, yards, and wind catchers above the yards for natural ventilation for cooling purpose.

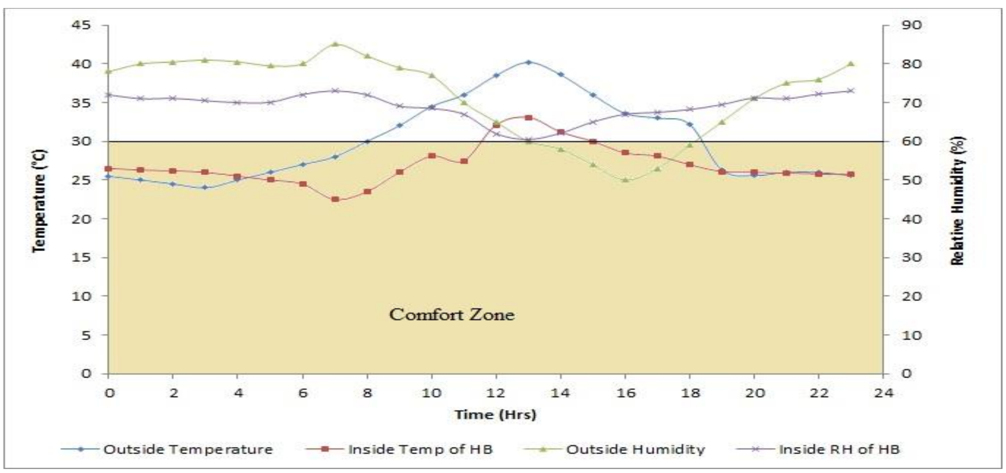

Figure 5 Comparison of inside temperature and relative humidity with ambient temperature and relative humidity for Heritage building

In modern style buildings the ambient temperature swing of 16.2°C was found while the inside house temperature varies from 28°C to 37°C showing the diurnal deviation of 9°C (Figure 6). From the data it is clear that the maximum temperature inside the room was around 37°C and the minimum temperature was about 28°C. When these data matched with ASHRAE standards it was found that inside room temperature does not fall in the comfort zone. The reasons behind this are that the modern style buildings has Concrete roof with iron rod, small sunshades, minimum thickness of wall, and small ventilation for cooling. Figure 7 shows that inside temperature variation in the ancient building and modern style buildings. It is noted that minimum temperature in the ancient buildings is 22.5℃ and the minimum temperature noted in the modern style building is 28℃.

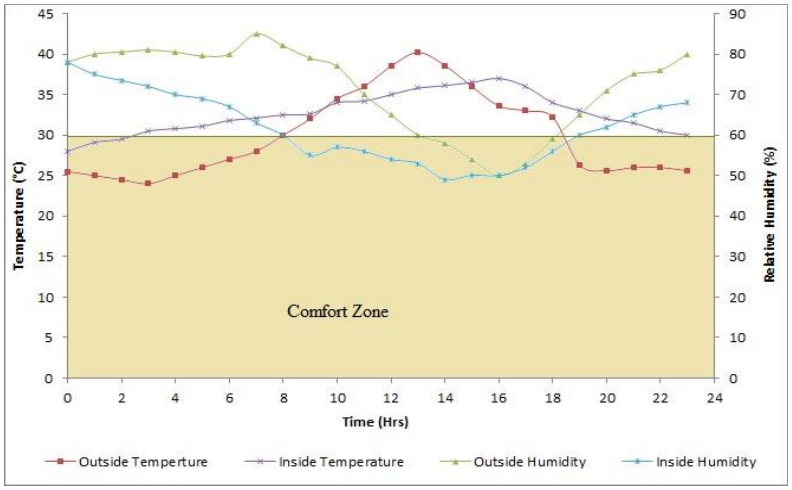

Figure 6 Comparison of inside temperature and relative humidity with ambient temperature and relative humidity for Modern style building

From Figure7 it is clear that minimum temperature is greater by 5.5°C in modern style buildings when compared with minimum temperature of the ancient buildings. The maximum temperature in modern style buildings is higher than traditional building by 5.5°C.

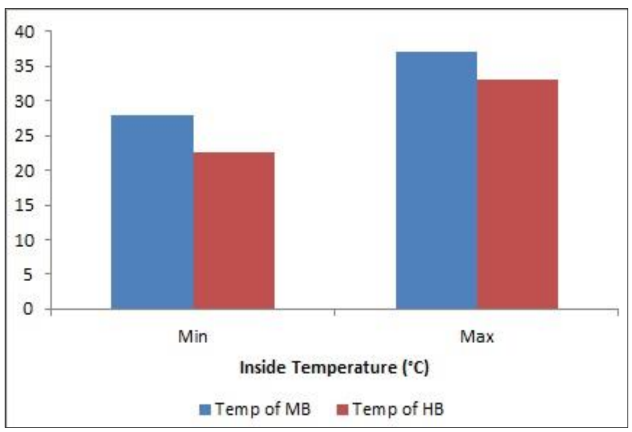

Figure 7 Inside temperature variation in Heritage and Modern style Building

The ambient temperature is varying from 24°C to 40.2°C. As from Figure 8 it is clear that the temperature inside the heritage building was close to the thermal comfort temperature range given by ASHRAE. While in modern building, the inside temperature is crossing the limit of thermal comfort for more time as compared to heritage building. The maximum temperature inside the heritage builging was 33.1°C while in modern building it was 37°.

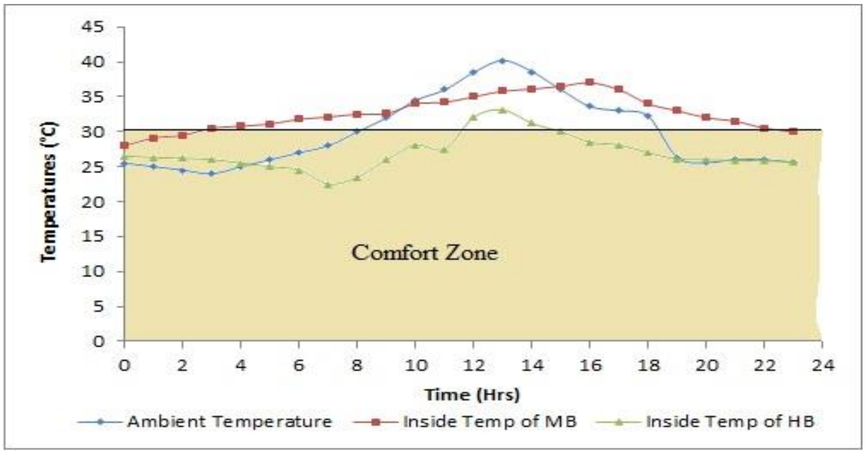

Figure 8 Variation in Inside temperature in comparison to ambient with Time for heritage and modern style building

7. Conclusion

It is observed that the Ancient building is more thermally comfortable than the Modern style building for the same environment. The inside ambient temperature is tremendously much greater in modern style building then the Ancient building with the same outside temperature in both the buildings. The causes for significant temperature difference between inside and outside temperatures of ancient building in summer is because of that the evaporative cooling phenomena take place in mud mortar based traditional houses. Low thermal conductivity and less thickness of roof and walls of concrete based modern style buildings shows the higher temperature differences when compared with traditional buildings. As a result, it can be concluded that the solar natural features used in traditional buildings should be used in the modern style.

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Assessment of Residents' Socio-demographic Factors Associated with Visit to Green Infrastructure Facilities in Lagos Metropolis, Nigeria

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ABSTRACT

Despite global efforts at promoting environmental sustainability through development of Green Infrastructure (GI) facilities at urban centres; social menaces, depletion and wrong use of green spaces still persists in many developing nations. Indeed, attitude of residents towards the use of these facilities have not been commensurate to the reasons why the GI facilities were created. This study therefore examines the socio-demographic factors associated with visiting GI sites among residents of Lagos Metropolis, Nigeria. Multi-stage sampling technique was used to select 1560 participants in a questionnaire survey. Descriptive statistics was used to explore data distributions while Chi-square test was used to investigate residents' socio-demographic characteristics associated with visit to green infrastructure sites in the study area. Participants were mostly men (58.6%) and younger than 50 years old (85.8%). Percentages of residents visiting GI facilities for either spiritual exercises (male=26.4%, female=23.8%) or joblessness (male=48.9%, female=52.1%) is higher than percentages of residents visiting GI facilities for recreation/relaxation (male=24.7%, female=24.1%) activities in Lagos Metropolis. The study suggests among others that, the Lagos State government should develop GI facilities to enhance more opportunity for job generation, while more public orientation on positive attitude toward use of GI facilities should be emphasized.

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1. Introduction

Rapid and uncontrolled urbanization is greatly altering the spatial pattern of urban land use worldwide. The phenomenon is particularly recognised as one of the biggest environmental problems confronting many cities worldwide (Graham, Gurian, Corella-Barud & Avitia-Diaz 2004; Balogun, Adeyewa, Balogun, & Morakinyo, 2011; UN-Habitat, 2015; Popoola *et al.,* 2016). Presently, urbanization is rapid worldwide and is expected to continue in the coming decades, especially in the developing world where studies by the United Nations Population Fund (UNPF-2007) projected that 80% of the world's urban communities will be found by 2030 (Beardsley *et al.,* 2009). Consequently, the resulting depletion of urban natural environment to cater for the increase in population at local to global level are continuously altering urban ecosystems. Recent researches on this aspect (Ward Thompson, Aspinall & Roe, 2014, Adegun, 2018, 2019) has emphasised the importance of urban Green Infrastructure (GI) as well as their rapid losses due to geometric progression in urban growth as GI form an essential component of urban spatial elements. Urban GI helps provide a framework on which sustainable environment and development lies. The aesthetic, air quality maintenance, sense of community and therapeutic benefits that these facilities provide cannot be over-emphasized (Popoola *et al.,* 2016).

More importantly, the positive health effects of green environments have been described across different field of study including landscape architecture, descriptive epidemiology, environmental psychology, public health, ecology and behavioural studies (Hartig *et al.,* 2003; Takano *et al.,* 2002; Maas *et al.,* 2006; Bonnes, Passafaro & Carrus, 2011). Proximity to green environments has been found to be associated with a number of health benefits (De Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Morita *et al.,* 2007; Nielsen and Hansen, 2007). Residents in greener areas report their physical, mental and overall health status to be better than those living in less green areas (De Vries *et al.,* 2003; Bell *et al.,* 2008). It is pertinent to note that the developed and developing world is facing a health crisis of alarming proportions as physical inactivity, obesity, mental and emotional illness increase. Creating awareness that green environment might play a role in enhancing health, and perhaps prevent illness as well the high cost that would be needed for medical intervention, has attracted attention from policy makers and researchers (Morris *et al.,* 2006; Ward Thompson *et al.,* 2014). Neighbourhood GI facilities like green gardens, urban parks, street trees, urban forests, fountains, urban agriculture, public open space, sports facilities and other green spaces contribute to individual well-being, and through their social, economic and environmental attributes contribute to more liveable and attractive towns and cities (Bell *et al.,* 2008) and as well have a role to play in promoting residents' health and well-being (Bedimo-Rung, Mowen, & Cohen, 2005). Some of the many other benefits of urban GI are; improved air and water quality, mitigation of the impact of environmental pollution, carbon sequestration, regulation of microclimate, habitat for urban wildlife, recreational, spiritual and therapeutic value as well as social integration (Schipperijn *et al.,* 2010; Jahdi & Khanmohamadi, 2013; Nurul Nazyddah, Othman, & Nawawi, 2014; Wolch *et al*., 2014; Liu *et al*., 2015).

Despite the well-established benefits of urban GI facilities, residents' attitudes toward the use of GI facilities still remain not commensurable to the reasons why these facilities were provided and this has attracted attention of researchers recently. Although there is an increase in frequency of studies on benefits of urban GI (Bedimo-Rung *et al.,* 2005; Benedict & McMahon 2006; Bell *et al.,* 2008; Baycan-Levent & Nijkamp, 2009; Dipeolu, 2015; Mexia *et al*., 2018), there is still not a clear and consistent understanding of the factors motivating users and other practitioners towards the use of GI facilities in developing nations like Nigeria. Only a limited number of studies (Otegbulu, 2011; Popoola *et al.,* 2016) investigated and began to systematically consider questions related to this idea. This paper attempts to fill this gap by identifying the socio-demographic factors associated with visiting GI sites among residents of Lagos Metropolis, Nigeria.

1.1 Concept of Green Infrastructure

Green infrastructure includes strategically planned and delivered networks of high-quality green facilities that contribute to the protection of natural habitats, species diversity and other environmental features designed and managed with the aim of delivering ecological services and quality of life benefits to people in communities (Natural England, 2009). The concept originated in the United States in the mid-1990s with emphasis on the significance of the natural environment and its life support functions in handling land use planning issues. Sandstrom (2002) noted that the concept of GI promotes the quality as well as quantity of urban and sub-urban green areas, their multifunctional role with emphasis on interactions between habitats. Benedict and McMahon (2002) submitted that GI is an interconnected network of water features, wetlands, streams, woodlands, wildlife habitats, and other natural areas; greenways, parks, gardens, and various conservation lands; farms and forests; and other open spaces that support various native species and contribute to quality human life. It comprises all environmental resources which makes GI approaches to contribute towards sustainable planning and management.

These assertions are broadly on two aspects namely; terrestrial habitat connectivity and aquatic habitat connectivity. from the definitions, the following elements has been frequently mentioned as constituting green infrastructure strategies: ecological processes, waterways, multi-functionality, access, connectivity, human benefits, spatial variance, biodiversity and sustainability.

Green infrastructure concept took different styles and focus in its evolution in many developed nations. Beatley (2009) described these differences in evolution style as being a function of planning orientations and styles commonly practiced in those nations. In the UK for example, Howard (1985) concepts of garden cities and the special attractions of green areas at major cities gave birth to GI planning and management. Howard's attempts at creating spaces that promote recreation and quality of life for urban dwellers through major green facilities became very prominent in these cities (Williamson, 2003). According to Beatley (2009), the development of GI in Europe could be traced to the evolution of green plantings cohesively integrated within high density landscapes in major towns. However, the North American GI evolution could be traced to early developments in landscape conservation to enhance balanced ecology in the city (Benedict & McMahon, 2002; 2006).

Generally, GI has its origin in two fundamental principles: connecting parks and other green areas for the benefit of people, and conserving and connecting natural areas to benefit biodiversity and counter habitat fragmentation. These two fulcrums enhance the multifunctional capacity of GI facilities (Pakzada & Osmonda, 2016). The concept of GI emphasizes the value of functionally and spatially connected, healthy ecosystems and the importance of ensuring that they keep providing their goods and services. GI has a vital role to play in the conservation of the Nigeria's biodiversity and in tackling fragmentation. This implies that the role of GI in achieving environmental sustainability cannot not be overemphasized, especially in rapidly growing cities in the Global south.

1.2 Types of Green Infrastructure And Their Importance In The Built Environment

Green infrastructure are of different types as found in the review of literature. Generally, they can be categorized into four different groups namely; a green feature GI (e.g green roofs, green parks, gardens, sport fields), tree feature GI (e.g street trees, woodlands, community forests), water feature GI (e.g streams, fountains, rivers, flood plains) and other spaces GI that cannot fit into those earlier mentioned (e.g open spaces, Permeable pavement, cemetery, wildlife habitats) (Wolch et al., 2014; Mullaney, Lucke & Trueman 2015; Adegun, 2018). The connectivity between the different types of GI are important strategies through which GI perform their functions in ecosystem services. GI systems functions by restoring natural ecosystems thereby creating opportunity for sustainable growth and development in cities (Benedict & McMahon, 2006). In doing so, they provide a diversity of ecological, social, and economic functions and benefits, like enriched habitat and biodiversity; improved health; maintenance of natural landscape processes; provide cleaner air and water and increased recreational opportunities.

GI facilities have been reported to have the capacity to provide various environment-related benefits such as carbon sequestration, improved air and water quality, control of air pollution and urban heat island effect (Whitford, Ennos & Handley, 2001; Gómez-Munoza et al., 2010). GI provision contributes to energy conservation initiatives by insulating buildings, shading building envelopes and ameliorating the urban heat island effect. In addition to the direct energy saving benefits, they can also be built as a complement to sustainable energy generation practices. Furthermore, developments that incorporate GI practices into the initial planning and design phase are better able to take advantage on the cost-saving, climate change resilience and other benefits GI provides (Naumann et al., 2011). Nigeria and other developing world are faced with a multiplicity of challenges in addressing sustainable development but GI strategies can provide perfect solution to tackle these challenges.

Empirical evidences have also evaluated the roles of various types of GI on storm water management as well as carbon emission control (Liu, Chen & Peng, 2014; Liu et al., 2015; Pugh, MacKenzie, Whyatt & Hewitt, 2012). The roots of some trees serve as filters for underground water and thus highly improve quality of drinking water (Dong, Guo & Zeng, 2017). Well planned green space has also been shown to increase property values and decrease the costs of grey infrastructure and services, including the costs for stormwater management and water services (Benedict & McMahon, 2006; Poudyal et al., 2009; Otegbulu, 2010; Tan, 2011). The concept of GI promotes the value of functionally and spatially connected, healthy ecosystems and the importance of ensuring that they keep providing their goods and services. Therefore, residents must be aware of the concept and make use of GI sites in more positive ways that nature provides.

2. Methodology

2.1 Description of Study Area

Lagos state lies in the South-western area of the Federal Republic of Nigeria within the longitude 2° 42’E and 3° 42’E and latitude 6° 22’N and 6° 52’N (Figure 1). The Metropolitan part of the state is on low land, with about 20000 hectares of built-up area (Oduwaye, 2009). Administratively, Lagos is made up of twenty (20) Local Government Areas with sixteen (16) of these LGAs statistically classified as Lagos Metropolis (Ajose, 2010) while the remaining four (4) LGAs (Ikorodu, Epe, Badagry and Ibeju/Lekki) are in the sub-urban area of Lagos state (Figure 2).
With the high urbanization and industrial growth rate, Lagos is one of the most densely populated regions on earth with a population of about 9.3 million recorded in the 2006 Census (Adesuyi, Njoku & Akinola, 2015). This figure was further estimated to have grown to about 21 million people in 2016, surpassing Cairo to become the largest city in Africa and one of the fastest growing urban centre the world over. Lagos is the centre of business and economic development in Nigeria, hosting about 70 percent of the country’s industrial establishments, 60 percent of Nigeria’s non-oil economy and more than 65 per cent of all commercial activities (Adelekan, 2010).

The rapid physical development going on in Lagos have among other things intensified the depletion of initial greens areas of the state. Various community forests, open and green spaces have been depleted in lieu of massive grey infrastructure. This has consequently increased adverse effects of various environmental sustainability challenges in the state. Thus, the need to develop strategy that can re-invent green spaces in this city. In attempt to provide solution to this, Lagos State Government established the Lagos State Parks and Gardens Agency (LASPARK) in 2011 as a parastatal under the State Ministry of Environment for the purpose of improving the quality of the environment through tree planting and maintenance of open spaces, design and beautification of open spaces and monitoring, and enforcement of compliance to protection of the existing stock of GI in the State (Dipeolu, 2017).

Consequently, the efforts of LASPARK have brought about the availability of all the four categories of GI (green, tree, water and other spaces GI) in the study area. Green spaces GI are basically of green features and mostly plant materials (such as grasses, gardens, parks, city farms and sports fields), tree GI are mostly of tree features and their assemblage (such as street trees, community forest, woodlands and horticultures). Water GI are those of water/aquatic ecosystems (such as streams, rivers, lake, floodplains and fountains), other spaces GI are those GI cannot be categorized into any of the earlier mentioned group (such as open spaces, permeable pavement, school yards and cemetery). Presently, it is not uncommon to notice street trees on major high ways in Lagos Metropolis (Figure 3) creating rhythm and serenity to observers. Also, initial slum areas in Lagos have been planted with green plants to create parks and gardens for recreation and public gathering (Figure 4). Most of these gardens are well maintained with green grasses, trees and water bodies thus creating environment that is cool, aesthetically pleasing and habitable.

Figure 1: Map of Nigeria showing the location of Lagos in south-western Nigeria
Source: Federal Ministry of Environment, Maps Department, Abuja.

Figure 2: Map of Metropolitan Lagos State Showing the 16 Local Government Areas.
Source: Lagos State Ministry of Environment

Figure 3: Pictorial view of street trees along Ikoyi road, Victoria Island, Lagos State.

Figure 4: Pictorial view of a green garden at Ojota, Kosofe LGA, Lagos State.

2.2 Data Collection

The data presented in this paper were sourced from authors field-work in a survey conducted between the months of March and July 2017. Totally, 1560 residents participated in the study. Participants were household heads or adult representative who can and were willing to provide the needed information.

To ensure the validity of findings of this study, the questionnaire instrument used was pre-tested in an unselected Local Government area of Lagos Metropolis and feedback incorporated into the final version of the questionnaire administered to the residents. Multi-stage sampling techniques were used in the administration of the questionnaire. First, a random sampling technique was used in selecting 4 LGAs (25%) from the 16 LGAs in the sampling frame, which was followed by another random sampling of Enumeration Areas (EAs) in the four sampled LGAs. This was achieved through the collection of list and maps of Enumeration Areas in Lagos Metropolis from the Lagos State National Population Commission (NPC). At the second stage, in each EA, households were systematically sampled from the list of numbered houses (households) until the required number allocated to the EAs was reached. For the third stage, a questionnaire was given to every consenting household head to fill. A total of 1620 questionnaires were administered from which 1560 (96.3%) were retrieved. Questions were structured to elicit responses on socio-demographic characteristics of participants such as age, marital status, household size, highest education qualifications among others and issues relating to availability of green infrastructure in their neighbourhood such as type of GI present in their neighbourhood, the location of the GI facility, reasons why they visit GI facilities/sites, distance of GI facilities to their place of residence, evaluation of government supports for GI development in their neighbourhood and the type of support they expected from the government. Others questions were on the type of housing and the type of residential neighbourhood of respondents. The data were analyzed using both descriptive and inferential statistics and findings are presented in the subsequent section of the paper.

2.3 Data Analysis

2.3.1 Socio-demographic characteristics of the respondents

Nearly half of the participants (48.2%) were aged 30-49 years old while only 12.1% of the participants were 50 years or older. Participants were mostly male (58.6%) living in household comprising of two-four (46.9%) and more than four (41.9%) persons per household. Also, 54.7% were currently married at the time of the study, whereas 37.9% were not yet married and 4.0% were previously married but now separated or divorced. More than half of the participants (62.1%) had tertiary education while only few (5.4%) have no formal education. Some participants (31.0%) were management staff/business owners, while 26.3% were junior staff and 14.3% were senior staff in either civil services or private companies (Table 1).

2.3.2 Socio-demographic factors associated with visit to GI facilities

To further investigate other issues related to the objective of this study, chi-square test was carried out to assess participants' socio-demographic characteristics in relation to their reasons for visiting the available GI facilities in Lagos Metropolis. Chi-square test was employed based on the nature of data generated by the study and to also be able to select among others, those factors that motivate the residents toward the use of GI facilities in Lagos Metropolis.

In Table 2, compared with any other household size, the proportion of participants visiting GI for spiritual exercise was significantly higher among those with only one person (29.5%; p=0.020) in the household while the proportion visiting GI due to joblessness was significantly higher among participants with two-four persons in the household (53.8%; p=0.020). Similarly, the proportion visiting GI sites for relaxation was significantly higher among respondents with more than four persons in the household (27.9%; p=0.020).On the other hand, among participants with only one person in the household, proportion visiting GI due to joblessness (50.0%) was significantly higher than any other reasons for visiting GI facilities. Actually, joblessness accounted for the major reasons why people visit GI facilities in the study area (Table 2).

Also, results from the rank in occupation/income level shows that the proportion of participants visiting GI for spiritual exercise was significantly higher among management staff/business owners (30.2%; p=0.007) while the proportion visiting GI due to joblessness was significantly higher among the junior staff participants (54.9%; p=0.007). Similarly, the proportion visiting GI sites for relaxation was significantly higher among respondents who are senior staff in their various organisations (28.6%; p=0.007). Proportion of participants visiting GI due to joblessness continued to be significantly higher (54.9%) than any other reasons for visiting GI facilities. So, joblessness can be confirmed to be the major reasons why people visit GI facilities in the study area.

Table 1: Socio-demographics Characteristics of Respondents N=1560

Variables	Frequency	Percentage (%)
Sex		
Male	914	58.6
Female	646	41.4
Current age		
<30	587	37.6
30-49	752	48.2
>=50	189	12.1
Not Reported	32	2.1
Marital Status		
Never Married (Single)	592	37.9
Married	896	57.4
Previously Married	62	4.0
Not Reported	10	0.6
Household Size		
One person	166	10.6
Two-four Persons	731	46.9
More than Four Person	654	41.9
Not Reported	9	0.6
Religious Affiliations		
Christianity	1004	64.4
Islam	471	30.2
Others	80	5.1
Not Reported	5	0.3
Ethnic group		
Yoruba	1102	70.6
Others	457	29.3
Not Reported	1	0.1
Highest Educational Qualification		
No Formal Education	84	5.4
Primary Education	108	6.9
Secondary / Technical Education	395	25.3
Tertiary Education	968	62.1
Not Reported	5	0.3
Profession		
Unemployed	173	11.1
Self employed	704	45.1
Private/Public employee	439	28.1
Students and Others	244	15.6
Rank in Occupation / Income level		
Junior Staff	410	26.3
Senior Staff	223	14.3
Management staff/ Business owners	483	31.0
Not Reported	444	28.5

Source: Authors' field work, 2017

Table 2: Socio-demographic factors associated with visit to GI facilities

	Reasons for visiting Green Infrastructure sites				
Socio-demographic Characteristics	**For Relaxatn/Rec. Purpose**	**Because I am Jobless**	**For Spiritual Exercises**	**Chi-square**	**P value**
Sex				1.92	0.384
Male	239(24.7)	474(48.9)	256(26.4)		
Female	161(24.1)	348(52.1)	159(23.8)		
Age				2.51	0.643
<30	142(23.8)	312(52.3)	142(23.8)		
30-49	201(24.9)	395(49.0)	210(26.1)		
>=50	47(23.3)	98(48.5)	57(28.2)		
Marital Status				8.39	0.780
Never married (Single)	139(23.0)	325(53.7)	141(23.3)		
Married	237(24.7)	470(49.0)	252(26.3)		
Formally married	19(30.2)	23(36.5)	21(33.3)		
Household size				11.66	0.020*
One person	34(20.5)	83(50.0)	49(29.5)		
2-4 persons	168(22.0)	411(53.8)	185(24.2)		
>4 persons	194(27.9)	324(46.6)	178(25.6)		
Religious Affiliations				6.35	0.175
Christianity	241(22.8)	550(52.1)	265(25.1)		
Islam	137(27.7)	233(47.2)	124(25.1)		
Others	19(23.5)	37(45.7)	25(30.9)		
Ethnic group				2.16	0.340
Yoruba	294(25.3)	582(50.1)	285(24.5)		
Others	106(22.4)	239(50.4)	129(27.2)		
Highest educational qualifications				7.45	0.281
No Formal Education	19(22.9)	40(48.2)	24(28.9)		
Primary Education	35(32.4)	45(41.7)	28(25.9)		
Secondary/Tech. Education	105(26.6)	198(50.1)	92(23.3)		
Tertiary Education	241(23.0)	535(51.1)	270(25.8)		
Profession				3.64	0.934
Unemployed	42(24.0)	86(49.1)	46(26.3)		
Self employed	174(24.8)	353(50.2)	172(24.5)		
Private/Public employees	132(25.5)	249(48.1)	135(26.1)		
Students and Others	52(20.8)	134(53.6)	62(24.8)		
Rank in occupation				17.83	0.007*
Junior staff	103(23.7)	239(54.9)	89(20.5)		
Senior staff	71(28.6)	121(48.8)	56(22.6)		
Management staff/ business owners	115(22.7)	235(46.4)	153(30.2)		

Source: Author's field survey, 2017

2.3.3 Evaluation of Government Supports for the Development of GI in the Study Area

Figures 5 and 6 are the result of the residents' evaluation of government supports for the development of GI in Lagos Metropolis. Specifically, majority (34%) of the residents rated present supports for GI facilities by the government to be average. While 26% of the residents rated government support to be low and only 14% rated government supports for GI in Lagos Metropolis to be high. Also, despite the high reported score of 28% for technical supports, the residents highly reported (39%) that they expect more financial commitments from the government than provision of free seeds (15%) and free lands (12%) respectively.

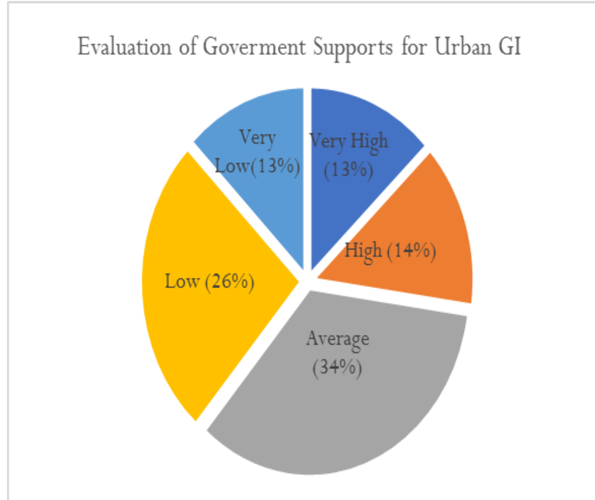

Figure 5: Government Supports for Urban GI in Lagos Metropolis.

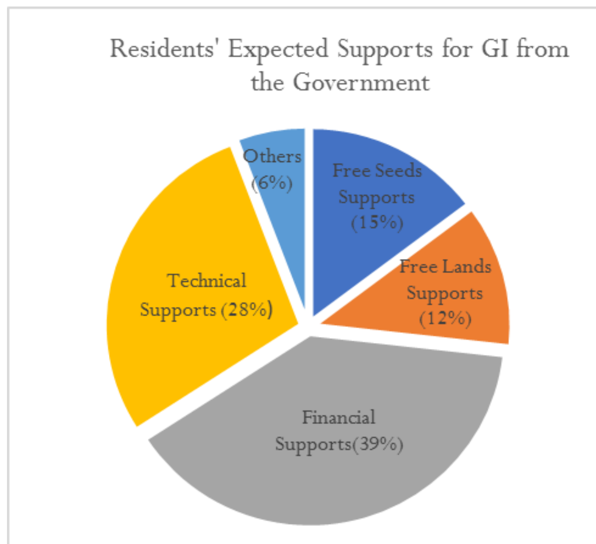

Figure 6: Expected Government Supports by Lagos Metropolis

3. Discussion

This study is an attempt at assessing the socio-demographic factors associated with visit to GI facilities/sites in Lagos Metropolis. Previous study like that of Riaz, Batool, Younas and Abid (2002), emphasized that socio-economic characteristics such as gender, age, education and occupation of the respondents play very important role in the determination of human attitude towards the use of green spaces and realities of life. However, findings from the present study indicated that *household size* and *rank in occupation* are the two major socio-demographic factor associated with visit to GI facilities in the study area. This suggests that diversified recreational facilities that can be more useful for households or family recreation should be set up, and that a multifunctional facility should be developed, such as the provision of more stone or wooden seats and tables for playing board games, reading, meeting friends, family discussions among others (De Vries *et al.,* 2003; Zhang, Chen, Sun & Bao, 2013). It also suggests that these facilities should be provided at different levels of operations so that all categories of residents (irrespective of their economic strength and rank in occupation) will find the facilities affordable and be very enthusiastic to pay and make use of the GI facilities at different levels. To achieve this, thoughtful designs fortified with adequate facilities are required to attract residents, encourage active participation and multiple users (Giles-Corti *et al.,* 2005).

In contrast to the evidence from previous studies, highest education attained did not emerge as a socio-demographic factor associated with visit to GI facilities in the survey. Whereas, education has been previously identified to be one of the most consistent predictors of positive environmental attitude. In fact, studies of Wall (1995), Ewert and Baker (2001) indicate that individuals with high levels of education tend to appreciate, visit and care more about green spaces in the environment than the less educated people. However, to a certain extent, the result of this study which shows that highest educational attained did not account for reasons why users visit GI facility sites, is consistent with the study by Maas et al. (2009) who concluded that the amount of available green space in the neighbourhood was less important for social contacts of high income people; residents with low income or low level of education benefit most from green space in their living environment.

This study also discovered that men visited and participated in the activities around GI facilities more than women. This result is in agreement with previous findings that differences exist with respect to the gender around green spaces: men shows different sensibility and expectations with respect to urban GI and the younger men are mostly driven by the wish to seek to escape from children interference in their busy schedules and therefore showing preference for the use of parks to meet friends and to rejuvenate from everyday stress. Women on the other hand, are more sensitive to safety and children facilities and will prefer to play with the children especially around the home compared to their male counterparts (Jahdi & Khanmohamadi, 2013; Conedera, 2015). In all, the findings show that environmental approaches to restore natural space in developing nations can have a positive impact on levels of use of the green space and on stewardship to the environment.

On government supports for green infrastructure development in Lagos Metropolis, the residents perceived that government supports for development of GI is still on the average. This may be due to the fact that while government is concentrating on provision of technical supports, tree seeds for planting, land provision and preparation; the public have not felt the impact of government supports or official development assistant by the government adequately in their neighbourhoods. They therefore perceived that if government make more funds available for the development of GI, the facilities will be more available and spread throughout Lagos Metropolis.

4. Conclusion and Recommendations

Green infrastructure has many roles and capacity to provide diverse benefits for cities and their residents (Venn & Niemelä, 2004). A number of empirical studies have indicated that urban residents, values urban green space as place to recuperate from physical, emotional and psychological illness, as well as overcoming stress (Takano *et al.,* 2002; Bonnes, *et al.,* 2011).
Overall, the results in the present study indicate that the degree of use of GI site in Lagos Metropolis is still very far from the purpose for which the facilities are provided. Although, some of the participants still visit GI facilities for the purpose of relaxation and recreation, a large majority of the respondents mentioned that they visit due to joblessness and for spiritual exercises. However, a correct use of the facilities would yield health benefits such as feeling of freshness, mental relaxation, and opportunity for body exercises, early recovery from illness, quality air and control of micro-climate (Benedict & McMahon 2006; Jahdi & Khanmohamadi, 2013; Dipeolu, 2015). Green infrastructure within residential neighbourhoods provides a place of contact between people and nature, increases the potential of meeting neighbours, developing sense of community and enables social well-being and social inclusion, among various categories of users (Germann-Chiari & Seeland, 2004; Seeland *et al.,* 2009; Conedera et al., 2015). It is concluded that GI makes the quality of life better by improving health and creating functional environment through environmental, social and economic impacts. So, a correct use and attitude toward the facilities should be encouraged among residents. The study however makes the following recommendations:

(1) That, the Lagos State government should allow GI facilities to enhance more opportunity for job generation. This could be achieved from the planning stages of implementing GI projects. The project should be planned to generate jobs for residents especially those in the field of built environment. Workers in horticulture, plant scientist, landscape architects and artisans in carpentry, masons, and iron benders can also be employed to carve appropriate shapes and implement professional designs on GI sites. Others that can also benefit from establishment of GI facilities are the tax officers, administrative staff, security and guards that manage the affairs and security of the facilities.

(2) More public orientation on attitude toward use of GI facilities should be emphasized by the government. This could be achieved through various media organisations and public lectures regularly organised for the citizens so that they can be well equipped with needed information and understanding of the benefits and usefulness of GI facilities. This understanding will have capacity to develop in resident's correct and positive environmental attitude in citizens which gradually affect their use and care for GI facilities in their neighbourhood.

(3) There is need for more financial commitment by the government to environmental greening projects in Nigeria. This will allow every department related to environmental designs to have more resources to implement green infrastructure projects and consequently spread GI sites across the nation. As environmental greening is encouraged in the nation through

these recommendations, challenges related to environmental sustainability can be sufficiently tackled.

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Glass Curtain Wall Technology and Sustainability in Commercial Buildings in Auckland, New Zealand

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ABSTRACT

Glass curtain wall provides an attractive building envelope, but it is generally regarded as unsustainable because of the high energy needed to maintain thermal comfort. This research explores the advances in the technology of glass cladding and the complex issues associated with judging its sustainability. It assesses the technology and sustainability of glass curtain wall on a sample of thirty commercial buildings in Auckland, New Zealand. Field observations of the glass-clad buildings, coupled with surveys of the building occupants and of glass cladding professionals are used to investigate the cladding characteristics, operational performance, sustainability aspects and future trends. The majority of the sample buildings are low-rise office buildings. The occupants like the aesthetics and indoor environment quality of their glass-clad buildings. However, continuous heating, ventilation and air conditioning are needed in order to maintain thermal comfort within the buildings and this has high energy consumption. The increasing use of unitized systems with double glazing instead of stick-built systems with single glazing improves the sustainability of the cladding through less material wastage and better energy efficiency. Inclusion of photovoltaic modules in the curtain wall also improves energy efficiency but it is currently too expensive for use in New Zealand. Environmental sustainability is also improved when factors such as climate, the orientation of glazed façades, solar control, ventilation and the interior building layout are considered. Any assessment of glass curtain wall sustainability needs to consider the economic and social aspects as well as the environmental aspects such as energy use.

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1. Introduction

Glass curtain wall (GCW) is a popular cladding material and is commonly used on iconic commercial buildings worldwide. It gives the exterior view of the building a pleasing, glossy appearance and the occupants enjoy the view outside and the bright interior that comes from penetration of sunlight inside the building. However, these properties come with some disadvantages. Firstly, in the construction phase of a building, GCW is a relatively expensive form of cladding that needs skilled installation. Secondly, in the operating phase of the building, the heating ventilation and air conditioning (HVAC) costs are high because they need to counteract the effects of solar radiation penetrating the glass. The attempts of the construction sector to become increasingly sustainable means that attention is being focused on the greater energy use for the HVAC systems in GCW buildings. New types of glass and new GCW systems are being developed to improve the energy efficiency of GCW buildings but these innovations are expensive and not necessarily more sustainable over the building life cycle. Finally, the occupants' perspective on GCW buildings is very important since it is related to occupant productivity and the cost of occupant salaries is much greater than the HVAC energy costs during the operation of the building.

GCW was first used in New Zealand in the early 1980s, with the first three buildings located in Auckland (Bennett, 1987), a city of about 1.6 million people that covers an area of 531 square kilometers and has a temperate climate. Standard GCW is unsuitable for buildings in earthquake-prone regions but although earthquakes are common in New Zealand, Auckland is a region with little seismic activity. Consequently the density of buildings with GCW is higher in Auckland than in other New Zealand cities.

This research reviews the published studies on the technology and sustainability of GCW and summarizes the findings in sections 1.1 and 1.2. It then assesses GCW in New Zealand using a case study of thirty commercial buildings with glazed façades in Auckland's central business district. The technology of the GCW is based on identification of the building characteristics (curtain wall system, glass type, building use, age, size and maintenance). The sustainability of the GCW is examined using the occupants' perspectives on their buildings and the opinions of industry experts on the use of GCW in New Zealand. The expected future use of this type of façade in Auckland is discussed in the context of its sustainability.

1.1 The Technology of GCW systems

There are several different GCW systems including the stick-built, unitized and frameless systems (Bedon and Amadio, 2018; Mehta, Scarborough and Armpriest, 2018). The stick-built system was the earliest GCW system with a metal framework of vertical mullions and horizontal transoms attached to the building and supporting glass panels. This was followed by the unitized system, where preassembled modular units of glass in aluminium or steel frames are interlocked with adjacent units and fixed to the building with rigid brackets. Frameless GCWs are relatively new and aim to give the outside view of the building the appearance of continuous glass, unbroken by frame elements. The three most common types of frameless GCWs are metal structure supported (MSS) GCW, Suspended Glass Assemblies (SGA's) and cable net supported (CNS) GCW (Mehta et al., 2018).

The choice of curtain wall system and materials has a significant impact on the aesthetics of a building and can account for 15-25% of total construction costs. There is a high risk associated with innovative GCW systems so that designers tend to favour GCW systems they are familiar with and those that have the most secure warranties and technical backup (Kassem, Dawood and Mitchell, 2012).

Aside from the system classification above, GCWs can have many different characteristics such as place of assembly, curtain wall function (for example fire rated or blast resistant), glass type (for example reflective, low emissivity), glass attachment, glass configuration (single pane, double skin, freeform) and curtain wall heat transfer performance (for example, with the inclusion of thermal breaks). These are discussed in Pariafsai (2016) and Kazmierczak (2010). The latter also gives the common performance failures for GCWs such as poor heat flow (causing condensation), glare, inadequate noise control, moisture leakage, glass breakage, falling curtain wall components and cosmetic defects (in the glass itself, in the coatings, from corrosion or from poor maintenance). In addition to these, the local climate has to be considered when making the decision to use GCW; they may not be appropriate for certain buildings in tropical climates. For example, in Singapore many residential condominiums have GCWs that have very high electricity costs, excessive glare and poor privacy (Maheswaran and Zi, 2007). Simmler and Binder (2008) discuss the use of venetian blinds to offset the overheating problems that are common with unshaded glazed buildings.

GCW has two conflicting requirements; it should allow as much natural light into the building as possible while at the same time having minimal heat transfer across the building envelope. Glass has generally poor thermal performance characteristics – it transfers heat into and out of the building readily so that GCWs tend to have a significant effect on building operation costs and energy efficiency (Cuce, Cuce and Young 2016; Kassem et al., 2012). The greater the area of glass the worse the problem (Cuce, Young and Riffat, 2015a) and the higher the frame ratio (area of the metal frame/area of the GCW) the greater the heat transfer and the poorer the thermal performance of the curtain wall (Bae, Oh and Kim, 2015).

The heat transmission (or U-value) of a single pane of clear glass is about 5.8 W/m^2K. Double glazing with argon in the gap and low emissivity glass has a U-value of 1.1 W/m^2K, meaning that its heat transfer is only about one fifth of that for single clear glass panes. Thus, with considerably increased cost, a GCW can have acceptable thermal performance. However, when light transfer is considered the picture changes. A single pane of clear glass in a room transmits about 85% of incoming solar radiation to the inside of the room. It reflects about 10% and it absorbs about 5%. The absorbed radiation makes the glass hot so that it becomes a low temperature radiator; it transmits heat (by radiation and convection) to each of its faces. The proportion transmitted to each face depends on the face temperature – the lower the face temperature, the greater the proportion of heat transmitted to it. If both faces of the glass are at the same temperature, then 50% of the absorbed 5% radiation (i.e. 2.5%) is radiated inside the room so that a total of 87.5% of the incoming solar radiation goes into the room. In practice it is slightly worse than this because for a cooler exterior, the outside surface is cooler and more heat is transferred out of the building while, for a hotter exterior, the inner surface is cooler and more heat is transferred into the building. Expressed as a fraction, the solar radiation transmissivity of a single pane of clear glass is 0.87 (Bouden, 2007; Mehta et al., 2018). By comparison, the solar radiation transmissivity of double glazing with argon in the gap and low emissivity glass is 0.64 (Manz, 2004) i.e. about 75 percent that of a single pane of clear glass.

Tinting the glass makes it absorb more heat (which it will then re-radiate); it does not change the U-value of the glass but it does lower the amount of light transmitted through the glass (Mehta et al., 2018). People are particularly sensitive to radiant heat, so although sunlight passing through tinted glass does not heat the room up much, it makes the occupants feel hot (Baggs, 2016). Applying a reflective coating to the glass lowers the transmissivity, for example to 0.12 for double glazing with an air gap and reflective coating but this has poorer thermal transfer (a U-value of 2.3 W/m^2K) and potentially unacceptable glare on neighbouring buildings (Manz, 2004). In summary, there is a trade-off between U-value, transparency and radiant heat; the lower the U-value (and heat transfer), the less transparent the glass (Cuce et al., 2015a) and the greater the re-radiated heat, with implications on GCW cost, building operation costs and occupant comfort.

The main innovation in GCW systems is building integrated photovoltaics (BIPVs), i.e. the inclusion of semi-transparent photovoltaic (PV) modules in those parts of the glass façade that get the most sunlight in order to generate power (Young, Chen and Chen, 2014). This has led to the production of heat insulation solar glass (HISG) – a glass product that can generate electricity (like photovoltaic panels), has good thermal insulation (a U-value of 1.1 W/m2K), is self-cleaning, aesthetic and has good acoustic properties. It only transmits a small fraction of the visible light (7%) instead of 87% for ordinary clear glass. HISG glass curtain walls have 100% ultraviolet light blocking rate, which is important for occupants' health. Additionally, thermal radiation problems are greatly reduced (Cuce, Riffat and Young, 2015b). There are also double skin modular facade systems with glass and photovoltaic panels – the latter folded into various configurations (saw tooth, multi-fold/faceted geometries) to increase the PV area (Hachem and Elsayed, 2016). Folded facades have greater heating loads (a disadvantage) but this is compensated by their smaller cooling loads as well as some electricity generation.

There have also been innovations in the design of GCW itself. With specialized design of the connectors GCWs can withstand seismic and blast events (Bedon and Amadio, 2018). Standard glass used in GCWs does not behave well in a fire. Fire resistant glazing behaves better providing all the component parts (glazing seals, beads, fixings, and frame) are appropriately designed and specified – but the cost is too great for common use (Bedon, 2017). Interactive glass façades with automated blind systems, new electrochromic glazings, automated dimmable lighting and smart lighting and HVAC controls are discussed in Selkowitz, Lee and Aschehoug (2003) and these may help minimize some of the problems with GCWs. Despite these innovations, glass claddings do not currently perform as well as opaque materials (such as concrete and brick) in terms of heat transfer, sound transfer, fire resistance and blast resistance (Kazmierczak, 2010).

1.2 The Sustainability of GCW

The concept of sustainability originally meant ensuring that present actions did not compromise future actions. Economic, social and environmental factors contributed equally to sustainability and each of these factors was assessed over an entire life cycle (which, in the case of a building façade, includes the design, construction, operation, demolition and waste treatment phases). In the 21st Century, attention has focussed on the environmental factors which include components such as use of energy and water, indoor environment quality (IEQ) and emission of pollutants such as greenhouse gases.

As one of the largest users of environmental resources and a significant polluter of the environment, the construction sector is under pressure to improve its sustainability. Any improvement needs to be quantified, and global green ratings for buildings are commonly used as the assessment tool. There are many of these tools and they are reviewed in Ding (2008); the Building Research Establishment Environmental Assessment Method (BREEAM) is the most widely used assessment tool and New Zealand uses the Green Star rating tool. Within each tool, credits are awarded for a variety of environmental categories (energy use, IEQ, water use, emissions, etc.) with different weightings; the greatest credits that may be gained are for energy use and IEQ, while there are fewer credits for emissions. The total credits gained for a building are assumed to be an indication of its 'greenness' and higher green rating implies greater sustainability. Almost all of New Zealand's green rated office buildings have high proportions of unshaded glass facades (Byrd and Leardini, 2011) and the buildings are sealed and air-conditioned.

There are several problems with green rating tools and their link with sustainability. Firstly, the tools focus on the environmental aspects and ignore the economic and social aspects of sustainability. A building that is energy efficient may be green but it will also need to be comfortable, usable and durable in order to be sustainable (Kumar & Raheja, 2016). Secondly, there is no universal consensus on the weighting of the environmental categories (although energy use usually has the highest weighting) and whether the multi-dimensional assessment criteria provides an accurate measure of sustainability (Flemmer & Flemmer, 2005). Thirdly, green certification often happens at the design phase of the building but is not met in practice during the operation of the building where energy use is higher than expected and natural light use is lower than expected (Onyeizu 2014; Shameri, Alghoul, Elayeb et al., 2013). Fourthly, the link between green certification and environmental sustainability is somewhat tenuous; Byrd and Leardini (2011) show that New Zealand office buildings (mostly glass-clad) can get green certification while barely achieving the country's building code requirements for minimum energy performance. They suggest that green certification of buildings may be aimed more at commercial marketing than at genuine environmental sustainability and Flemmer and Flemmer (2005) suggest that the same is true for green certification of many products (other than buildings). Finally, green rating tools often fail to consider factors such as climate change and the availability of resources that affect the long term component of sustainability. In the New Zealand context, Byrd and Leardini (2011) predict that in the long term there will be increased temperatures due to global warming, greater energy required to cool buildings and increased likelihood of electricity shortages. The latter would make buildings with glazed envelopes uncomfortably warm. Consequently, they recommend that the energy weighting in green rating tools should be increased to reflect what is likely to be a global energy crisis.

Buildings with glazed envelopes are usually judged to be unsustainable (Butera, 2005), based primarily on high consumption of energy needed to maintain thermal comfort during the use of the building. Heat transfer through the GCW has improved over time (Arslan & Eren, 2014) and innovative skins with PV cells (Barkkume, 2007) are reducing the net energy consumption which implies improved sustainability over the operation of the building. However, Byrd and Leardini (2011) cite several studies suggesting that the improvements in energy efficiency are small and often unquantified. Finally, the operation of a building is just one phase of the building life cycle and it is important to look at total energy use (including embodied energy) over the entire life cycle before assessing the sustainability.

The daylighting through GCW is considered a positive aspect in its environmental assessment since it is linked to improved occupant productivity and to reduced need for artificial lighting (and its associated energy use). This is not always true; if the GCW has blue-green tinted glass (the most common tint) then the light transmitted through the façade is too cold (i.e. it has a high correlated colour temperature) and additional energy is used in artificial lighting to compensate for this (Butera, 2005). Moreover, researchers argue that daylighting can be provided thorough strategically placed windows rather than fully glazed envelopes (Kumar & Raheja, 2016) and that productivity itself is hard to assess (Onyeizu & Byrd, 2011).

It is apparent that judging the sustainability of GCW is complex. Focussing just on the environmental aspects and the operation phase of the building lifecycle there is consensus that GCW is not very sustainable but is 'more sustainable' when factors such as the climate, orientation of glazed facades, solar control, ventilation and the interior building layout are considered (Kumar & Raheja, 2016; Barkkume, 2007; Lim & Gu, 2007). There is however a need to consider the broader economic and social aspects of its sustainability. The economic aspects are obvious and include initial cost, running cost, rental revenue, etc. The fact that the economic calculus is positive is clearly demonstrated by the increased prevalence of GCW buildings. The social aspects can be complex and can themselves impact on the environmental and economic aspects. For example, there is a trend in big cities towards high-rise buildings which can alter the sunshine and wind patterns on neighbouring spaces (Al-Kodmany, 2016). Shading from neighbouring buildings may reduce energy generation in PV façades (Futcher, Mills, Emmanuel et al., 2017). Other factors such as heritage, transportation, public spaces, pedestrian comfort and safety may also contribute to the social impact of a high-rise building. Ultimately, buildings are made for people to use so an important factor in the social aspect of the sustainability of GCW is the opinion of the building occupants. Finally, the effects of climate change and availability of resources have a strong influence on the long-term sustainability of buildings with GCW.

2. Methodology

The purpose of the research was not to inventory all the glass clad buildings in Auckland, but rather to get a representative sample of such buildings and assess their characteristics. Accordingly, the researchers inspected the Auckland central business district (CBD) in March and April 2018 and identified a sample of thirty commercial buildings with GCW. The criteria for selection was that the buildings had glass cladding covering more than 80% of the façade and that the sample of thirty buildings had a wide range of heights, ages, glass cladding systems and building uses. The address, building business use and building characteristics (number of levels, glass cladding condition) were recorded. Visual inspection of the GCW was made (by the researchers) to assess the condition and this was expressed as 'Very Good' if the GCW appeared to be pristine, 'Good' if the GCW had some dirt build-up and 'Medium' if the GCW had dirt build-up and visible deterioration of the support frame or sealant.

Over the next four months, a staff person from each building, who knew about or was involved in the building operation was interviewed to get information on two aspects namely, the building construction and maintenance details (building age, glass type, cladding system, maintenance schedule and type of maintenance) and their opinion of the building functionality. The respondents consisted of four property management agents and twenty-six tenants (managers, administrators and receptionists). The age of construction was verified from Quotable Value Limited, a state-owned enterprise of the New Zealand government that records property details associated with value.

Two building professionals with at least 15 years' experience; one in GCW manufacture and one in GCW construction were selected from organizations with a relatively large market share of the industry. They were interviewed to gain insight into the New Zealand GCW industry.

3. Results and Discussion

Table 1 shows the characteristics of the 30 buildings, including their age, height, type of glass and cladding system. The GCW on all 30 buildings was maintained by washing and Table 1 shows the wash frequency, an assessment of the condition of the GCW and the building use.

Figure 1 shows the variation in the number of GCW buildings in Auckland's CBD with the stick-built system and the unitized system over time.

Table 2 shows the staff assessment of the operational performance of the sample of 30 glass clad buildings in terms of various operational factors.

Table 3 summarizes the staff opinion of their glass clad buildings from the sample of 30 buildings.

Table 1 Characteristics of GCW buildings in Auckland CBD showing number of buildings and percentage of the sample of 30 buildings

Characteristic	Number and percentage of sample buildings				
Construction date	1970-1979 2 (6.7%)	1980-1989 5 (16.7%)	1990-1999 8 (26.7%)	2000-2009 4 (13.3%)	After 2010 11 (36.7%)
Height	1-2 levels 12 (40.0%)	3-5 levels 10 (33.3%)	6-10 levels 7 (23.3%)	11-20 levels 0 (0%)	20+ levels 1 (3.3%)
Glass type	Single layer 26 (86.7%)	Double layer 4 (13.3%)	Tinted 19 (63.3%)	Reflective 4 (13.3%)	Not tinted or reflective 7 (23.3%)
Cladding system	Stick built 11 (36.7%)	Unitised 18 (60.0%)	SGA[1] 1 (3.3%)	SF[2] 1 (3.3%)	
Wash frequency	Once a month 2 (6.7%)	Once every 2-3 months 14 (46.7%)	Once every 4-6 months 10 (33.3%)	Once every 7-12 months 4 (13.3%)	
Condition	Very Good 12 (40.0%)	Good 16 (53.3%)	Medium[3] 2 (6.7%)		
Building use	Offices 27 (90.0%)	Educational 2 (6.7%)	Other (bus station) 1 (3.3%)		

Note that percentages do not always add to 100.0% because of round-off error

1: SGA Suspended glass assembly 2: SF Semi-frameless with sealant 3: constructed in 1970 and 1980 respectively

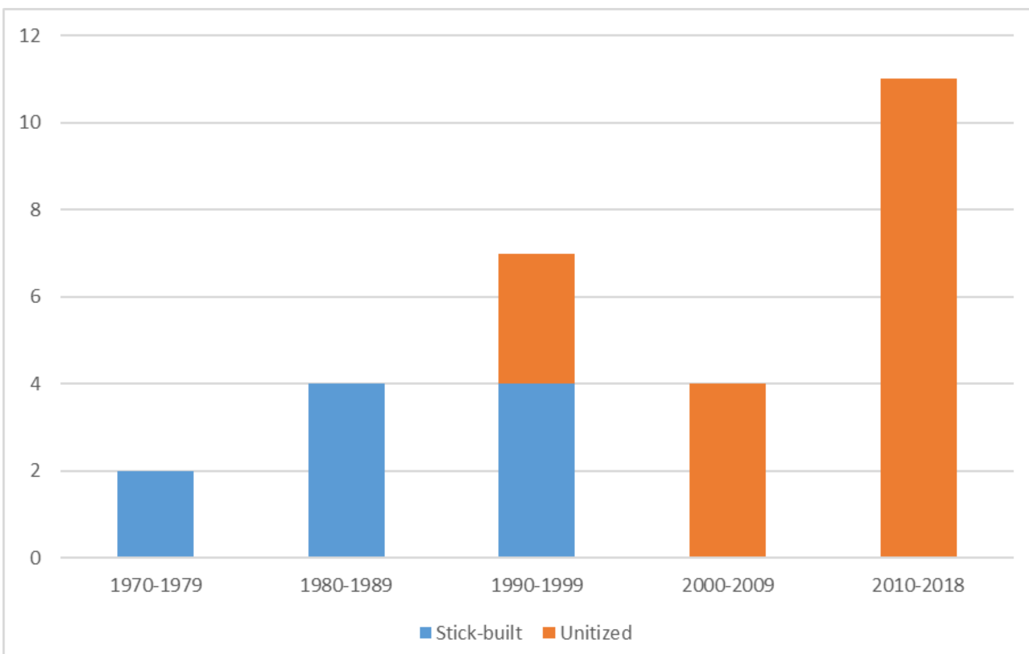

Figure 1 Variation in number of GCW buildings in Auckland's CBD having stick-built and unitized systems from 1970 to 2018

Table 2 Assessment of the operational performance of the sample of 30 buildings

Factor	Assessment, number and percentage of sample buildings			
Glare	Serious 1 (3.3%)	Acceptable 26 (86.7%)	Not noticed 3 (10.0%)	
Acoustic	Very good 14 (46.7%)	Good 16 (53.3%)	Medium 0 (0%)	Poor 0 (0%)
Thermal	Very good 3 (10.0%)	Good 22 (73.3%)	Medium 4 (13.3%)	Poor 1 (3.3%)
Impact on HVAC[1] expenditure	Large 2 (6.7%)	Medium 26 (86.7%)	Small 1 (3.3%)	None 1 (3.3%)
Use of HVAC system	All the time 30 (100.0%)	Only in summer 0 (0%)	Only in winter 0 (0%)	Never 0 (0%)

Note that percentages do not always add to 100.0% because of round-off error
1: HVAC Heating, ventilation and air conditioning

Table 3 Staff opinion of their GCW building

Staff preference for GCW?	Reason given
Yes: 28 (93.3%)	• Good view: 25 (83.3%) • Looks good/pretty/modern: 9 (30.0%) • Bright interior: 13 (43.3%)
No: 1 (3.3%)	• Poor thermal comfort: 1 (3.3%)
Indifferent: 1 (3.3%)	• No reason given: (3.3%)

Note that percentages preference does not add to 100.0% because of round-off error. The percentages listed for the reason for the preference may be greater than 100% because occupants could choose more than one reason.

Table 4 summarizes the information from the two GCW professionals from the New Zealand construction industry.

The results (Figure 1 and Table 1) show that the number of buildings in Auckland CBD with GCW is increasing. The earliest buildings used stick-built GCW systems, but modern buildings are increasingly using the unitized system. This finding was confirmed by the GCW professionals who noted that the unitized system is much quicker to install than the stick-built system. Other characteristics of the sample buildings showed the following:

- Most of the buildings are low rise, with 73% less than 6 storeys.
- Single glazing is used in 87% of the GCW systems and tinted glass is used in 63% of the GCW systems.
- 80% of the buildings use washing every 2-6 months to maintain the GCW and this agrees with the maintenance recommended by the GCW professionals.
- The visual assessment of the condition of the GCW is good or very good for 93% of the buildings and, as expected, the oldest buildings had the poorest GCW condition.
- 90% of the buildings were used as offices. This agrees with the observations made by the GCW professionals. Businesses that are concerned with corporate image can justify the expense of GCW cladding on their offices because of its significant aesthetic appeal. The design of buildings used for other purposes, such as educational facilities and bus stations, is likely to focus on less expensive, more utilitarian factors which is why GCW is less commonly used.

The staff/occupants of the buildings were mostly satisfied with the glare, acoustic performance and thermal performance of the buildings but the HVAC system was run all year round for all buildings and had a medium to high running cost (Table 2). The occupants liked the view, the aesthetics and the brightness of the GCW buildings and only one occupant suffered from thermal discomfort (Table 3). The value of these findings is limited by the small sample size; a larger sample of occupants from each building is needed before any general conclusions can be made.

The GCW professionals noted that a common misperception with GCW is that natural ventilation (i.e. ventilation from an open window) is problematic (Table 4). They confirmed that for low rise buildings, which are common in Auckland, it is easy to incorporate windows into the GCW system. Other findings from the GCW professionals were:

- Thermal performance and glare in GCW can be controlled with double glazing and specialized glass (such as low emissivity glass or reflective glass).
- GCW has acceptable seismic performance providing it has been appropriately designed and engineered.
- Research into GCW is focused on using BIPV to generate energy to partially offset the high HVAC use. In New Zealand, this is currently too expensive for practical use but is likely to be used in the future.

Table 4 Summary of information from GCW manufacturer and GCW installer

GCW Aspect	Information
Type of GCW used in New Zealand and current trends	• The older stick-built system is not used much now; 90% of current projects use the unitized system. • The unitized system has much quicker installation than the stick-built system. • Frameless GCW is mostly used in New Zealand for ground floor/shop front applications. In other countries it is used on high rise buildings but it costs 50-60% more than unitized GCW so it is very uncommon on high rise buildings in New Zealand where the construction sector prefers low-cost construction.
Provenance	• The glass is imported; the rest of the system is made in New Zealand.
Building Use	• GCW is mostly used for commercial offices and for some educational institutions.
Durability	• The average service life is 20-25 years but if the recommended maintenance is done GCW can last 70 years.
Maintenance	• Recommended maintenance is washing every 3 to 6 months. • More frequent washing is needed in coastal or industrial environments.
Energy efficiency & thermal performance	• Single glazing is less expensive than double glazing but is not very energy efficient and is being used less on new projects. • Double glazing with argon in the space between panes performs well. • Low emission glass and reflective coatings can improve thermal performance and reduce interior glare.
Ventilation	• There is a perception that natural ventilation (opening windows) is hard to incorporate in GCW. This is only true for high rise buildings. • Most buildings in Auckland that use GCW are low rise and it is easy to incorporate windows in the curtain wall.
Seismic performance	• As long as the GCW is well designed and engineered it has satisfactory seismic performance. • Auckland is a region with low seismic activity but buildings with GCW in Wellington and Christchurch (which have high seismic activity) perform well.
Sustainability	• Prefabrication of unitized GCW reduces the wasted product. • Glass is recyclable.
Future trends in GCW	• Advanced GCW technology is being developed worldwide. • GCW research aims at balancing the advantage of light penetration with the disadvantage of high HVAC use from solar radiation. • Incorporating photovoltaic systems into the glass is a way to generate energy which can be used to offset the HVAC energy requirements. Heat insulation solar glass (HISG) is one such product. In New Zealand it is called Building Integrated Photovoltaics (BIPV). It is not currently used as it is too expensive but it may be used in the future.

4. Conclusions

In Auckland, buildings with GCW tend to be low rise (less than 6 storeys) and are primarily used for offices. Low-cost GCW with single glazing dominates the sample buildings and there is a trend showing the declining use of stick-built systems with a concurrent increase in the use of unitized systems. Correct maintenance (washing every 2-6 months) is used in most of the buildings and the GCW condition is good.

The sustainability of GCW is a complex issue. From an energy perspective, GCW is generally viewed as having poor performance; continuous HVAC operation is needed to offset the effects of incoming radiation in order to maintain thermal comfort within the building. This is energy intensive and it is likely that double glazing will steadily replace single glazing in new GCW construction in an effort to save energy. The inclusion of photovoltaic modules in parts of the glass façade that get the most sunlight in order to generate power is another way to improve GCW energy efficiency, but it is currently too expensive for use in Auckland.

A complete assessment of sustainability needs to include economic, social and environmental factors and each of these factors needs to be assessed over the entire life cycle of the

GCW. An important part of the social aspect is the occupants' perspective. In the case study, most occupants seem to like their GCW buildings, in terms of both building aesthetics and building performance.

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Psychometric Testing of Shopping Mall Universal Design Assessment Tool (SM-UD)

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ABSTRACT

While there are people with disability live in Kurdish parts of Iraq, a very limited number of buildings are properly designed to serve these people. Considering the challenges that people with disability face in public buildings, the United Nations has recommended the implementation of the Universal Design (UD) principles in public buildings in Iraq to ensure that all people could have access to the public buildings regardless of their abilities and backgrounds. Hence, there is a need to gather pertinent data by assessing the adherence of shopping malls in this part of Iraq to the Universal Design (UD) principles given the role of the facilities to the locals. The present study aims to develop a tool for assessing whether the shopping malls in Sulaymaniyah city adhere to Universal Design principles. An analytical tool, which was abbreviated as SM-UD, was developed using a wide range of shopping mall design elements. The tool was tested for reliability and validity through several statistical tests. Besides, the tool was tested for practicality and communicability in six different shopping malls of Sulaymaniyah. The reliability and validity test indicate that the majority of items showed good to excellent reliability and fair to excellent validity. The results of using the tool show that it is capable of identifying the drawbacks of shopping malls in terms of their universality of design. The proposed tool appears ready to be used by shopping malls' managers and researchers.

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1. Introduction

More than 1 billion people around the world suffer from various types of disability WHO (2013). This equals to nearly 15% of the world's population. Countries like Iraq involved in several wars in the two recent decades. Thus, the higher number of People with Disability (PWDs) is expected in different parts of this country. Over 100 thousand PWDs live in Kurdish part of Iraq (European Network on Independent Living 2018). A recent report by the United Nations Assistance Mission for Iraq (UNAMI 2016) determined the PWDs challenges in Iraq and proposed a number of solutions to alleviate the PWDs daily challenges.

This report considered the huge number of PWDs in Iraq as a serious issue and emphasized on the necessity of implication of implication of Universal Design (UD) across the Iraq to ensure the accessibility of different places to the PWDs.

Broadly speaking, UD is a design concept that attempts to accommodate a broader range of users irrespective of their backgrounds and abilities (Baer, Bhushan et al. 2016). Despite the development of several UD guidelines across the globe, very limited number of assessment tools are available which measure the adherences of the built environments to the UD principles. Several public places such as malls, parks, hospitals, and so on are needed to be inspected to ensure these places are suitable for PWDs, children, and seniors.

Shopping mall is an important part of urban life in cities of developing countries. There are several shopping malls in the Kurdish part of Iraq, which have not been assessed for adherence to the UD principles. Literature also confirms that, to date, there is no systematic approach to assess the suitability of shopping malls in Iraq, particularly the Kurdish Part (Jalil Abdullah and Jian 2019). This paper presents a part of wider research endeavor to leverage the use of UD in the design and assessment of shopping malls in Kurdish part of Iraq. The authors identified and confirmed the contributory design factors of shopping malls to the UD principles in Jalil Abdullah and Jian (2019). In this paper, the authors aim to illustrate the development process of a tool for assessing the shopping malls in Kurdish part of Iraq based on UD concept. This paper is structured as follows. The next section reviews definition and its principles of the UD and its translation into the shopping complex design criteria, reviews the existing design guidelines and standards of the UD in shopping malls, and the design factors of shopping malls. In method section, the mathematical modeling and case study are presented. We conclude the paper with some discussions and recommendations for future research.

2. Background

Story (1998) defined the Universal Design as the "design of products and environments that can be used and experienced by people of all ages and abilities, to the greatest extent possible, without adaptation". The UD has seven main principles, including equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and use. However, implementation of these principles in practice is complicated (Story, Mueller et al. 1998).
UD has been applied in several fields of research, including but not restricted to education, production, and built environment design. Although more than two decades is passed from the proposing UD for different purposes, a very limited number of tools have been developed for assessing the adherence of the design or products to the UD principles. Stephanidis, Akoumianakis et al. (1998) proposed guidelines that were subsequently translated into key development requirements which were preserved in user interface development tools for them to provide the required support for building user interface software for different users and contexts of use. Lenker, Nasarwanji et al. (2011) developed the Rapid Assessment of Product Usability & Universal Design (RAPUUD), a 12-item user-report tool based on the principles of universal design. Oh (2015) developed the design evaluation tool and guidelines of universal design for applying to the design of different spaces, including residential space, educational space, working space, and cultural space.

Concerning education, Fogarty (2017) proposed a clinical practice assessment tool to create access and equity for all students.
The body of literature is extremely thin regarding the implementation of UD in shopping malls. A number of studies attempted to identify problems of the application of restroom facilities, entrance and circulation facilities, and signage system to produce alternative solutions to those problems based on UD in the shopping centers of Surabaya, Indonesia (Kusumarini, de Yong et al. 2012, Kusumarini, de Yong et al. 2012, Kusumarini, de Yong et al. 2012). These studies used qualitative research and design thinking approach to assess the shopping malls. However, the qualitative approach of these studies might result in subjective assessment. Afacan and Erbug (2009) proposed a framework to heuristically evaluate the adherence of shopping malls to the UD principles. However, their proposed method was complicated and time-consuming.

More recently, Jalil Abdullah and Jian (2019) translated the general definition of UD into the shopping mall design criteria. In their translation, the shopping malls should be design in a way to accommodate all shoppers and visitors regardless of their backgrounds and abilities. Besides, the design of shopping malls should provide the shoppers with a usable, safe, and comfortable environment to the shoppers. They also used a structural equation modelling (SEM) to identify the most important shopping mall design factors based on UD. These factors are used in the present study to develop an easy to follow tool for assessing the adherence of the shopping malls to the UD principles.

Many countries around the world set the rules which ask the authorities of the public places follow the Universal Design principles. For example, the government of Dubai provides a detailed UD guideline in terms of built environment and transportation facilities (Dubai 2017). This UD guideline defines how the built environment and transportation systems in the Emirate should be designed, constructed and managed to enable one to approach, enter, use, egress from and evacuate independently, in an equitable and dignified manner, to the greatest extent possible, in line with the Universal Design concept. Many other countries across the globe also provide the same regulations and codes to the architectures, practitioners, and managers to serve all people regardless of their abilities and backgrounds.

More recently, the universal design principles have established in South Korea as a fundamental basis in developing and designing elderly residential houses, public spaces and public facilities. The knowledge of diversity for people especially in disability and elderly have been affected by universal design principles. The Universal Design removes all obstructions and encourages people to live, use and access all facilities easily without any barrier (Harsritanto, 2016).

Malaysian has also shown some development in catering to the need of persons with disabilities (PWD). Nevertheless, as appealed by Kamal Malhotra, the United Nations Resident Coordinator, in the National Conferences on "Accessibility and Universal Design: Implications for Public Transport and the Built Environment", yet, there is the need to efficiently implement universal design in Malaysia, the need for more professionals or researchers in this area, and the need to revisit the current standards codes. Thus, their study was called to enhance and complement the precedent studies that have been done on Malaysia accessibility issues and universal design implementation in public buildings (Kadir and Jamaludin 2012).

In recent years, in order to confirm the universal design and increased accessibility, many acts and regulations have been amended in Norway. The action plan is intended to support the implementation of the new Anti-Discrimination and Accessibility Act, new Planning and Building Act and other new legislation dealing with universal design. The action plan is also intended to help meet Norway's obligations when Norway ratifies the UN Convention on the Rights of People with disabilities. The government's vision that Norway is to be universally designed by 2025 can be achieved using various instruments that are adapted to suit the various sectors and tasks. Goals that are subject to deadlines are used (EQUALITY 2009).

3. Method

3.1 Design Factors

As pointed out earlier, the present paper is an extension of previous work aimed at translating the general definition of UD into the shopping mall design criteria and identifying the most important design factors of shopping malls based on UD principles, in a Kurdish context.

The authors conducted a literature review to first, translate the general definition of UD and its principles into the shopping complex design criteria; and second, to identify the widest range of design elements of shopping complexes and their contributions to the UD translated. The authors used expert opinions in two rounds. In the first round, the UD translated and the design elements identified were sent to a panel of experts who were asked to read and discuss the translations and the design elements. They were instructed to comment on each translation and design element, as well as to identify important elements that were missing or should be deleted.

Thus, the authors made some modifications based on the expert's comments. For example, in terms of UD translation and the new categorization, a number of unclear definitions (e.g., definitions of usability and comfort) were clarified to create a comprehensive theoretical classification. Concerning the design elements and their contribution to the UD translated aspects, the experts suggested that we add a number of design elements (e.g., stairs) to the list. The experts also considered more contributions of design elements to the UD translated aspects (usability, comfort, and safety). In fact, the experts confirmed that all the design elements identified have contributions to all three aspects of usability, comfort, and safety. The authors then used a Structural Equation Modelling (SEM) technique as a confirmatory analysis to determine the weighting of the stable extracted factors

Consequently, the authors have developed a tool using the design factors identified in Jalil Abdullah and Jian (2019), which are shown in Table 1. To develop the tool, we needed standards to compare the existing condition with the ideal condition. Thus, we have used some well-known UD guidelines that are widely available. In table 1, many UD standards are considered for each design factor.

Table 1 Tool items and standards

Design factor	Source	UD standard(s)	
Stairs	(Centre for Excellence in Universal Design 2014)	1	The internal stairs should be clearly visible and easy to identify.
		2	The spiral stairs or stairs with tapered treads should be avoided.
		3	The rise of stairs should be in the range 150mm to 180mm. The depth should be in the range 300mm to 450mm.
		4	Steps' edge should have a non-slip applied nosing.
		5	Clear width of stairs should not be less than 1200mm.
		6	Single steps should be avoided.
		7	Tactile hazard warning surface at the top and bottom of a flight should be provided.
		8	Handrails should be provided to both sides of stairs.
		9	Second handrail at a lower height should be provided to both sides of stairs.
		10	The handrails should be contrasted with surrounding surfaces.
		11	Illumination of stairs should not be less than150 lux.
Ramps	(Centre for Excellence in Universal Design 2014)	1	Ramps should have a gradient not exceeding 1 in 20.
		2	Clear width of ramp should not be less than 1500mm.
		3	The length of landings should not be less than 2000 mm and the width should be equal to the width of the ramp.
		4	Handrails should be provided to the ramp and landings.
		5	Second handrail at a lower height should be provided.
		6	The ramp slope should contrast visually with landing surfaces.
		7	Tactile hazard warning surfacing should not be used on ramp.
		8	Upstanding kerb should be available along the ramp with 100mm high.

		9	Ramp Illumination should be more than 150 lux at the ramp surface.
Elevators	(Centre for Excellence in Universal Design 2014)	1	The lift should be located adjacent to an accessible flight of stairs.
		2	Internal dimensions should be at least 1800mm x 1800mm.
		3	Visual and tactile floor numbers should be available at each landing.
		4	Signaling systems of visual and audible should be available at the lift.
		5	Control buttons with any mounting plate should be contrasted.
		6	Mounting plate with the adjacent wall surface should be contrasted.
		7	An emergency communication system that is suitable for all users should be available.
		8	Illumination at lift should be more than 100 Lux at tread level.
		9	Half-height mirror to rear wall should be available at elevator.
Doors appearance	(Centre for Excellence in Universal Design 2014)	1	Width of opening should be 1000mm and more.
		2	Vision panels should be incorporated into all entrance lobby doors visually contrasting markings.
		3	Entrance doors should be visually contrast with adjacent walls or screens.
		4	Contrasting strip on edges of frameless glass doors should be available.
Maneuvering space	(Centre for Excellence in Universal Design 2014)	1	The dimension of maneuvering space should be in the range 2440mm × 2440mm for swing doors and 1100mm × 1370mm for sliding doors.
Service desks	(Centre for Excellence in Universal Design 2014)	1	Service desks should be located in a logical position with direct access from main entrance.
		2	Counters at different heights should be available.
		3	Knee recess for people in seated position should be available.
		4	2440mm × 2440mm or more clear space for approach to desk should be provided.
		5	Ensure counter has visually-contrasting.
		6	Illumination at counter level should be more than 200 lux at tread level.
Restrooms	(ADA 2010, The City of Calgary 2010, Austrailian Government 2013, Ministry of Business Innovation and Employment 2019)	1	Different toilet height should be available.
		2	Automatic activated flush systems should be available.
		3	Color contrast of toilet with its immediate background (walls and floors) should be available.
		4	Different hand basins height should be available.
		5	Color contrast of hand basin with its immediate background (walls and floors) should be available.
		6	Grab rails in toilet should be provided.
Hallways	(Centre for Excellence in Universal Design 2014)	1	The dimension of hallways should be in range of 1600mm × 1900mm.
		2	Junctions between different floor finishes should be fixed with threshold plates.
Waiting areas	(Centre for Excellence in Universal Design 2014)	1	Seating areas that accommodate people with prams and pushchairs; people using wheelchairs and electric scooters; and for assistance dogs should be available.
		2	Obstruction of circular routes by seats should be avoided.
		3	Clear aisle to the front and rear of the block of seats should be provided for all seat blocks.
		4	Visually contrast with surrounding surfaces should be available.
Escalators	(Centre for Excellence in Universal Design 2014)	1	The direction of movement of escalators should be clearly indicated with a sign at the top and bottom.
		2	Contrast of footway at both ends of escalator with the escalator should be available.
		3	Escalator dimensions should be in range of 580mm and 1100 mm for width and
		4	240mm for height.
		5	Visually contrasting band at each step should be available.
		6	Vertical clearance (2300mm and more) should be provided.
		7	Clear approach (10m long and more) area should be provided.
		8	Level moving section should be 2000mm long and more for top of escalator and 1600mm long and more for bottom of escalator.
		9	Audible warning at the top and bottom of the escalator should be provided.
		10	Emergency stop control should be provided.
Path of travel	(Centre for Excellence in Universal Design 2014)	1	Width of path of travel should be 2000mm and more.
		2	Short constrictions should be 1200mm and more.
		3	The wall-mounted items should be fully recessed along the corridor.
		4	The projections should be fully guarded along the corridor.
		5	The seats should be provided at 20 m or less intervals along the corridor.
		6	The furniture should not obstruct the path of travel.

Architectural wayfinding	(Ministry of Business Innovation and Employment 2019, Ministry of Business Innovation and Employment 2019)	1 2	Visual links with the outside should be provided on circulation routes. Many glares in the internal environment should be provided.
Graphical wayfinding	(Ministry of Business Innovation and Employment 2019, Ministry of Business Innovation and Employment 2019)	1 2	Visual, tactile and audible information in signage should be incorporated. Signage should be clear, consistent, and easy to understand.

3.2 Mathematical Definition

Mathematically, the SM-UD score can be defined as follows:

$$\mathrm{SM-UD_{score}} = \sum_{i=1}^{13} S_j\, W_j \qquad (1)$$

Here, SM-UD score = shopping mall universal design score, W = normalized weight of shopping mall indicator, S = indicator score, and J = indicator number.

The weight of each indicator is presented in Table 2. The weights were achieved in Jalil Abdullah and Jian (2019) that used a structural equitation modelling (SEM) technique to propose a model for shopping complex design based on Universal Design concept. According to this study, each shopping mall complex contributed in one or more aspects of Universal Design. The association value of each design factor with the UD aspect was considered as a weight. Then, for each design factor, the sum of the values was calculated and considered as the final raw weight. Finally, the raw weights were normalized to the range from 0 to 100.

Table 1 Indicators' weight according to Jalil Abdullah and Jian (2019)

Indicator	Usability	Safety	Comfort	Sum	Normalized Weight
Stairs	0.5	0.5	0.64	1.64	11.14
Ramps	0.51			0.51	3.46
Elevators	0.64	0.62	0.59	1.85	12.57
Doors appearance	0.51	0.54	0.66	1.71	11.62
Maneuvering space	0.51		0.53	1.04	7.07
Service desks	0.99	0.99	0.56	2.54	17.26
Restrooms	0.82	0.59		1.41	9.58
Hallways		0.51	0.55	1.06	7.20
Waiting areas		0.59		0.59	4.01
Escalators			0.62	0.62	4.21
Path of travel			0.65	0.65	4.42
Architectural wayfinding			0.59	0.59	4.01
Graphical wayfinding			0.51	0.51	3.46

To achieve the SM-UD score, the S must be calculated. To assess each shopping mall design factor, one or more assessment items are proposed. The S for each shopping mall design factor is achieved by calculating the mean score from all assigned evaluators' assessment scores to the assessment items. Therefore, the factor assessment score is defined as follows:

$$S_j = \frac{1}{n} \sum_{\substack{1 \le i \le n \\ 1 \le j \le 13}} M_{ij} \qquad (2)$$

Here, S = design factor assessment score, M = mean score of the statements within each design factor, i = number assigned to the assessment items (referring to Table 1), j = number assigned to the shopping mall design factor (referring to Table 3), and n = total number of assessment items within each shopping mall design factor.

Explaining the results of SM-UD by means of percentage facilitates the understanding of the SM-UD value. This percentage show scores that existing shopping malls can achieve from total possible points. The percentage of SM-UD is indicated as follows:

$$\mathrm{SM-UD\%} = \frac{\mathrm{K-UDS\ Score}}{\sum_{j=1}^{13} PS_j w_j} \times 100 \qquad (3)$$

Here, PSJ = the highest possible score

Table 4 presents the different range of scores, descriptions, and required levels of improvement (RLI). SM-UD 'A' (80 ≤ SM-UD % ≤ 100) indicates that the shopping mall is in very good condition. SM-UD 'B' (60 ≤ SM-UD % < 80) indicates that the shopping mall is in good condition and limited improvements are needed. SM-UD 'C' (40 ≤ SM-UD % < 60) means the shopping mall condition is acceptable, but needs some improvements. SM-UD 'D' (20 ≤ SM-UD % < 40) and 'E' (0 ≤ SM-UD % < 20) show that the shopping mall are in poor condition and not appropriate for using; these shopping malls need to get special attention to be improve

Table 2 Assessment items of the shopping mall design factors

Item ID	Assessment item	Item ID	Assessment item
a	Circulation Elements - Stairs	f	Circulation Elements - Elevators
a.1	Visibility of stairs	f.1	Is the lift located adjacent to an accessible flight of stairs?
a.2	Spiral stairs or stairs with tapered treads	f.2	Minimum internal dimensions of 1800mm x 1800mm
a.3	Steps' dimension	f.3	Visual and tactile floor numbers at each landing
a.4	Steps with projecting noising	f.4	The lift signalling system is both visual and audible
a.5	Clear width of stairs	f.5	Contrast of control buttons with any mounting plate
a.6	Single steps	f.6	Contrast of mounting plate with the adjacent wall surface
a.7	Tactile hazard warning surface at the top and bottom of a flight	f.7	An emergency communication system that is suitable for all users.
a.8	Handrails	f.8	Illumination at lift
a.9	Second handrail at a lower height	f.9	Half-height mirror to rear wall.
a.10	Visual contrast of handrails with surrounding surfaces	g	Entering and Exiting Elements - Doors Appearance
a.11	Illumination of stairs	g.1	Width of opening
b	Circulation Elements - Ramps	g.2	Vision panels
b.1	Ramps gradient	g.3	Visually contrasting markings
b.2	Clear width of ramp	g.4	Entrance doors contrast visually with adjacent walls or screens
b.3	Landings dimensions	g.5	Contrasting strip on edges of frameless glass doors
b.4	Handrails	h	Entering and Exiting Elements - Maneuvering Space
b.5	Second handrail at a lower height	h.1	Dimensions (pull side)
b.6	Contrast of ramp slop with landing surface	i	Wayfinding Elements - Architectural Wayfinding (Overall Assessment)
b.7	Tactile hazard warning surfacing on ramps	i.1	Provision of visual links with the outside
b.8	Upstanding kerb	i.2	Glare in the internal environment
b.9	Ramp Illumination	j	Wayfinding Elements - Graphical Wayfinding
c	Circulation Elements - Escalators	j.1	Incorporation of visual, tactile and audible information in signage
c.1	Signage at the escalators	j.2	Comprehension of signage
c.2	Contrast of footway at both ends of escalator with the escalator	k	Obtaining Products and Services - Service Desks
c.3	Escalator dimensions	k.1	Location and access from main entrance
c.4	Visually contrasting band at each step	k.2	Counters at different heights
c.5	Vertical clearance	k.3	Knee recess for people in seated position
c.6	Clear approach area	k.4	Provision of clear space for approach to desk
c.7	Level moving section	k.5	Ensure counter has visually-contrasting
c.8	Audible warning at the top and bottom of the escalator	k.6	Illumination at counter level
c.9	Emergency stop control	l	Obtaining Products and Services - Waiting Areas
d	Circulation Elements - Path of Travel	l.1	Seating areas that accommodate people with prams and pushchairs; people using wheelchairs and electric scooters; and for assistance dogs
d.1	Width	l.2	Obstruction of circular routes by seats
d.2	Short constrictions	l.3	Clear aisle to the front and rear of the block of seats
d.3	Recess of wall-mounted items	l.4	Visually contrast with surrounding surfaces
d.4	Guarding the projections into the clear width	m	Public Amenities - Restrooms
d.5	Seats along the corridor	m.1	Different toilet height
d.6	Obstruction of travel path	m.2	Automatic activated flush systems
e	Circulation Elements - Hallways	m.3	Colour contrast of toilet with its immediate background (walls and floors)
e.1	Dimensions	m.4	Different hand basins height
e.2	Junctions between different floor finishes	m.5	Colour contrast of hand basin with its immediate background (walls and floors)
		m.6	Grab rails in toilet

Table 3 SM-UD % interpretation

SM-UD %	Grade	Condition	Description	Level of required improvements
80 ≤ SM-UD % ≤ 100	A	Very Good	The shopping mall provides excellent support for the universal design principles	Shopping mall needs very limited improvements
60 ≤ SM-UD % < 80	B	Good	The shopping mall provides adequately support for the universal design principles	Shopping mall needs limited improvements
40 ≤ SM-UD % < 60	C	Regular	The shopping mall provides partial support for Universal Design principles	Shopping mall needs some improvements
20 ≤ SM-UD % < 40	D	Poor	The shopping mall do not support the universal design principles	Shopping mall needs many improvements
0 ≤ SM-UD % < 20	E	Awful	The shopping mall do not provide support for Universal Design principles and for people with disability	Shopping mall needs too many improvements

3.3 Case Study

The SM-UD tool was tested for communicability, practicality, reliability, and validity in six shopping malls, including City Center Mall, Majdi Mall, Caso Mall, Rand Gallery, and City star, which are the biggest shopping malls in Sulaymaniyah. These malls were built recently and based on our observations and informal conversations with their designers, the malls follow some principles of UD. However, their design is still not efficient enough since they consider a very limited number of UD features.

3.4 Reliability And Validity

The SM-UD tool was tested for reliability and validity. Reliability was tested through intra-rater and inter-rater reliability. Validity was also assessed through the criterion validity. Two evaluators (not including the first author) evaluated the case study using the SM-UD tool. Each rater assessed five zones on two separate occasions (period of 2 weeks between both ratings). The objectives of reliability tests were: (1) to assess the level of agreement over repeated measures and (2) to assess the level of agreement between team members (on first occasion). The reliability tests were conducted using PABAK kappa statistic (for Inter-rater reliability) and Cohens' kappa statistic (for Intra-rater reliability). To assess the criterion validity of SM-UD tool, the baseline degree of agreement for evaluators was investigated. On the first occasion that five zones of the case study were evaluated by two evaluators, the first author also evaluated these zones. For each evaluator, the degree of agreement was calculated with regard to the first author. The validity test was carried out using Cohens' kappa statistic.

3.5 Testing Results

To test the proposed tool, the authors split each case study into five zones. Each zone was evaluated by two evaluators for reliability tests, as well as testing the practicability of the tool. The Inter-rater reliability test was conducted based on two evaluators' ratings; Intra-rater reliability was carried out based on the one of evaluators' ratings in two different occasions; and the validity test compared the ratings of one of the evaluators with the first author ratings. The results of assessment also calculated based on the first author ratings.

3.6 Reliability

The results of reliability and validity tests are presented in Table 5. The ICC values show that six items had excellent reliability and six items had good reliability. The average Cohens' Kappa value of intra-rater reliability show that all items had excellent reliability. In addition, Cohens; kappa value of criterion validity indicate that two items had fair to good validity, and remains had excellent validity.

Table 4 Results of reliability and validity tests

Design factor	Inter-rater reliability	Intra-rater reliability	Criterion validity
	Average ICC	Average Cohens' Kappa	Average Cohens' Kappa
Stairs	0.89	0.94	0.79
Ramps	0.76	1.00	0.74
Escalators	0.95	0.91	0.91
Path of travel	0.81	0.82	0.63
Hallways	1.00	1.00	1.00
Elevators	0.89	1.00	0.82
Doors' appearance	0.89	0.83	0.76
Maneuvering space*	-	-	-
Architectural wayfinding	1.00	1.00	1.00
Graphical wayfinding	1.00	1.00	1.00
Service desks	0.93	1.00	0.87
Waiting areas	1.00	0.77	1.00
Restrooms	0.83	0.87	0.75

*No statistics are computed.
ICC ≤ 0.5: poor; 0.5 < ICC ≤ 0.75: moderate; 0.75 < ICC ≤ 0.90: good; ICC > 0.90: excellent (Koo and Li 2016)
Kappa ≤ 0.40: poor; 0.40 < ICC ≤ 0.75: fair to good; Kappa ≥ 0.75: excellent (Fleiss, Levin et al. 2013)

4. Assessment Results

The SM-UD% is calculated for the City Center Mall (refer to Eq. 3). To obtain the SM-UD% for each of the shopping mall design factors and overall SM-UD% for the shopping mall, it is vital to determine the level of improvements of the shopping mall as a whole and the shopping mall design factors, in particular. Table 6 indicates the SM-UD% for the selected shopping mall, and also the level of required improvements (LRI) for the shopping mall design factors and the whole shopping mall. According to Table 3, SM-UD% of the shopping mall was 27.56; therefore, the grade of the universality design of the shopping mall was 'D', which shows that the shopping mall do not support the universal design principles and needs many improvements. Among the shopping mall design factors, the factors that achieve 'poor' and 'awful' SM-UD% need many and too many improvements, such as stairs, ramps, escalators, path of travel, hallways, elevators, doors' appearance, graphical wayfinding, service desks, waiting areas, restrooms, and architectural wayfinding. Only one design factor achieved 'regular' SM-UD% in the selected shopping mall, which was maneuvering space and needed some little improvements. No design factors achieved "A" and "B" grades.

Table 5 SM-UD% and condition of City Center Mall

Indicator	Mean of scores	Factor weight	SM-UD score	SM-UD %	Grade	Condition	LRI
Stairs	3.09	11.14	34.43	34.00	D	Poor	2
Ramps	2.38	3.46	8.22	26.72	D	Poor	2
Escalators	2.44	12.57	30.73	33.85	D	Poor	2
Path of travel	2.83	11.62	32.92	34.00	D	Poor	2
Hallways	1.50	7.07	10.61	30.00	D	Poor	2
Elevators	1.78	17.26	30.68	32.00	D	Poor	2
Doors' appearance	2.00	9.58	19.16	22.22	D	Poor	2
Maneuvering space	5.00	7.2	36.00	50.00	C	Regular	3
Architectural way finding	1.00	4.01	4.01	10.00	E	Awful	1
Graphical way finding	2.50	4.21	10.53	25.00	D	Poor	2
Service desks	1.67	4.42	7.37	25.00	D	Poor	2
Waiting areas	1.50	4.01	6.02	17.14	E	Awful	1
Restrooms	1.83	3.46	6.34	18.33	E	Awful	1
Overall SM-UD %				27.56			
Overall LRI				2			

Level of required improvement: LRI; shopping mall needs very limited improvements=5; Shopping mall needs limited improvements=4; shopping mall needs some improvements=3; shopping mall needs many improvements=2; shopping mall needs too many improvements=1

Tables 7-9 display the SM-UD% of City Star, Rand Gallery, and Caso Mall in Sulaymaniyah. The SM-UD% of these shopping malls was below 20; therefore, the grade of the universality design of the shopping mall was 'E', which shows that these shopping malls do not provide support for Universal Design principles and for people with disability. These malls need too many improvements to support Universal Design principles.

Table 6 SM-UD% and condition of City Star

Indicator	Mean of scores	Factor weight	SM-UD score	SM-UD %	Grade	Condition	LRI
Stairs	1.55	11.14	17.22	17.00	E	Awful	1
Ramps	0.97	3.46	3.34	10.87	E	Awful	1
Escalators	0.89	12.57	11.17	12.31	E	Awful	1
Path of travel	1.50	11.62	17.43	18.00	E	Awful	1
Hallways	1.50	7.07	10.61	30.00	D	Poor	2
Elevators	0.78	17.26	13.42	14.00	E	Awful	1
Doors' appearance	1.60	9.58	15.33	17.78	E	Awful	1
Maneuvering space	3.00	7.2	21.60	30.00	D	Poor	2
Architectural wayfinding	1.50	4.01	6.02	15.00	E	Awful	1
Graphical wayfinding	1.00	4.21	4.21	10.00	E	Awful	1
Service desks	2.00	4.42	8.84	30.00	D	Poor	2
Waiting areas	2.00	4.01	8.02	22.86	D	Poor	2
Restrooms	1.33	3.46	4.61	13.33	E	Awful	1
Overall SM-UD %				18.55			
Overall LRI				1			

Level of required improvement: LRI; shopping mall needs very limited improvements=5; Shopping mall needs limited improvements=4; shopping mall needs some improvements=3; shopping mall needs many improvements=2; shopping mall needs too many improvements=1

Table 7 SM-UD% and condition of Rand Gallery

Indicator	Mean of scores	Factor weight	SM-UD score	SM-UD %	Grade	Condition	LRI
Stairs	1.82	11.14	20.25	20.00	E	Awful	1
Ramps	1.49	3.46	5.15	16.73	E	Awful	1
Escalators	1.22	12.57	15.36	16.92	E	Awful	1
Path of travel	1.67	11.62	19.37	20.00	E	Awful	1
Hallways	2.00	7.07	14.14	40.00	D	Poor	2
Elevators	1.00	17.26	17.26	18.00	E	Awful	1
Doors' appearance	1.60	9.58	15.33	17.78	E	Awful	1
Maneuvering space	3.00	7.2	21.60	30.00	D	Poor	2
Architectural wayfinding	1.00	4.01	4.01	10.00	E	Awful	1
Graphical wayfinding	0.50	4.21	2.11	5.00	E	Awful	1
Service desks	1.67	4.42	7.37	25.00	D	Poor	2
Waiting areas	2.00	4.01	8.02	22.86	D	Poor	2
Restrooms	1.50	3.46	5.19	15.00	E	Awful	1
Overall SM-UD %				19.79			
Overall LRI				1			

Level of required improvement: LRI; shopping mall needs very limited improvements=5; Shopping mall needs limited improvements=4; shopping mall needs some improvements=3; shopping mall needs many improvements=2; shopping mall needs too many improvements=1

Table 8 SM-UD% and condition of Caso Mall

Indicator	Mean of scores	Factor weight	SM-UD score	SM-UD %	Grade	Condition	LRI
Stairs	2.00	11.14	22.28	22.00	D	Poor	2
Ramps	1.64	3.46	5.68	18.46	E	Awful	1
Escalators	1.33	12.57	16.76	18.46	E	Awful	1
Path of travel	2.00	11.62	23.24	24.00	D	Poor	2
Hallways	1.00	7.07	7.07	20.00	D	Poor	2
Elevators	0.78	17.26	13.42	14.00	E	Awful	1
Doors' appearance	1.20	9.58	11.50	13.33	E	Awful	1
Maneuvering space	3.00	7.2	21.60	30.00	D	Poor	2
Architectural wayfinding	1.00	4.01	4.01	10.00	E	Awful	1
Graphical wayfinding	2.50	4.21	10.53	25.00	D	Poor	2
Service desks	1.67	4.42	7.37	25.00	D	Poor	2
Waiting areas	2.00	4.01	8.02	22.86	D	Poor	2
Restrooms	1.33	3.46	4.61	13.33	E	Awful	1
Overall SM-UD %				19.73			
Overall LRI				1			

Level of required improvement: LRI; shopping mall needs very limited improvements=5; Shopping mall needs limited improvements=4; shopping mall needs some improvements=3; shopping mall needs many improvements=2; shopping mall needs too many improvements=1

Tables 10 and 11 show the SM-UD% of Family Mall and Majdi Mall in Sulaymaniyah. The SM-UD% of these shopping malls was between 60 and 80; thus, the grade of the universality design of the shopping mall was 'B', which shows that these shopping malls provide adequately support for the universal design principles. These malls need limited improvements to support Universal Design principles.

Table 9 SM-UD% and condition of Family Mall

Indicator	Mean of scores	Factor weight	SM-UD score	SM-UD %	Grade	Condition	LRI
Stairs	6.09	11.14	67.85	67.00	B	Good	4
Ramps	6.04	3.46	20.91	67.98	B	Good	4
Escalators	5.44	12.57	68.44	75.38	B	Good	4
Path of travel	5.33	11.62	61.97	64.00	B	Good	4
Hallways	3.50	7.07	24.75	70.00	B	Good	4
Elevators	3.22	17.26	55.62	58.00	C	Regular	3
Doors' appearance	3.80	9.58	36.40	42.22	C	Regular	3
Maneuvering space	7.00	7.2	50.40	70.00	B	Good	4
Architectural wayfinding	6.50	4.01	26.07	65.00	B	Good	4
Graphical wayfinding	4.00	4.21	16.84	40.00	C	Regular	3
Service desks	4.50	4.42	19.89	67.50	B	Good	4
Waiting areas	6.00	4.01	24.06	68.57	B	Good	4
Restrooms	4.17	3.46	14.42	41.67	C	Regular	3
Overall SM-UD %				61.33			
Overall LRI				4			

Level of required improvement: LRI; shopping mall needs very limited improvements=5; Shopping mall needs limited improvements=4; shopping mall needs some improvements=3; shopping mall needs many improvements=2; shopping mall needs too many improvements=1

Table 10 SM-UD% and condition of Majdi Mall

Indicator	Mean of scores	Factor weight	SM-UD score	SM-UD %	Grade	Condition	LRI
Stairs	6.82	11.14	75.95	75.00	B	Good	4
Ramps	5.74	3.46	19.84	64.52	B	Good	4
Escalators	4.67	12.57	58.66	64.62	B	Good	4
Path of travel	5.17	11.62	60.04	62.00	B	Good	4
Hallways	2.50	7.07	17.68	50.00	C	Regular	3
Elevators	3.33	17.26	57.53	60.00	B	Good	4
Doors' appearance	4.40	9.58	42.15	48.89	C	Regular	3
Maneuvering space	8.00	7.2	57.60	80.00	B	Good	4
Architectural wayfinding	7.50	4.01	30.08	75.00	B	Good	4
Graphical wayfinding	4.00	4.21	16.84	40.00	C	Regular	3
Service desks	4.67	4.42	20.63	70.00	B	Good	4
Waiting areas	4.75	4.01	19.05	54.29	C	Regular	3
Restrooms	4.67	3.46	16.15	46.67	C	Regular	3
Overall SM-UD %				60.84			
Overall LRI				4			

Level of required improvement: LRI; shopping mall needs very limited improvements=5; Shopping mall needs limited improvements=4; shopping mall needs some improvements=3; shopping mall needs many improvements=2; shopping mall needs too many improvements=1

5. Discussion and Conclusion

This study was aimed to describe the developments and evaluation of a tool for assessment of universal design in shopping malls (SM-UD). A very limited number of assessment tools are available for assessing whether a public space adheres the Universal Design principles. The proposed tool assesses the universality design of shopping malls as an important component of cities. Since this tool is designed for Kurdistan, a wide range of shopping mall design factors were used based on Kurdish people perceptions. However, this broad spectrum of shopping mall design factors is capable of making this tool to be applicable in other countries with characteristics. In addition, SM-UD tool developed an easy-to-follow methodology for assessing universality design of different shopping malls. The inter-rater and intra-rater reliability tests were used to determine the reliability of the shopping mall design factors within SM-UD. In the selected shopping mall, all factors showed good and excellent reliability. As expected, the objective design factors obtained high reliability. The least Cohens' Kappa value for intra-rater reliability belonged to waiting areas (0.77). The possible explanation for this is inconsistency in the values of "obstruction of circular routes by seats", which somewhat requires a subjective judgment. Same subjectivity might cause that path of travel obtained the least (0.63) Cohens' Kappa value for criterion validity. Overall, the reliability and validity test results showed that all items of the tool exhibit good and stable psychometric properties. A simple check on the assessment results shows that the scores of the assessment items are consistent across the case studies. For example, waiting area in City Center Mall, which is very scarce in this shopping mall has obtained a SM-UD% below 20, which shows the awful condition of this item in the shopping mall. In fact, the SM-UD% of waiting area in the City Center Mall correspond with the observation survey in this case study. The consistency between the scores of assessment items and their condition in real world provides strong support for the validity of the tool assessment items.

The SM-UD tool is useful to architects, shopping malls' owners, and city planners for increasing the awareness about the universality design of the shopping malls. This tool also helps them to prioritize investments and upgrade the shopping mall facilities. Concerning the use of a wide range of design factors to assess the universality design of shopping malls, other researchers can use similar methodology and process to develop new assessment tools for other public spaces such as parks, hospitals, and so on. The proposed tool can be used in other countries with suitable modifications.

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Recreating Historical Malay Architecture with BIM Process

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ABSTRACT

In South-East Asia, the Malay architecture is among the popular subject of research because of its historical importance within the region, apart from many others. To some researchers, the Malay architecture is unique because of its intangible meaning and historically rich design characters. It is difficult to be reproduced, and only limited numbers of people are acknowledged as experts. With the introduction of technology such as BIM, it is hypothesized that the gap can be minimized. The idea of this paper is to outline the process of recreating cultural architectural design using a modern process such as Building Information Modelling (BIM) platform in specific, from data collection using Terrestrial Laser Scanning (TLS) and digitalization process in Revit software. This paper employs observation approach using data from laser scanner collected from case study and content analysis technique. While normally most of the cultural architecture is undocumented, the findings of this activity are aimed to provide guideline to develop geometrical information for heritage-enthusiast in practicing their undertakings. It is hoped that more historical and cultural architecture can be recreated and appreciated for the use and inspiration of current construction industry.

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1. Introduction

Across the world, the rate of decline and disappearance of historical buildings such as wooden traditional Malay houses in the Malay archipelago, churches in the European countries, castles in Japan and China or even mosques in the Middle East is accelerating. Designs on historical building are often intricate and difficult to reproduce, even by experts. Up until recent years, the re-production of as-built drawing for historic buildings are often being done by hand measuring, which is very tedious and time-consuming (Foxe,2010). At the end of the activity, most people are left with inaccurate and incomplete data because of unavoidable factors such as financial and time constraints. With the introduction of laser scanner, a highly accurate three-dimensional model of the complete interior and exterior of any building can be created in a shorter time (Pesci et al., 2012) Using the data, it is possible then to use any BIM software such as Autodesk Revit to reproduce the plans, elevations and sections of the designs and buildings. These documents can then be used as references for recreating the architectural design. Therefore, this paper intends to outline the process of recreating cultural architectural design using a modern process such as Building Information Modelling platform in specific, from data collection using Terrestrial Laser Scanning (TLS) and digitalization process in Revit software.

1.1 Historical Buildings and Styles of Malay architecture in Peninsular Malaysia

The Ministry of Cultural, Art and Heritage defined historical buildings as tangible heritage under the static category, which consists of monuments and buildings such as palaces, fortress, tombs, and towers. Any building which is more than 50 years of age and gazetted by the Department of National Heritage can be considered as heritage building whereas non-gazetted building is considered historical building. Fielden (2003) defined a historic building as any building that could give an impression and make a person curious about the race and culture that built them. He also said all buildings over 100 years old should be deemed historic buildings. In brief, a historic building can be described as a building that can depict particular values such as its history, architecture, symbolism, and feelings to local individuals.

The styles of Malay architecture in Peninsular Malaysia were comprised of many typologies such as buildings for administration, institutions, religious buildings, homes, and many more. Most of the buildings are beautifully decorated and have distinctive designs that are not found in most present buildings. Among historical buildings that exist in Peninsular Malaysia are shown in Table 1. These historic cultural buildings should be properly conserved and preserved as these national treasures are irreplaceable to our nation. Failure to manage and preserve these historic buildings can have a detrimental impact on our nation. This is because owing to any poor decisions or actions, a century of wealthy history that could be translated from a building can be destroyed by a split second. It can be seen nowadays that historical buildings such as shophouses, townhouses, and traditional Malay houses are now fighting for survival owing to factors such as demolition, neglect, and lack of effort to preserve them. According to Akadiri et al. (2012), damages that occur to building indirectly will affect their structural integrity and its fabric. It will also affect the façade, which gives negative impacts for tourism sectors, and it will eventually also give negative impression towards the conservation industry in Malaysia (Harun,2011). Historical buildings are prone to damages owing to many factors, and the damage must be correctly resolved according to conservation principles, philosophy, and ethics. All historic buildings must be continually preserved, not only when damage is noticeable. Regular check-ups should be performed, and adequate monitoring through technology such as BIM can be helpful.

1.2 Digitalization Using Laser Scanner: Scan-to BIM

Global trends are making AEC projects more complex, while advances in technology are helping industry professionals work more efficiently and effectively. The power of BIM is how it allows architects, engineers, and contractors to collaborate on coordinated models, giving everyone better insight into how their work fits into the overall project, ultimately helping them to work more efficiently. Traditionally, buildings have been documented by sending a team out into the field where the teams take measurement to their nearest centimetres or inch and produce hand-drawn drawings, which can take a long time to produce. Instead, a site can be scanned in a matter of hours or days and plans can be studied from those scans (Ali et al., 2018).

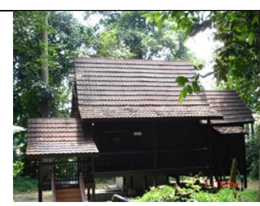
The BIM is increasingly being accepted and practiced in most part of the world; whether to assist in designing a project or to develop an operating system in constructing a building efficiently. Other countries, including Finland, Singapore, Denmark and Norway, have also adopted BIM (Ali et al., 2018). However, in the Malaysian industry, Zahrizan et al. (2013) found that the adoption of BIM in Malaysia needs attention. They highlighted that "Due to the lack of knowledge of BIM and the low level of BIM uptake by the Malaysian construction players, the implementation of BIM in the Malaysian construction industry thus lies between BIM level 0 and BIM level 1. This statement is later supported by CIDB BIM Report 2016. It was mentioned that the adoption is still low because the Malaysian construction industry has very slow development in using the application of Information Communication Technology (ICT). The challenges are the unavailability of sufficient experts within the country, relevant equipment for practicing are scarce, limited availability of trainers, and financial-related challenges (Del Giudice & Osello, 2013; Harun, 2011; Zahrizan et al., 2013; Abbasnejad & Moud 2013). These challenges, however, should not prevent, or even discourage construction players from taking advantage of this technological advancement in different ways.

The low adoption in implementing BIM has caused losses to the current industry in Malaysia as the benefit of BIM does not only improve the technology itself; it also changes the process of design and builds (Kymmel, 2008; Maina, 2018). Through the implementation of BIM, any vital information like the design information can be prepared and evaluate at a much faster time; enabling any decision-making process related to the project can be done in a much easier and efficient way (Mustafa et al., 2018; Maina, 2018). Moreover, BIM also conveniences to the project

Table 1 The example of different typologies of historical buildings that exist in Peninsular Malaysia

Sources: 1- Ministry of Agriculture and Agro-based Industry,
2- https://www.maisinggah.com/bangunan-bersejarah-di-malaysia/
3-https://www.orangnogori.com

Name of state	Building typology		
	Palaces	Aristocrats' house	Commoners' house
Perlis	 Istana Arau	 Rumah Tetamu Kangar	 Rumah Bumbung Panjang Perlis
Kedah	 Istana Balai Besar	 Seri Mentaloon, Alor Star	 Rumah Peladang Kedah
Kelantan	 Istana Balai Besar	 Rumah Menteri Besar	 Rumah Kelantan
Terengganu	 Istana Tengku Long	 Rumah Dato Biji Sura	 Rumah Limas Bungkus
Johor	 Istana Besar Johor	 Rumah Menteri Besar	 Rumah Johor Atap Limas
Perak	 Istana Kenangan,	 Baiturrahmah	 Rumah Kutai

Selangor	 Istana Bandar	 Carcosa Seri Negara	 Rumah Pak Ali
Pahang	 Istana Leban Tunggal	 Rumah Penghulu Hj Ismail bin Khatib Bakar	 Rumah Serambi Pahang
Negeri Sembilan	 Istana Seri Menanti	 Rumah Dato Kelana Syed Abdul Rahman	 Rumah Negeri Sembilan
Melaka	 Replika Istana Melaka	 Rumah Penghulu Ghani	 Rumah Melaka
Penang	 Seri Mutiara	 Rumah Tuan Guru Haji Othman, Bukit Mertajam	 Rumah Serambi Gajah Menyusu

team to make any variation or changes to the project at any time along with the phase of work due to its parametric modelling capability (Autodesk, 2019). All the data needs to be formatted in the right way and available at the right time is not acting as barriers to its full adoption. BIM software makes up about one-half of the components in the whole process.

BIM, however, has not been extensively applied to all aspects of a construction project (Mustafa et al., 2018; Seghier, Lim, Ahmad and Samuel, 2017). According to Kymmel (2008), the clearest benefit from BIM is that a 3D model improves the presentation ability in visualizing (understand) the model better. Many persons have difficulty understanding 2D drawing, and according to Maina (2018), there is an inadequate supply of qualified staff to meet specialised skills. While according to Eastman et al. (2008) and Rozana et al. (2018), the 3D model made by the BIM software is designed rather than generated from multiple 2D views. It is used to visualize the layout at any stage of the process expecting it will be consistent in every view.

Through virtual design and construction, BIM can provide an advantage to the Malaysian heritage industry by enhancing the cooperative level among various stakeholders. In the inspiration of ‘renaissance’ which means the revival of or renewed interest in something, clients will be able to have a wider range of design choices that reflects their cultural architecture (Autodesk, 2019; Ali et al., 2018). To achieve this, there is a need for a library of collected data on Malay architectural design to be made available, hence increasing the production efficiency and reduce the cost. Among data collection approach is by using a 3D laser scanner.

1.3 Dimensional Laser Scanner

The idea behind 3D laser scanning is LIDAR (light detection and ranging) and remote sensing. LiDAR is a remote sensing method that uses a laser to measure elevation and laser scanner works on the same principle (Quattrini et al. ,2015). Essentially, LIDAR is a beam of light that analyses the reflective light. The scanner then registers how long it takes for light to make its return, and using a set of an internal mirror and establishes horizontal and vertical angle by collecting point with correct x y and z coordinates. The collection of points taken by a single scan will be recorded as point clouds (Baik, 2017).

2. Methodology

This paper employs observation approach using data from laser scanner collected from case study and content analysis. To achieve this, the research conducted an action-based research using a real case study and employs a qualitative approach in describing the findings. Observation has been used as a method for collecting data about people, processes, or even cultures (Kawulich, 2012).

2.1 Selection of Case Study: Istana Balai Besar Alor Setar

Digitalizing historic Malay building is different from other buildings because of its unique characters. Its architecture has a blend of influences which has created its unique building forms (Endut, 1993). In this paper, a more complex building such as the 'Istana' (palace) will be studied as compared to traditional Malay house because it can provide more data as compared to the latter which is too simple. This is also because Istana also carries more significance as compared to the normal cultural house because more historic events take place there.

According to a report from Kedah's state Archive retrieved by researchers on July 2018, The Grand Palace (Istana Balai Besar) is a unique hall which was built in 1735 by order of Sultan Muhammad Jiwa Zainal Adilin Muazzam Shah, the 19th Sultan of Kedah (1710 - 1778). Its original function was to act as "Balai Penghadapan" for the king's official activities. The components were originally constructed from timbers, and after some incidents due to attacks from the Siamese (1821) and Bugis (1770), some part of the components were changed to steel and concrete. The building was re-constructed displaying the astonishing Malay's woodcarving at that time, and until now, its uniqueness still inspires many architect and tourists. This palace is among the oldest and the finest traditional Malay palaces which remains intact until today. However, it is subjected to the threats of natural decay, major flood and was once destroyed by fire, thus preserving its architectural and historical significance has become of paramount importance for posterity.

The process of reproducing the documentation comprises of two (2) main stages. The first stage is data collection on-site, where measurements need to be taken by the use of laser scanning technology. Laser scanning was selected as the technique of data collection because it is among the latest available measurement technology. The output from the laser scanner can be integrated with another technology such as BIM. In this research, 29 stations sites were used to capture data around the building, as shown in Figure 2. The second stage is the reconstruction of the building in the BIM platform, such as Autodesk Revit using the data collected from the laser scanning activity. In this study, Autodesk Revit was used because of the software's interface, which is user-friendly and easy to learn.

The scanner used is a TopCon GLS-2000. The specifications of the scanner are presented in Table 2.

Table 2 The specification of the scanner used for the scanning activity

SCANNER/ CHARACTERISTIC	Topcon GLS-2000
Laser Class	3R and 1R
Scanning method	Time of Flight
Vertical field of view (º)	270º
Horizontal field of view (º)	360º
Range (m) and reflectivity	Up to 350m; 90 % reflectivity (minimum range 0.4m)
Scan Speed (pts/sec)	120,000 points per/second
3D scanning accuracy	3.5 mm at 150m
Camera(single image pixel resolution)	5 megapixels
Processing software	JRC 3D RECONSTRUCTOR
Tilting Sensor	Dual-axis compensator

2.2 The Point Cloud Workflow On The Project

Commissioning a point cloud is similar to a traditional 2D survey. It is only the deliverable that is different. The scan itself will render with intensity. Although point cloud is just discrete points, the density actually causes them to mimic a solid surface. However, because the laser only uses visible light, rather than infrared, it only records the surface it hits, rather than what is hidden behind the structure. Thus, it is important to acknowledge that laser scanning is a line-of-sight technology. Hence, because it only records whatever it hits, the users actually need to reposition the scanner around the site in order to capture the object all around (Quattrini et al.,2015). In this research, 29 stations sites were used to capture data around the building, as shown in Figure 1. However, most importantly, there must be an area of overlap between all of the sites. This can be done by using targets.

In order to create a complete point cloud, the scanner needs to be moved around both the inside and the outside of the building that is being scanned to fill in the missing areas. Before capturing the next scan, targets are placed in the direction where the scanner is moving. The main usage of the targets is to tie a scan location to the next. These targets will be used to automatically combine the multiple scans into a single data set of the complete as the as-built condition. Finally, once all the data was collected, they will be joined using ScanMaster software and forms a complete building as point clouds.

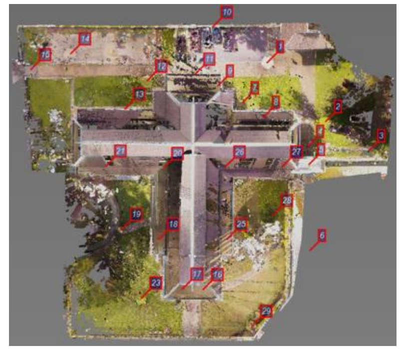


Figure 1: 29 scan stations are used during the data collection process (Authors, 2019)

Figure 2: Istana Balai Besar frontage in point clouds (Authors, 2019)

After all of the scans have been registered using the targets in the field, the complete point cloud can be seen, as shown in Figure 2. Next, the point cloud can be exported to an application used in design such as Autodesk Reality Capture or also known as Autodesk Recap. Recap is a high-performance point cloud visualization engine that can be used to view and navigate the point cloud by cutting sections of the data. By having point clouds, it is possible to view the model in ways that would otherwise be difficult if using data collected with traditional means of as-built surveying and measuring (Quattrini et al., 2015).

In Recap, it is possible to look at the scan in a planar view by taking the sphere of data, unrolls it to look at the entire scan and manipulate the data. From this view, as shown in Figure 3, direct measurements can be taken by measuring from the layout, and the dimension is broken out to provide true measurement as our primary data.

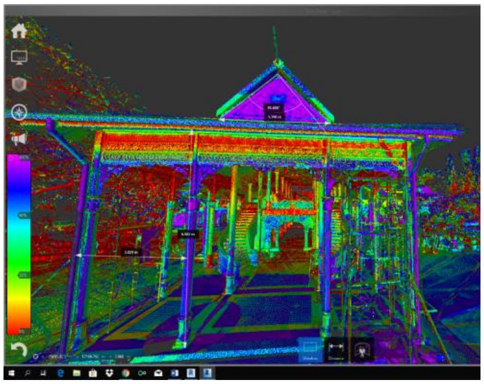


Figure 3: Measuring the dimension of building components can be carried out in the Recap platform (Authors, 2019)

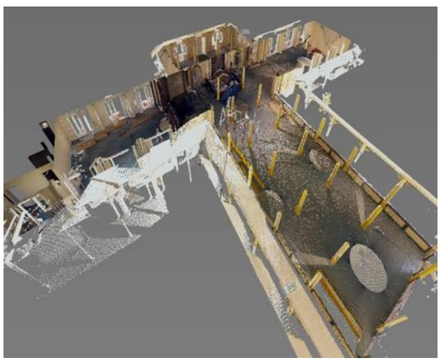


Figure 4: Cross-section of the building in point cloud (Authors, 2019)

In Figure 4, a cross-section of the building is made in order to view the floor to floor relationships and to determine the distance between the floors. By doing this, understanding of spaces within the building can be achieved (Abidin,1981) before modelling it in Revit. Measurement of the building also can be computed by point-to-point distance. For laser scanner TOPCON GLS-2000, the precision of measurement is up to 3.5mm.

Next, the point cloud is transferred into Autodesk Revit, where the point cloud is attached to a project as a link. After importing the point cloud, the plan section is cut all the way to the floor level so the floors' area can be clearly seen. From the floor plan, materials and finishes are recorded, and the building is modelled. As more information is needed for the modelling of the building, data from the point cloud in Recap is referred. The result in the form of as-built drawing is produced and presented.

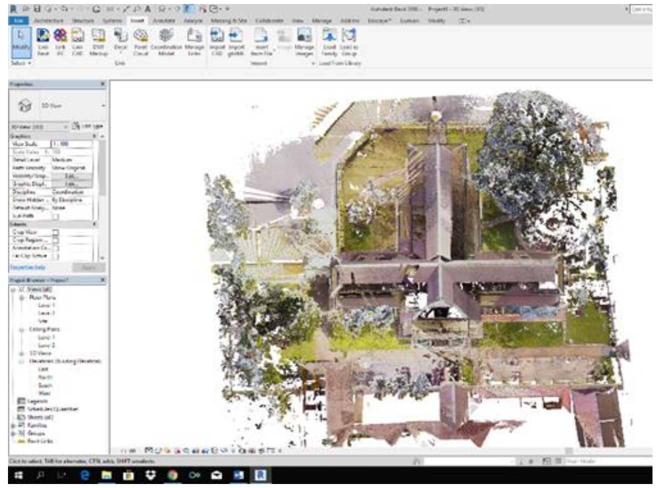


Figure 5: Point cloud in Revit (Authors, 2019)

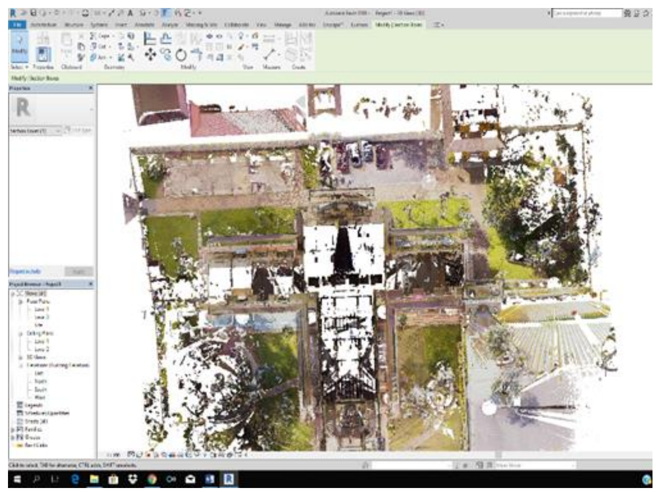


Figure 6: Layout floor plan of building (without roof) in Revit (Authors, 2019)

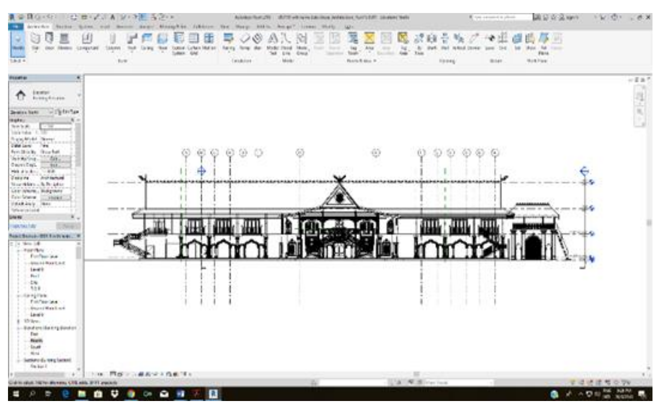


Figure 7: Positioning of Leica Terrestrial Laser Scanner P16 during scanning (Authors, 2019)

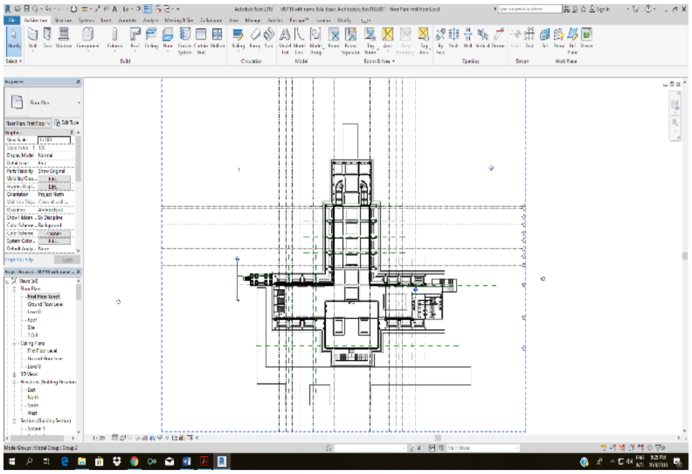


Figure 8: Building layout converted from point clouds to BIM using Revit (Authors, 2019)

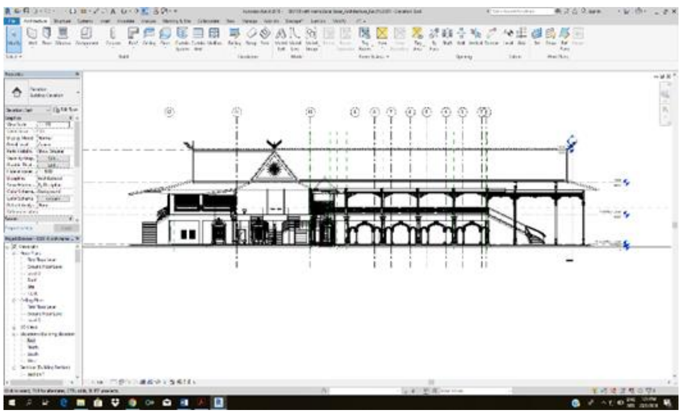


Figure 9: Building layout converted from point clouds to BIM using Revit in 3D view (Authors, 2019)

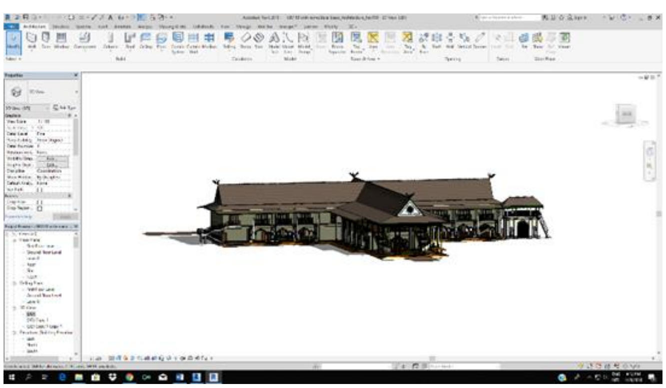


Figure 10: BIM model of Istana Balai Besar (Authors, 2019)

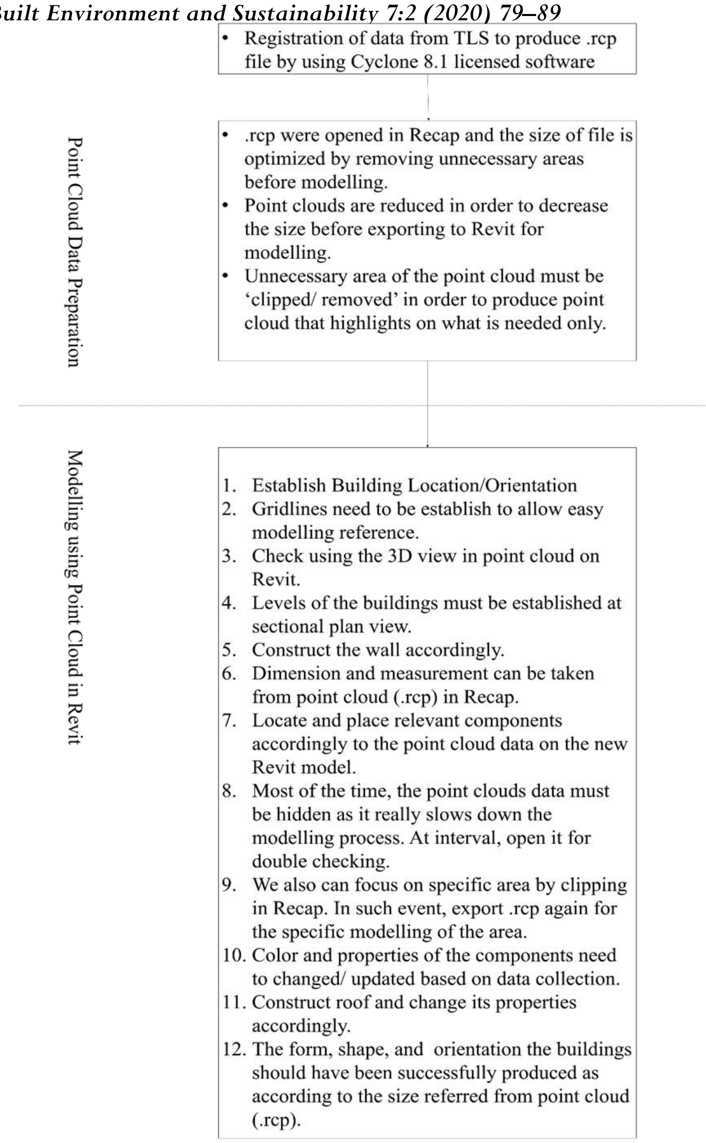


Figure 11: The process flow of digitalization using point clouds for Autodesk Revit(Authors' work)

3.0 Digitalization Result and Analysis of Istana Balai Besar from Point Cloud Data

One of the most useful aspects of BIM is that it can extract attributes data indicating, for example, the floor area of existing construction, or the variation of building components used for the building. Figures 5,6,7,8,9 and 10 are the results from the effort of modelling in BIM platform using the point clouds collected by laser scanning exercise meanwhile Figure 11 highlights the flow of digitalization using point clouds using Autodesk Revit. The as-built drawings of a traditional Malay building which has existed since 1735 have been successfully reproduced, with a variation of 3.5mm accuracy. The point cloud is invaluable for this case study because there is no ambiguity at all. This effort has simultaneously produced 2D drawings and 3D models successfully in a single work. By having data from laser scanning, it eliminates the need to have a frequent site visit, and the details of the building can be further explored from our workstation.

The result of this digitalization process has contributed to the know-how and know-what, especially in the management of point clouds for the documentation of historic building. The case study consists of a symmetrical design with two floors. During the modelling process, it was found that the building has used variant types of component. For example, the variations of the column found are five (5) and are shown in Figure 12.

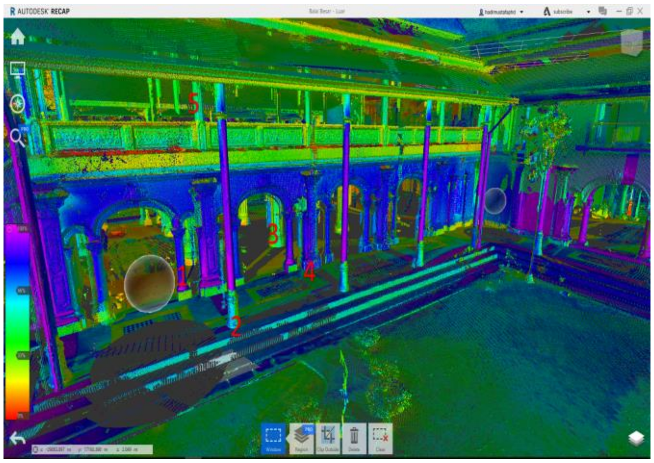


Figure 12: The numbers of column's variant found using point clouds for Istana Balai Besar (Author's work)

This case is considered to be another parameter to understand the advantage of technologies via action-based research. As another contribution from this action based-research activity, it can be extracted that the ground floor area of the building is approximately 2341 m2 and the first-floor area is 1341m2 as shown in Figure 13 and Figure 14. The information can serve as the basis for further research to understand the profitability and benefits involved in using TLS for historic buildings in all regards.

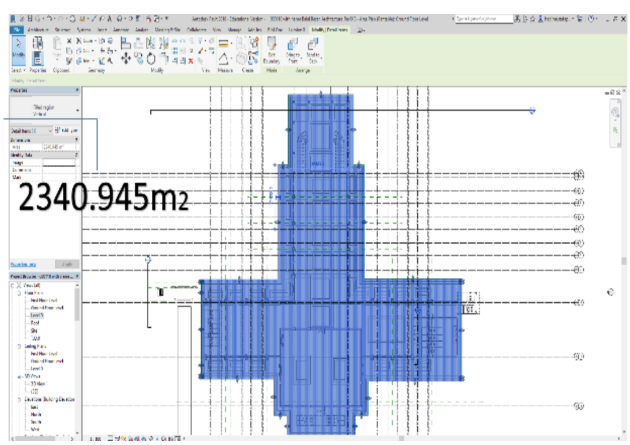


Figure 13: The extraction of Balai Besar Alor Setar's ground-floor layout area using BIM tool (Authors, 2019)

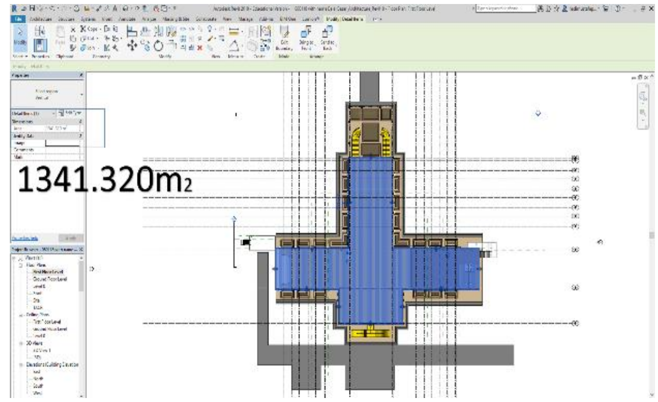


Figure 14: The extraction of Balai Besar Alor Setar's first-floor layout area using BIM tool (Authors, 2019)

This research has provided a process flow on data collection using laser scanner and managing the data for the purpose of documenting the details of historic building. It is also found that there is still room for improvisation on this approach; for example, the automation from laser scanning into the BIM model. Terrestrial laser scanner also has difficulty in capturing high rise building, but this is not a major problem since the point cloud can be obtained with the help of laser scanning using an Unmanned Aerial Vehicle (UAV) such as the drones. At the current state of development, it is not possible to directly convert point clouds into a BIM model as it only acts as references. It is anticipated future development might focus on producing the BIM model straight away from their main references without the need to remodel them again manually in other software.

4.0 Conclusion and Recommendations

BIM has become an integral part of the way for new businesses, and it can be seen that greater client engagement is possible with the use of these technologies. The ability to have visual access to information through 3D illustrations without having to be on the site is deemed to be a ground-breaking process in AEC. Point cloud surveying is although a rapid process but the programming of the modelling need to be understood, managed and discussed with other parties who will rely on the information. The ability to produce accurate building information now forms a core part of our construction industry. From this research, it can be concluded that laser scanning is an effective approach to producing plans and elevations for any buildings, especially for historic buildings due to the reduced time on-site as compared with the conventional approach. Embracing BIM is not anymore about adapting to the local government's vision and mandate, it is more about recognizing the potential to become more efficient and effective in the operation and to compete effectively on the international level. Lastly, this research would like to suggest for heritage-enthusiast in practicing their undertakings by:

i. Organizing appropriate and adequate training service on modelling of historical buildings, as simple methods need to be developed to obtain BIM models that guarantee accuracy, accuracy and quality at the same time.

ii. Integrating BIM with current historical buildings database within the conservation practice, which still is documented in a conventional approach.

iii. Encouraging young employees to possess competencies and qualities in utilizing technologies to increase the productivity and efficiency of their practice.

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